

Radiation therapy techniques



Assist. Prof Neda Milosavljević, MD PhD

Radiotherapy treatment can be perform as:

- Brachytherapy (direct or close contact with the radiation source)
- External beam radiotherapy (EBRT) (distance beetwen patient and radiation source – "source-skin distance, SSD").

Linear accelerators (LINAC)

- Kilovoltage x-ray beam therapy– energy < 500 kV.
 - typically only used for superficial irradiation of skin cancer and for intra-operative RT (IORT)
- Megavoltage X-rays service/unit – energy > 1MV (typically 4-25 MeV)



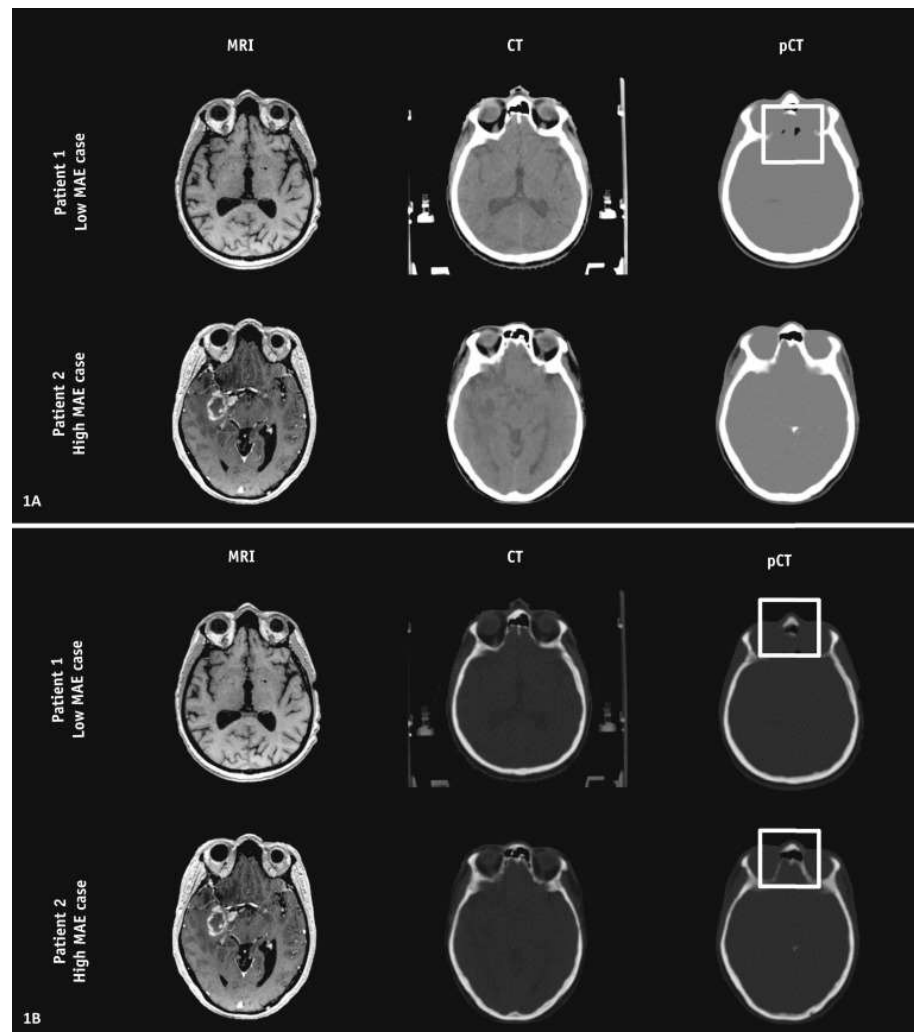
Conventional simulator (fluoroscopic planning machine)



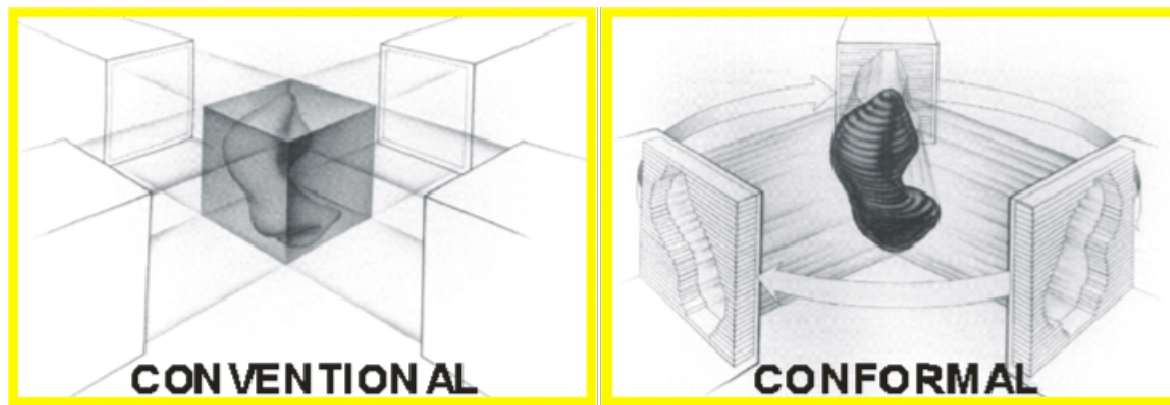
CT/MRI simulator

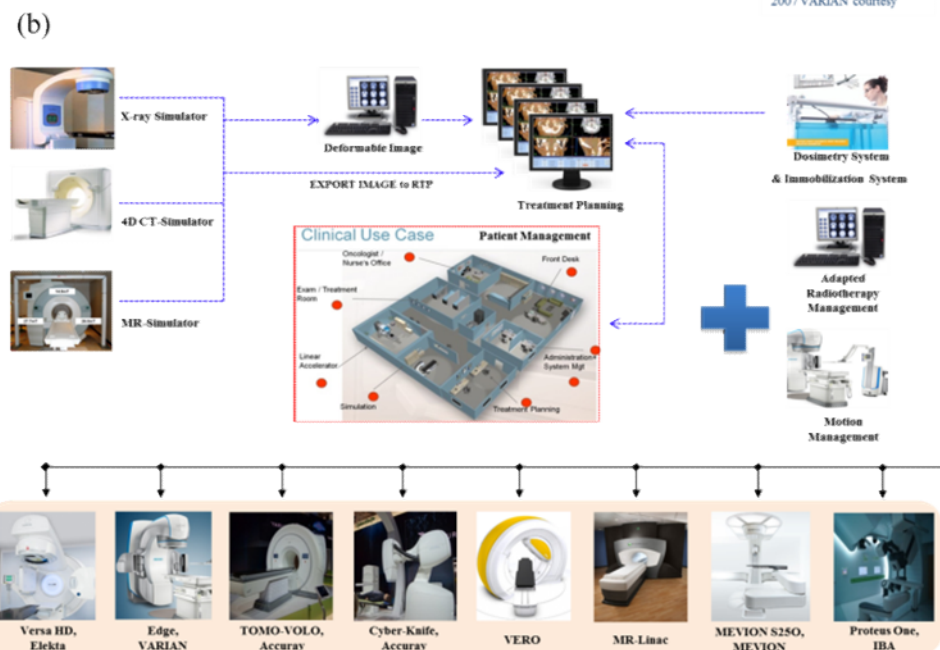
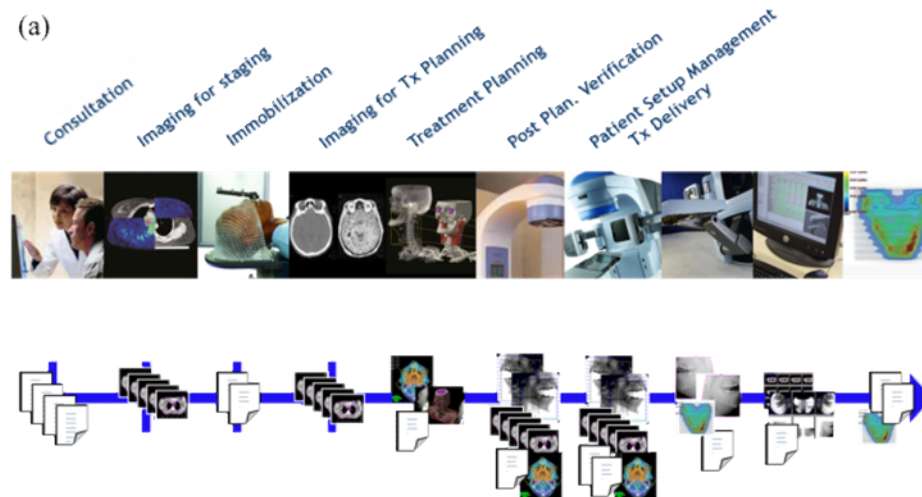


- Andres A. E. Int J of Radiation Oncology, Biology, Physics. , 2020.

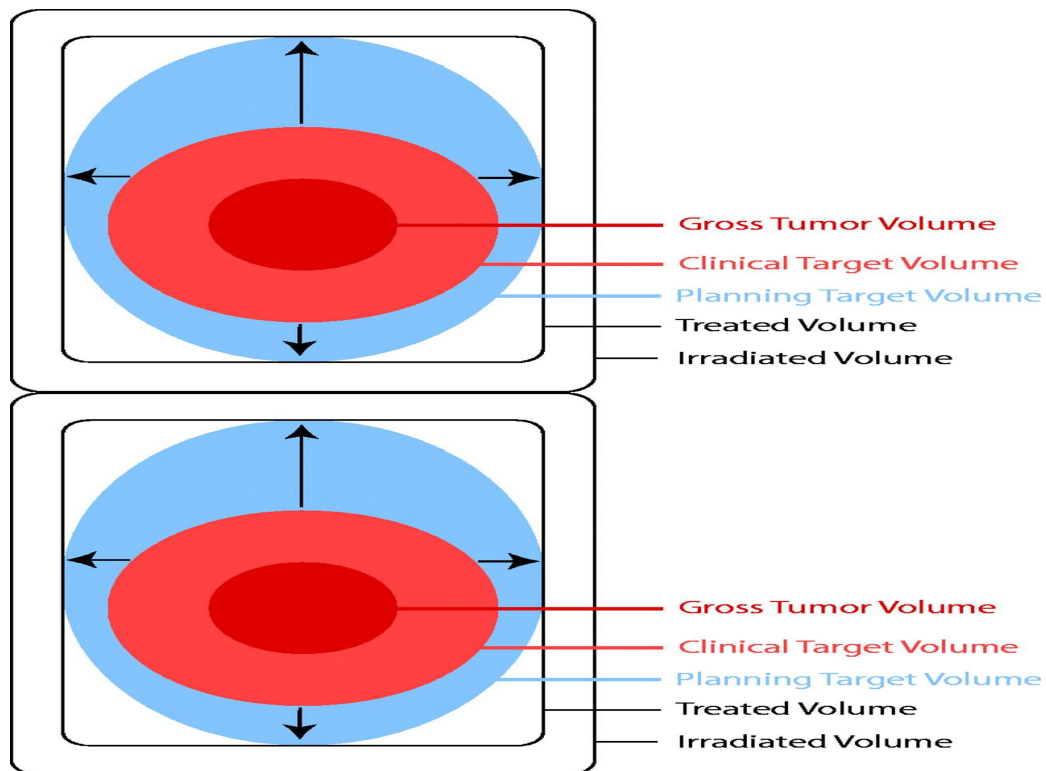


PRECISE DELIVERY OF THERAPEUTIC RADIATION DOSE IN THE TUMOR TISSUE WITH MINIMAL DAMAGE TO THE SURROUNDING, HEALTHY TISSUE





Lee S. 2014.
Evolution of Ionizing Radiation Research



- Conformal radiotherapy (CRT) – the beginnings of the 1960s.
- The development of imaging methods (CT, MRI, PET), information technology, modern radiotherapy devices - enabling the development of CRT
- Local disease control as a function of delivered dose
- Sparing of surrounding, healthy tissues
- Dose escalation

Target volume

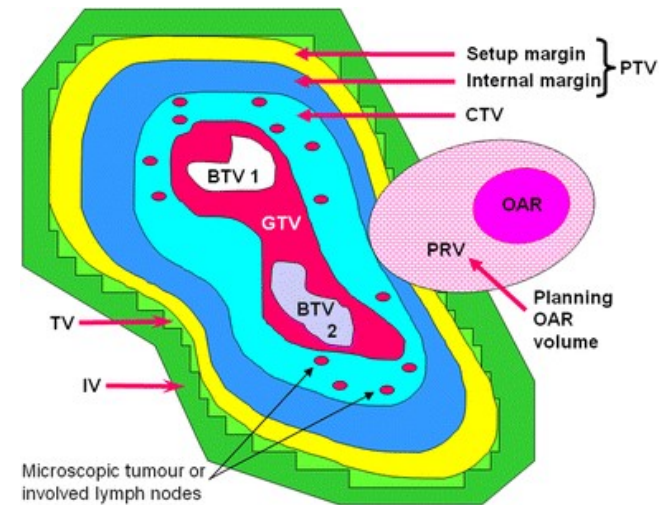
- Gross Tumor Volume (GTV): the visible part of the tumor (or lymph node), based on the performed clinical-diagnostic procedures. After a surgical treatment (R0 resection) the GTV is not visible.
- Clinical Target Volume (CTV): zone of microscopic spread of malignant cells around the visible part of the tumor (CTVt). CTVn is defined around enlarged regional lymph nodes (GTVn), it includes at least the entire anatomical group of lymph nodes to which the involved node belongs.
- Planning Target Volume (PTV): the margin that covers the interfractional/intrafractional variations of the CTV position in relation to the geometry of the beam/radiation field, and is caused by: variations in precision, physiological movements.

Organs at Risk (OAR)

- Healthy, surrounding tissues, whose sparing/radiosensitivity is taken into account when creating a radiation plan and carrying out radiotherapy treatment

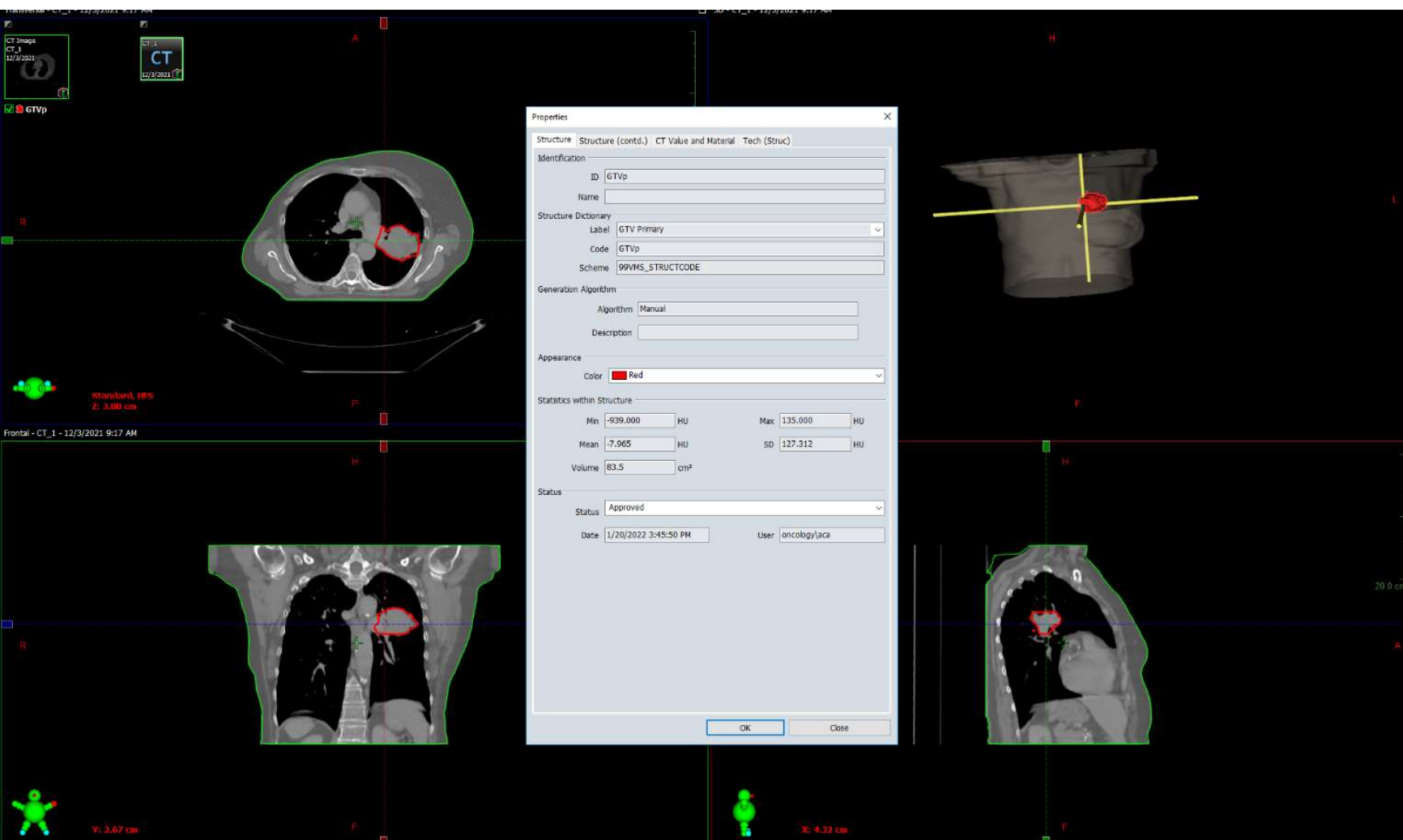
Additional volume around OAR (PRV - Planning Risk Volume)

A 3D model of the "virtual patient", with a volumetric representation of the geometry of the target volume and the spatial relationships of the target volume and the OAR



QUANTEC Summary:
Approximate Dose/Volume/Outcome Data for Several Organs Following Conventional Fractionation 3D-CRT

Organ	Endpoint	Dose (Gy), or dose/volume parameters	Rate (%)	Volume segmented	Irradiation type (partial organ unless otherwise stated)
Brain	Symptomatic necrosis	Dmax <60	<3	Whole organ	3D-CRT
		Dmax = 72	5		
		Dmax = 90	10		
Brain stem	Permanent cranial neuropathy or necrosis	Dmax <54	<5	Whole organ	Whole organ
		D1-10 cc * ≤59	<5		3D-CRT
		Dmax <64 <<1 cc (Point dose)	<5		3D-CRT
Optic nerve/ chiasm	Optic neuropathy	Dmax <55	<3	Whole organ	Given the small size, 3D-CRT is often whole organ
		Dmax 55-60	3-7		
		Dmax >60	>7-20		
Spinal cord	Myelopathy	Dmax = 50	0.2	Partial organ	3D-CRT
		Dmax = 60	6		
		Dmax = 69	50		
Cochlea	Sensory neural hearing loss (hearing at 4 kHz)	Mean dose ≤45	<30	Whole organ	Given the small size, 3D-CRT is often whole organ
Parotid	Long term parotid salivary function reduced to <25% of pre-RT level	Mean dose <25 (for combined parotid glands)**	<20	Bilateral whole parotid glands	3D-CRT
		Mean dose <20 (for single parotid gland)**	<20	Unilateral whole parotid gland	
		Mean dose <39 (for combined parotid glands)**	<50	Bilateral whole parotid glands	
Pharynx constrictors	Symptomatic dysphagia and aspiration	Mean dose <50	<20	Pharyngeal constrictors	Whole organ
Larynx	Vocal dysfunction (with chemo, based on single study)	Dmax <66	<20	Whole organ	3D-CRT
	Aspiration (with chemo, based on single study)	Mean dose <50	<30		
	Edema (without chemo, based on single study in patients without larynx cancer)	Mean dose <44	<20		
		V50 <27%	<20		
Lung	Symptomatic pneumonitis	V20 ≤ 30% (for combined lung)	<20	Whole organ	3D-CRT
		Mean dose = 7	5		3D-CRT (excludes purposeful whole lung irradiation)
		Mean dose = 13	10		
		Mean dose = 20	20		
		Mean dose = 24	30		



Properties

Structure: Structure (cont'd.) CT Value and Material Tech (Struc)

Identification

ID: GTVp

Name:

Structure Dictionary

Label: GTV Primary

Code: GTVp

Scheme: 99VMS_STRUCTURECODE

Generation Algorithm

Algorithm: Manual

Description:

Appearance

Color: Red

Statistics within Structure

Min: -939.000 HU	Max: 135.000 HU
Mean: -7.965 HU	SD: 127.312 HU
Volume: 83.5 cm³	

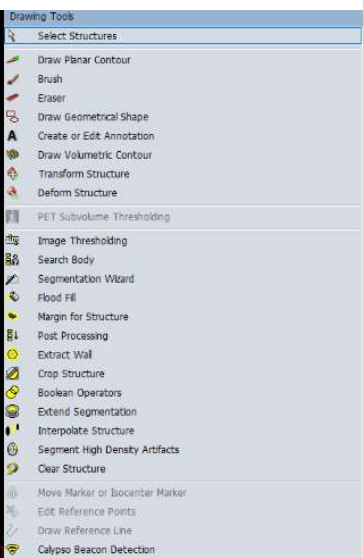
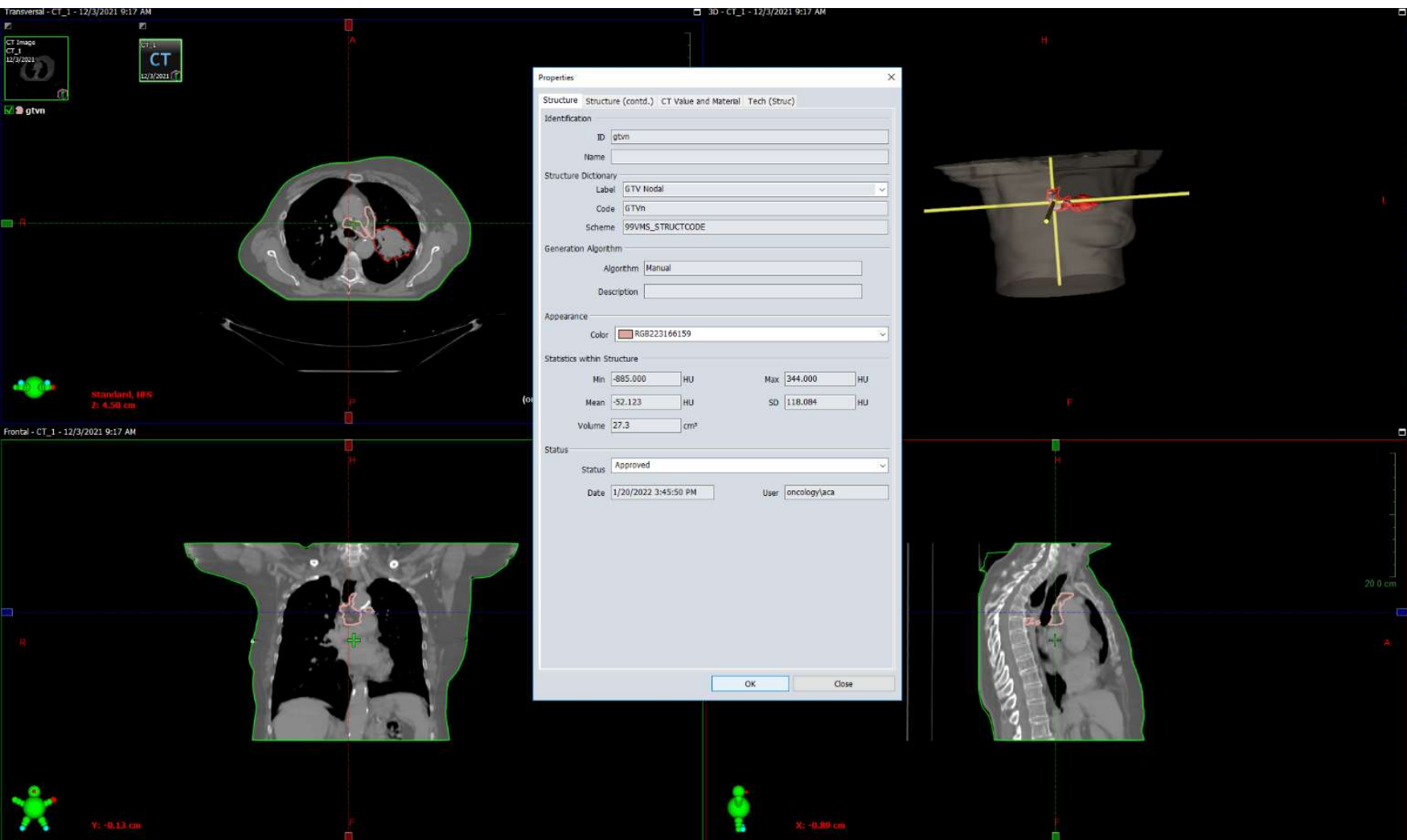
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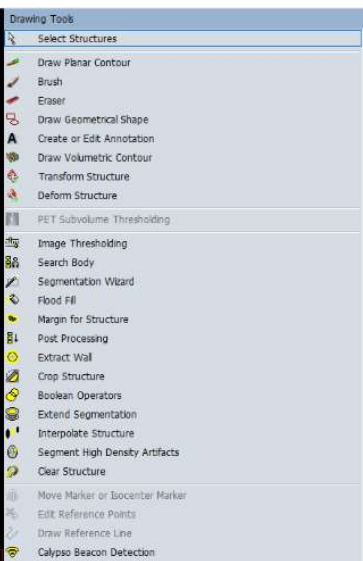
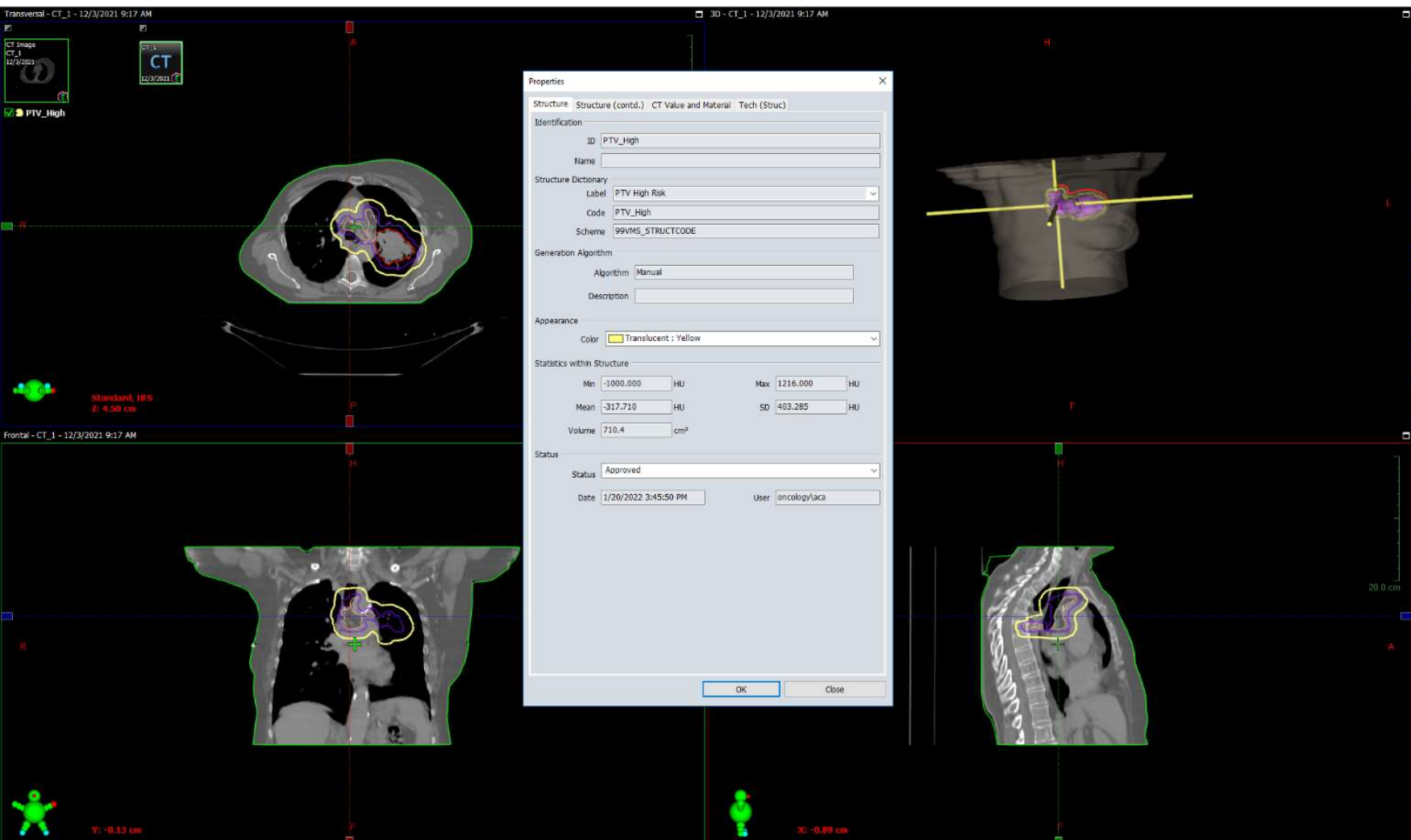
Status: Approved

Date: 1/20/2022 3:45:50 PM User: oncology/jaca

OK Close

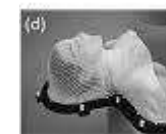
- Unwarp Tools
- Select Structures
 - Draw Planar Contour
 - Brush
 - Eraser
 - Draw Geometrical Shape
 - Create or Edit Annotation
 - Draw Volumetric Contour
 - Transform Structure
 - Deform Structure
 - PET Subvolume Thresholding
 - Image Thresholding
 - Search Body
 - Segmentation Wizard
 - Flood Fill
 - Margin for Structure
 - Post Processing
 - Extract Wall
 - Crop Structure
 - Boolean Operators
 - Extend Segmentation
 - Interpolate Structure
 - Segment High Density Artifacts
 - Clear Structure
 - Move Marker or Isocenter Marker
 - Edit Reference Points
 - Draw Reference Line
 - Calypso Beacon Detection





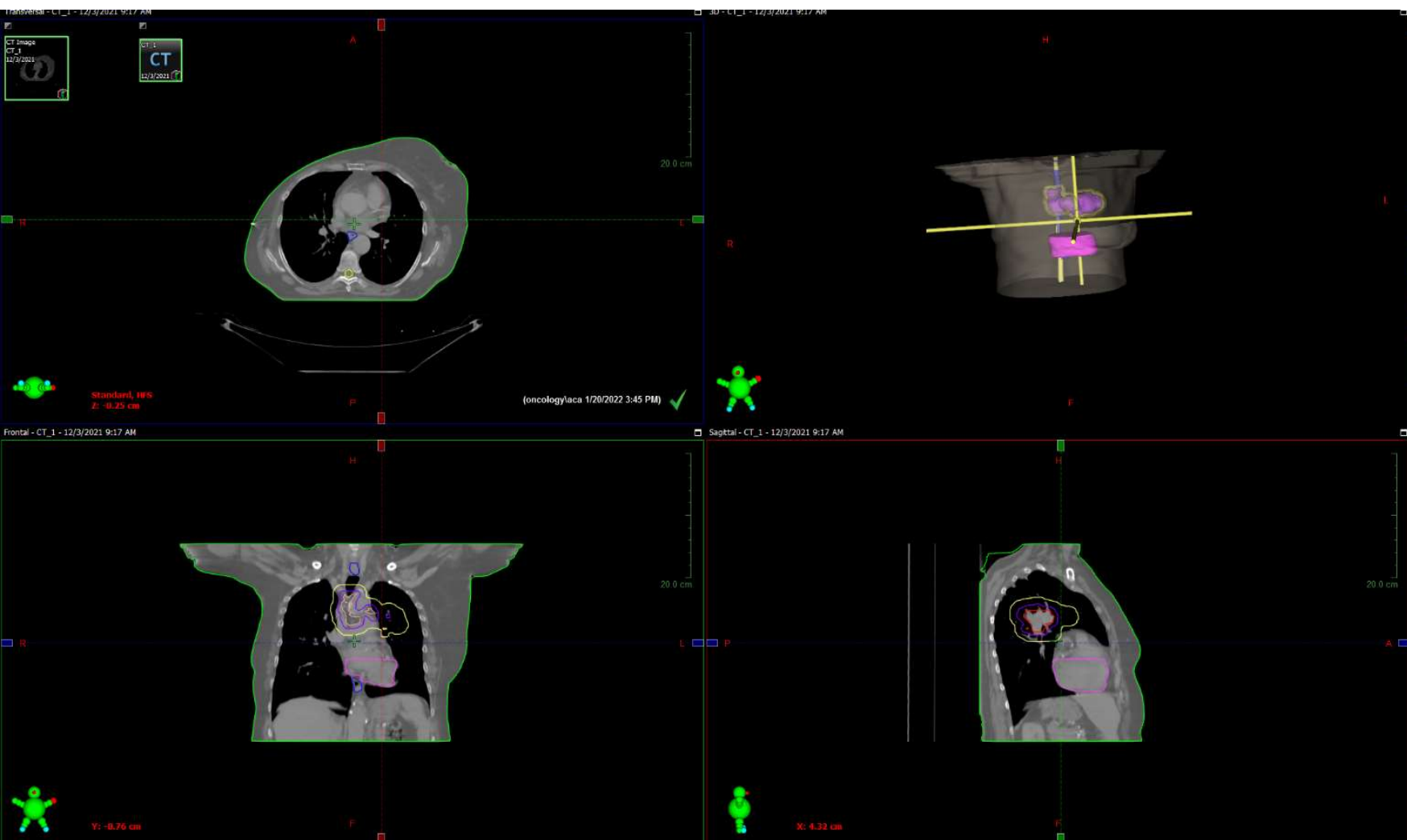
- Initial diagnostic work up (pathology and diagnostics)
- Disease staging and disease characterization (e.g. Tumor molecular profile)
- Multidisciplinary oncology team – treatment decision
- Initial exam, informed decision and patient consent
- Positioning and immobilisation
- CT/MRI simulation
- Radiotherapy planning (radiation oncologist + medical physicist)
- Radiotherapy treatment (with weekly check-up)
- Follow up

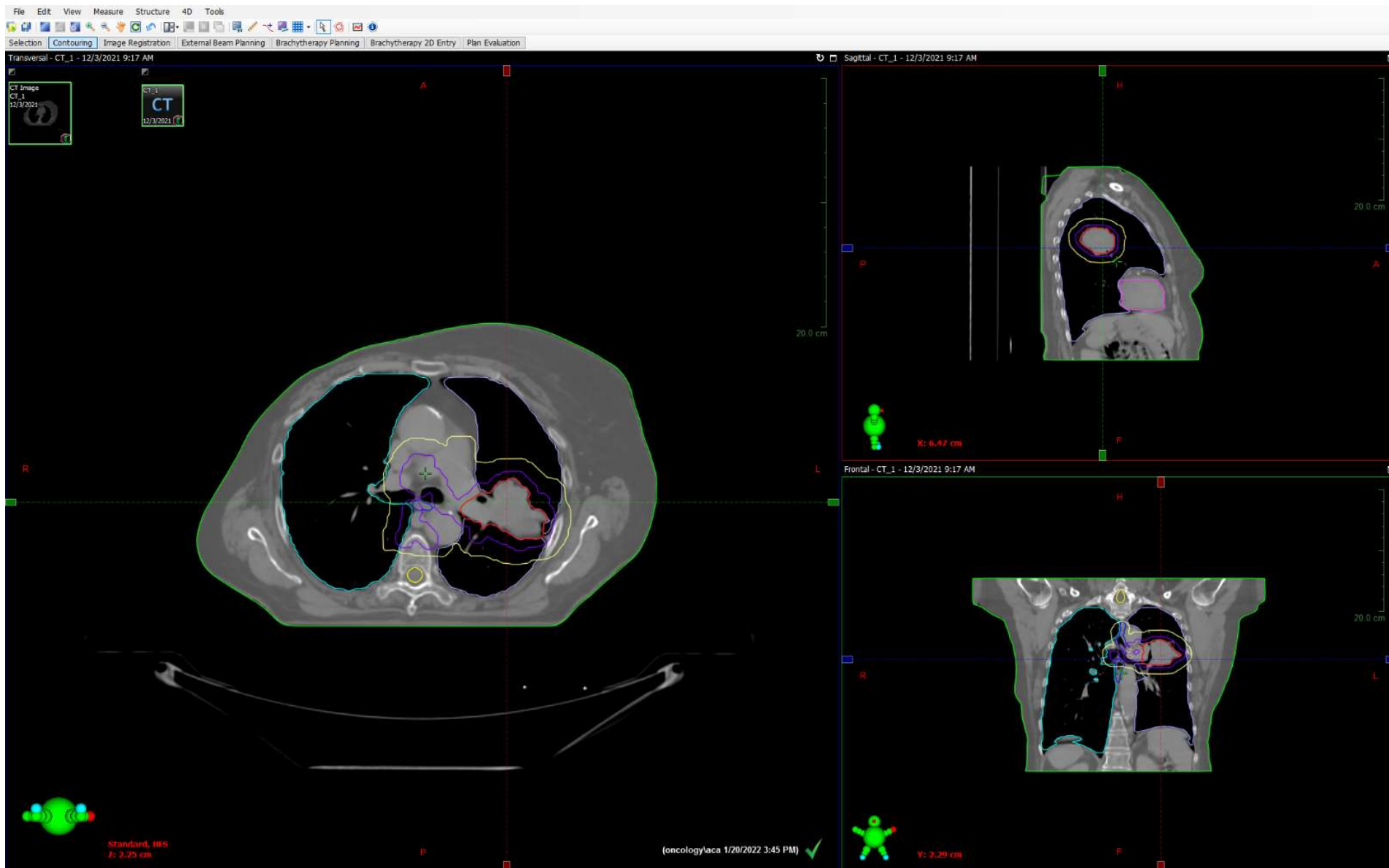
POSITIONING AND IMMOBILIZATION

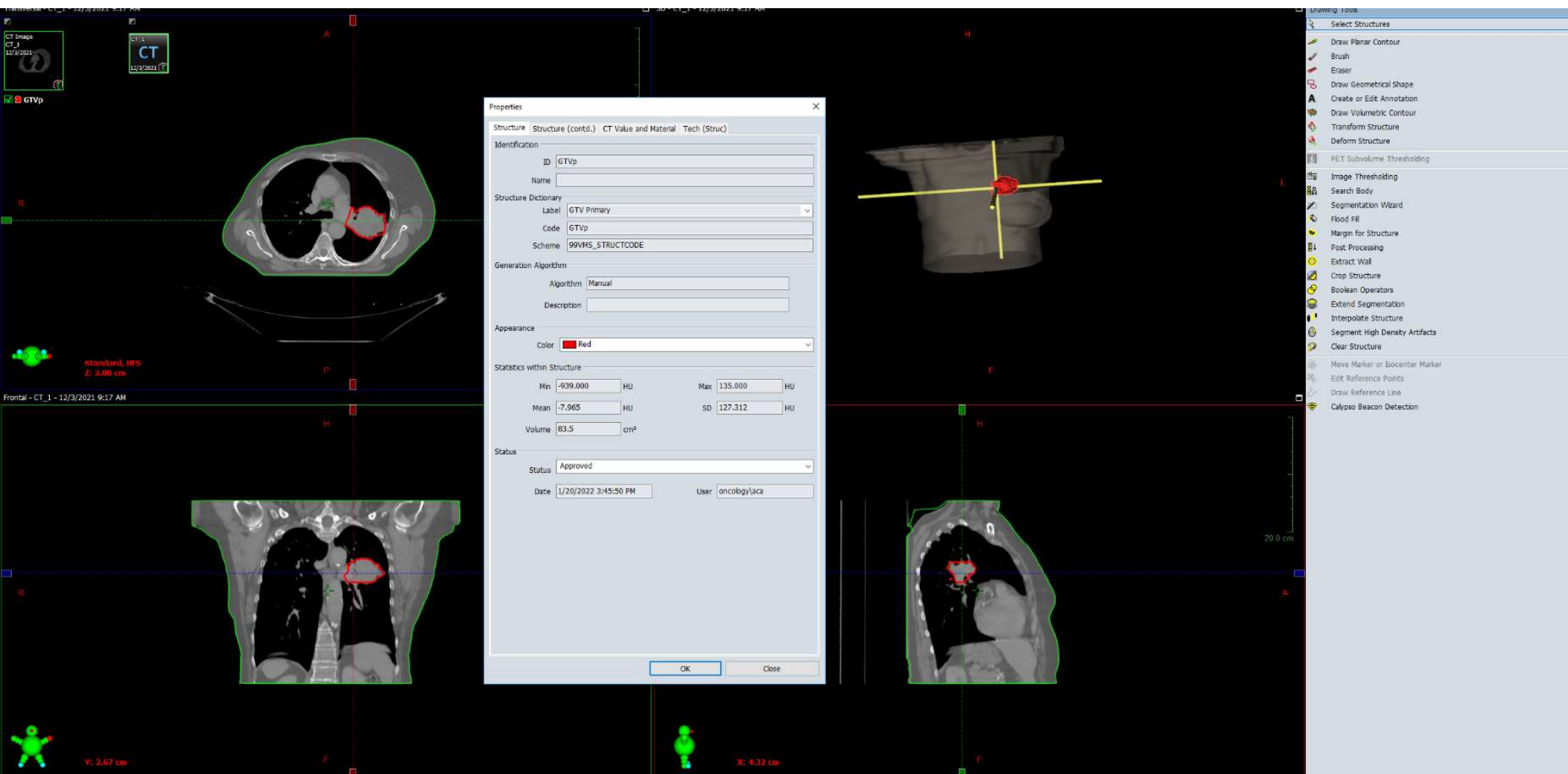


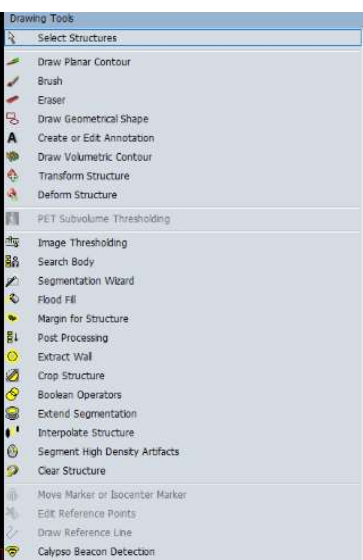
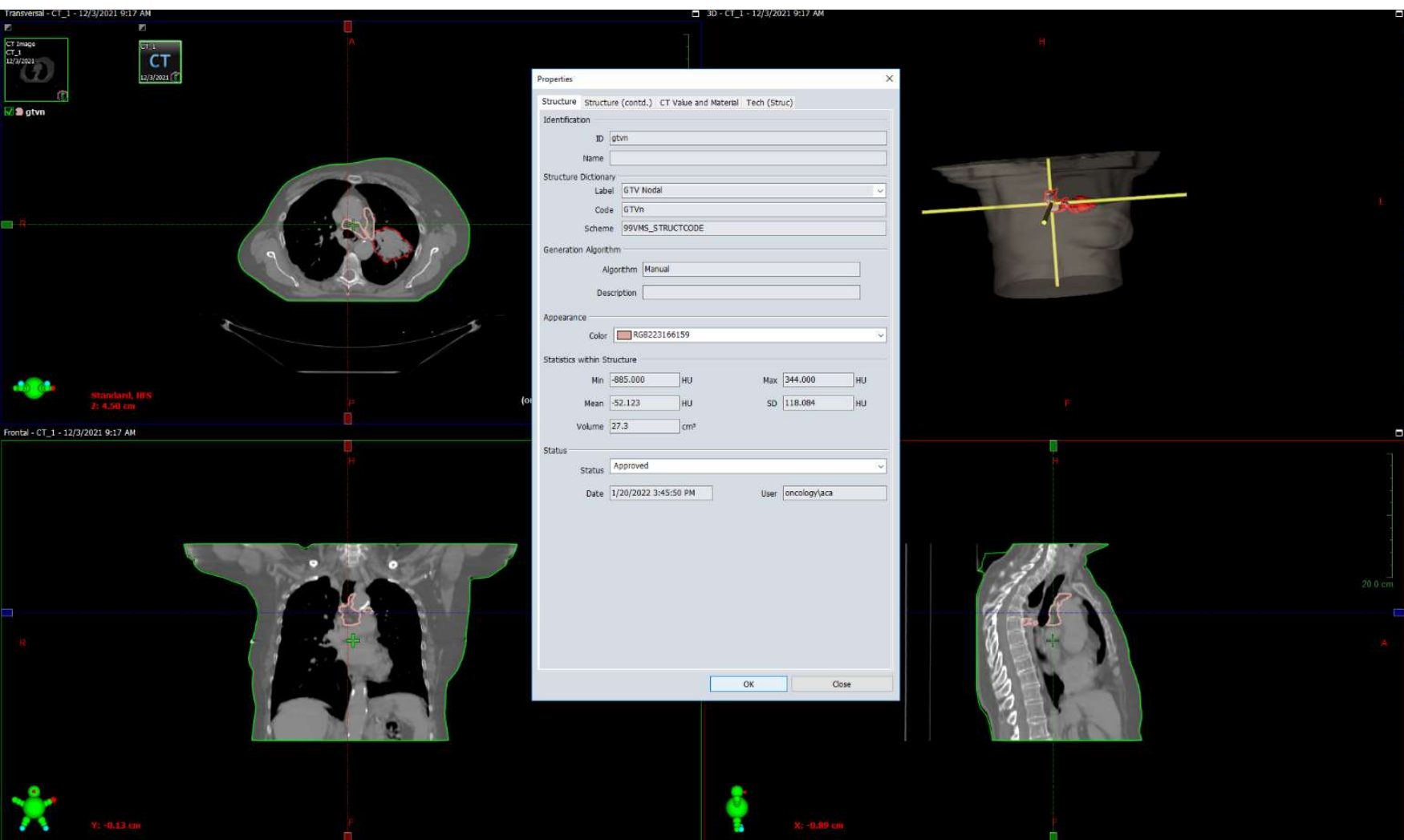
Three-dimensional conformal radiation, 3D-CRT

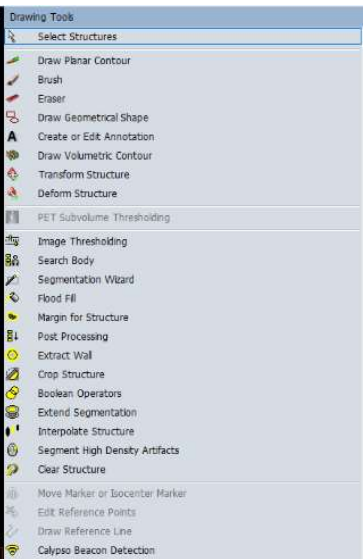
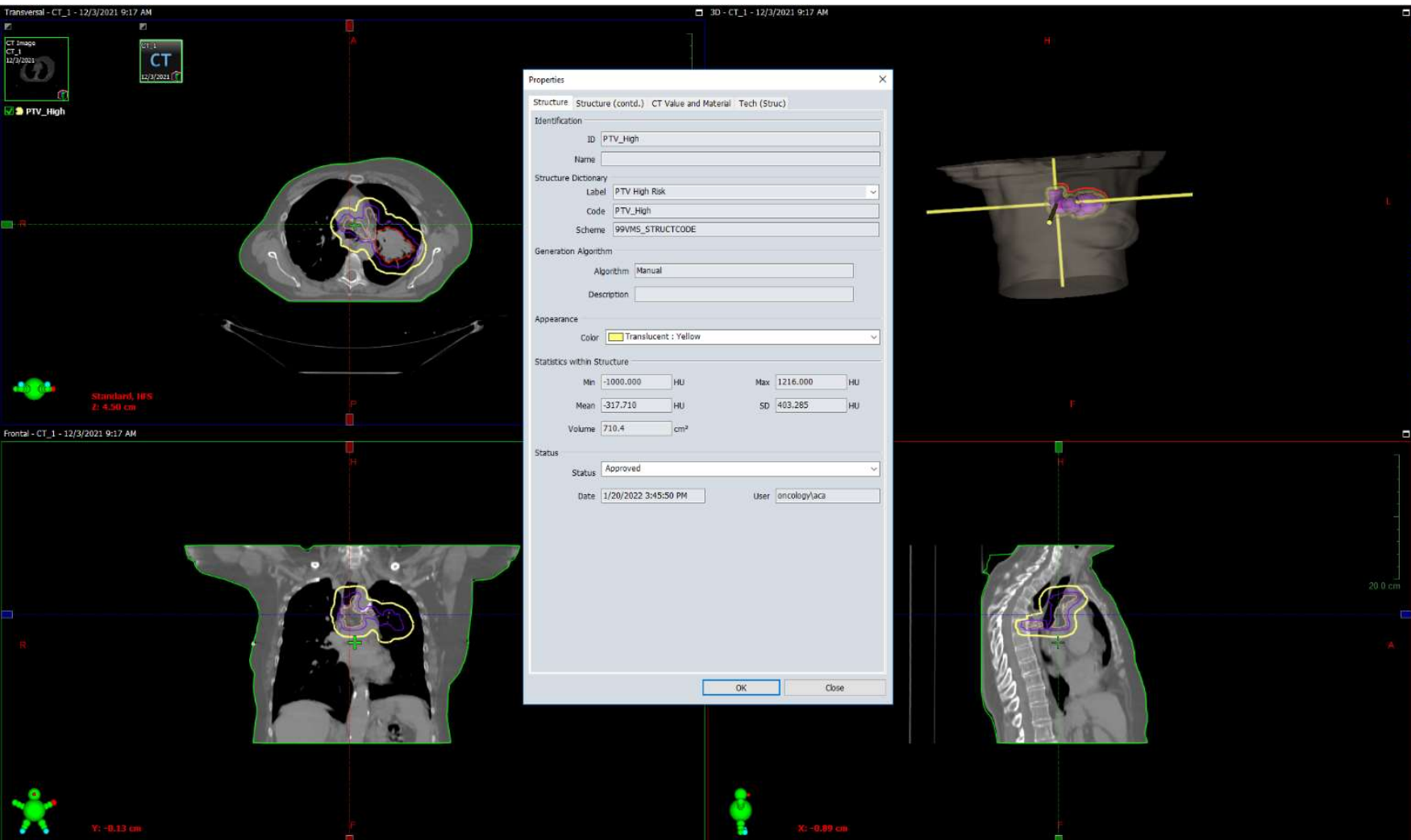
- Became widely used in the 1970s-80s
- CT-guided therapy allows the tumor and normal organs shape and size to be defined in three dimensions
- delivery of radiation to a three-dimensional volume using appropriate imaging studies and computer software
- Decreases the treatment margins and minimizes the volume of normal tissue receiving a clinically significant radiation dose

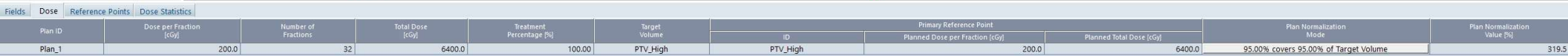












1
1:RO
Plan_1

Plan_1

Registered images

- CT_1
- BODY
- CouchInterior
- CouchSurface
- CTV_High
- Esophagus
- gtvn
- GTVp
- Heart
- Lung_L
- Lung_R
- PTV_High
- SpinalCord

User Origin

Reference Points

- PTV_High

Dose

Fields

- Isocenter Group I
- pi0
- pi0-DRR (Live)
- pi90
- pi270-DRR (Live)
- foto
- foto-DRR (Live)
- 48
- Field 3-DRR (Live)
- MLC
- 48.0
- Field3-DRR (Live)
- MLC
- 79
- Field 5-DRR (Live)

Dose Reference Points Dose Statistics

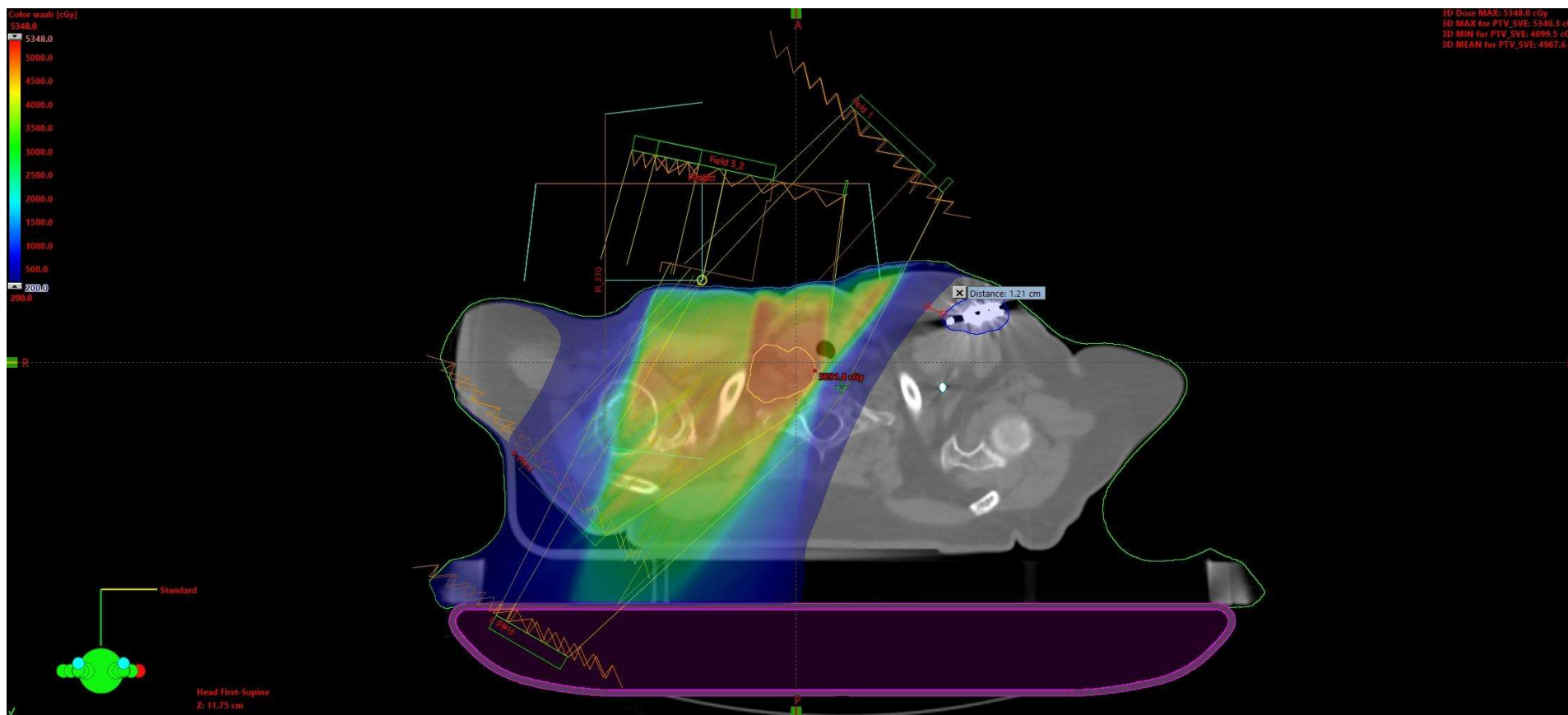
Show DVH	Structure	Approval Status	Plan	Course	Volume [cm ³]	Dose Cover [%]	Sampling Cover [%]	Min Dose [cGy]	Max Dose [cGy]	Mean Dose [cGy]	D99.0% [%]	V95.0% [%]	V107.0% [%]	V107.0% [cm ³]	V5120.0cGy [%]	V5985.0cGy [%]	V5992.0cGy [%]	V6630.0cGy [%]
<input checked="" type="checkbox"/>	Lung_L	Approved	Plan_1	1	1720.1	100.0	100.0	35.3	6944.9	2876.0	0.0	18.6	0.1	1.3180	29.5	20.1	20.0	4.8
<input checked="" type="checkbox"/>	Lung_R	Approved	Plan_1	1	2523.3	100.0	100.0	43.2	6773.6	1331.9	0.0	1.9	0.0	0.0000	3.8	2.2	2.2	0.0
<input checked="" type="checkbox"/>	BODY	Approved	Plan_1	1	21699.8	100.0	100.2	1.0	6984.6	1137.3	0.0	4.1	0.0	6.6403	6.1	4.4	4.4	0.9
<input checked="" type="checkbox"/>	Esophagus	Approved	Plan_1	1	29.0	100.0	100.2	100.1	6723.9	3170.9	0.0	38.3	0.0	0.0000	41.8	39.3	39.3	0.1
<input checked="" type="checkbox"/>	SpinalCord	Approved	Plan_1	1	37.9	100.0	99.4	6.3	4685.6	1195.3	0.0	0.0	0.0	0.0000	0.0	0.0	0.0	0.0
<input checked="" type="checkbox"/>	Heart	Approved	Plan_1	1	363.5	100.0	100.0	101.0	535.7	232.4	0.0	0.0	0.0	0.0000	0.0	0.0	0.0	0.0
<input checked="" type="checkbox"/>	GTVp	Approved	Plan_1	1	83.5	100.0	100.0	6054.7	6944.7	6621.3	0.0	100.0	0.7	0.5707	100.0	100.0	100.0	44.8
<input checked="" type="checkbox"/>	gtvn	Approved	Plan_1	1	27.3	100.0	100.0	5954.0	6984.6	6366.0	0.0	96.5	0.6	0.1578	100.0	100.0	99.9	12.1
<input checked="" type="checkbox"/>	CTV_High	Approved	Plan_1	1	277.0	100.0	100.0	5804.9	6984.6	6523.2	0.0	99.0	0.6	1.7779	100.0	99.9	99.9	34.2
<input checked="" type="checkbox"/>	PTV_High	Approved	Plan_1	1	710.4	100.0	100.0	4273.5	6984.6	6453.5	0.0	95.0	0.6	4.2090	99.9	97.0	96.9	24.3
<input checked="" type="checkbox"/>	(Lung_L OR Lung_R) S...	Approved	Plan_1	1	3946.6	100.0	100.0	35.3	6857.6	1619.8	1.5	1.5	1.5	1.4QNB	1.5	1.5	1.5	1.5

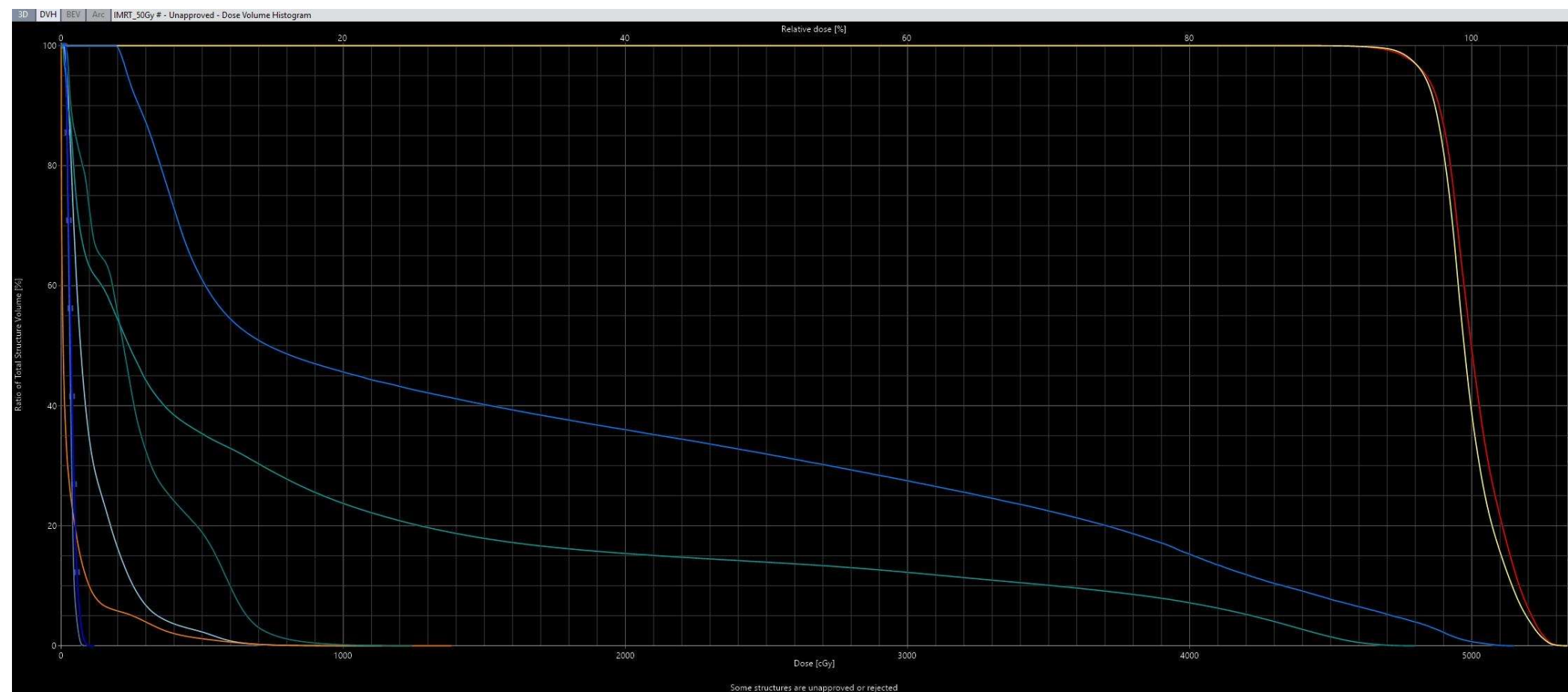
Ready

User: dr Neda Milosavljevic Group: Oncologist Site: Main CAP: NUM SCRL

INTENSITY MODULATED RADIATION THERAPY - IMRT

- delivers radiation precisely to the target volume while relatively sparing the surrounding normal tissues
- inverse planning and computer-controlled radiation and normal tissue avoidance
- ability to create multiple targets and multiple avoidance structures, to treat different targets simultaneously to different doses
- minimize acute treatment-related toxicity
- dose escalation = improved local tumor control
- accelerated fractionation scheme - simultaneous integrated boost (SIB)
- shortening the overall treatment time

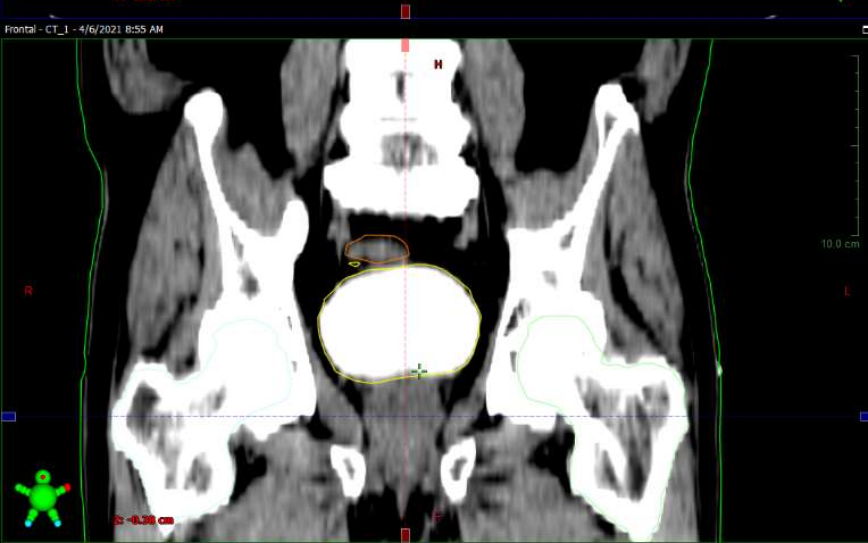
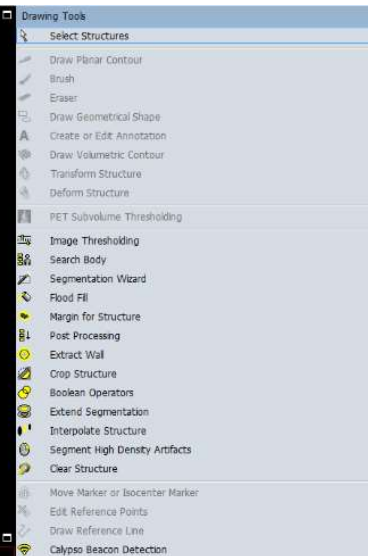
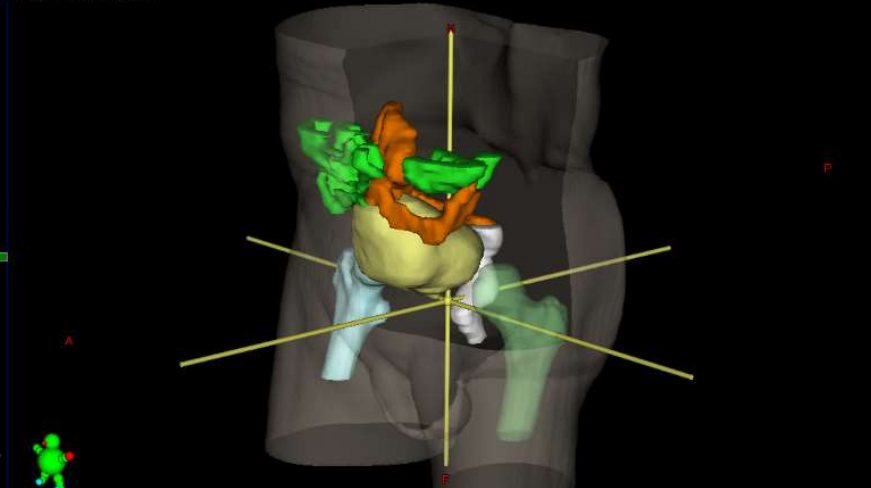


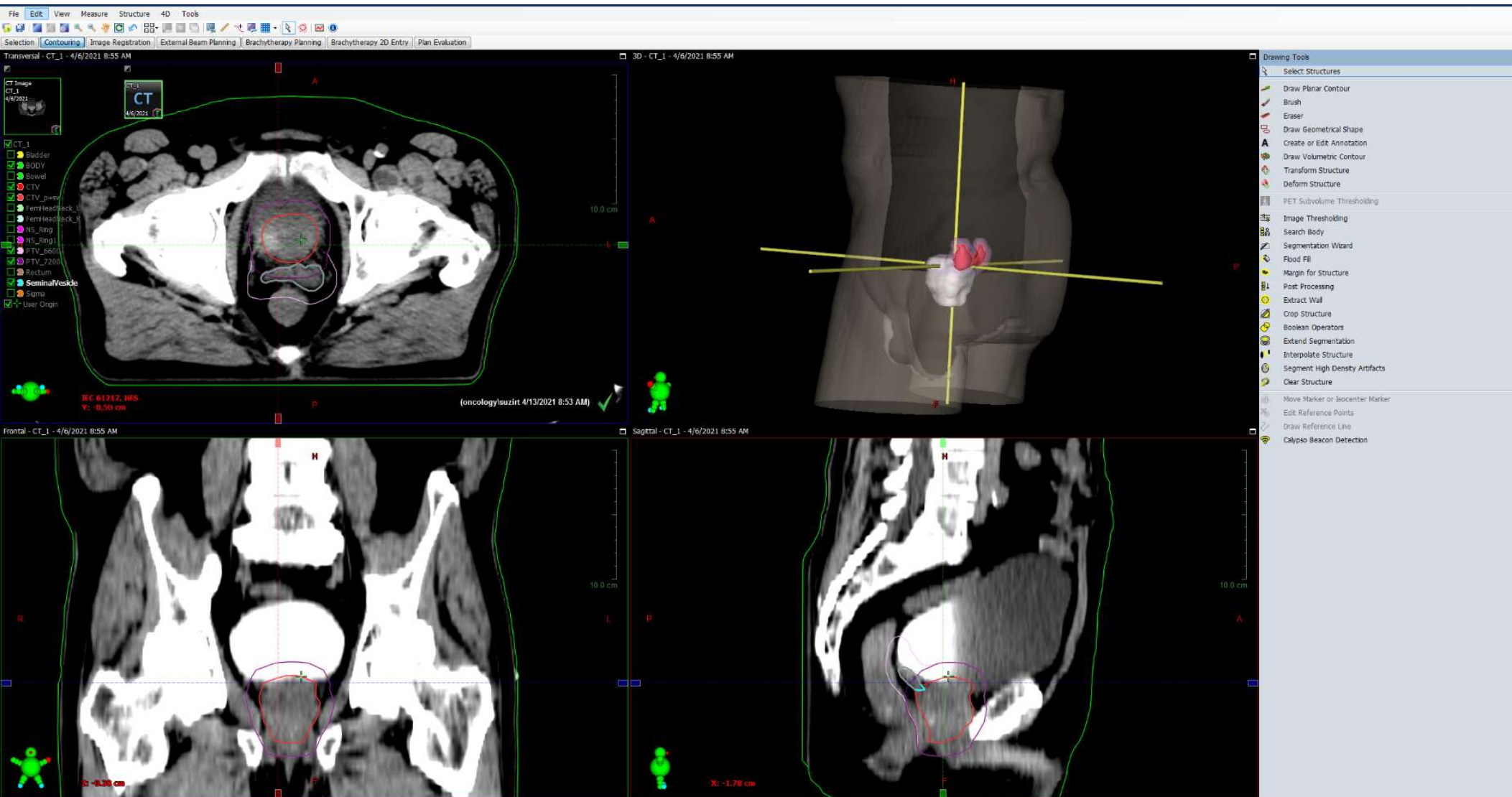
[illegible]

Volumetric Modulated Arc Therapy, VMAT

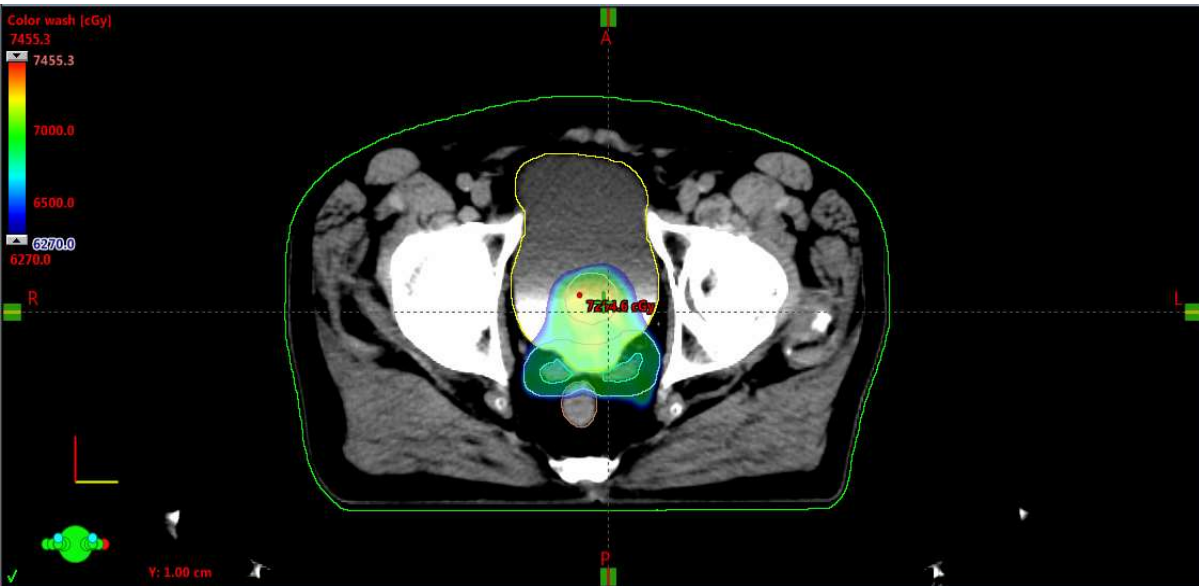
- highly conformal dose distributions with improved target volume coverage and sparing of normal tissues compared with conventional radiotherapy techniques
- reduced treatment delivery time compared with IMRT
- allowed the simultaneous variation of three parameters during treatment delivery: gantry rotation speed, treatment aperture shape via movement of MLC leaves and dose rate
- OAR sparing?

Transversal - CT_1 - 4/6/2021 8:55 AM 3D - CT_1 - 4/6/2021 8:55 AM

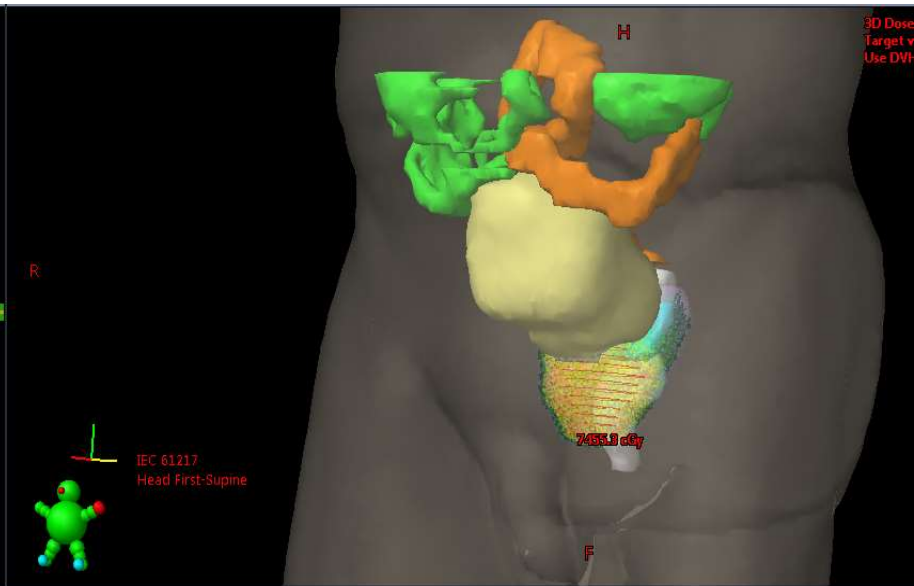




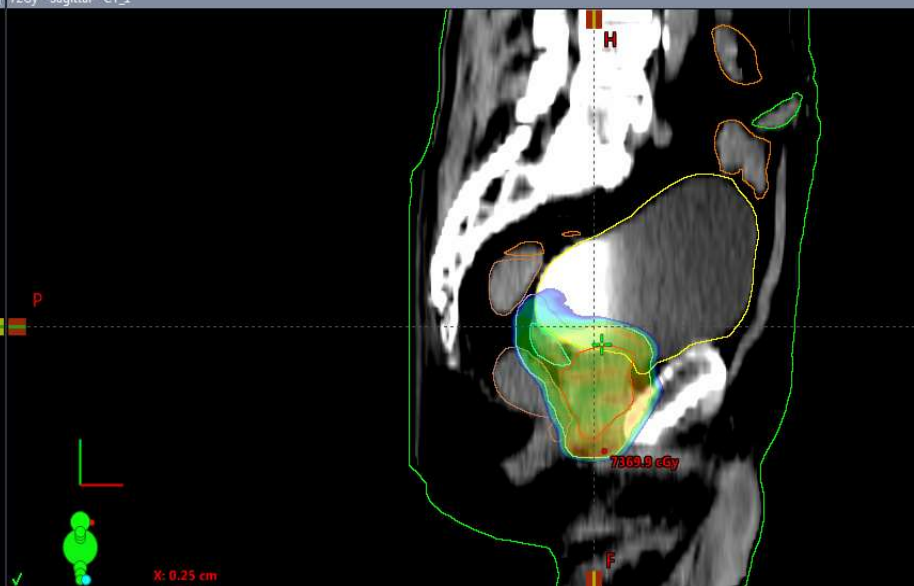
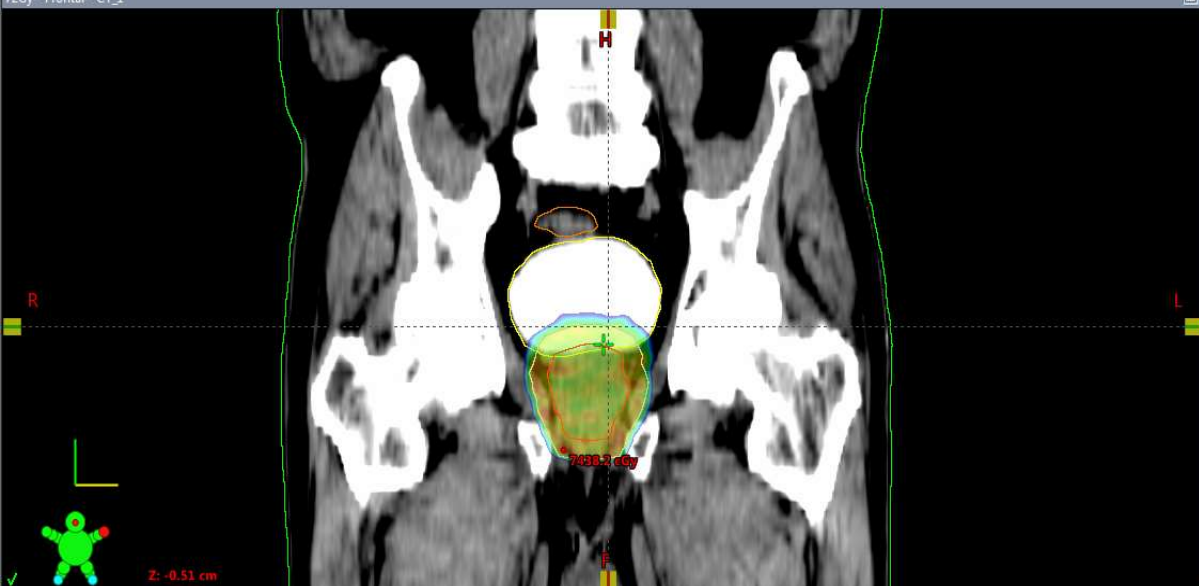
Color wash [cGy]
7455.3
7455.3
7000.0
6500.0
6270.0
6270.0

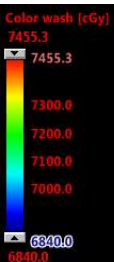


72Gy - Frontal - CT_1

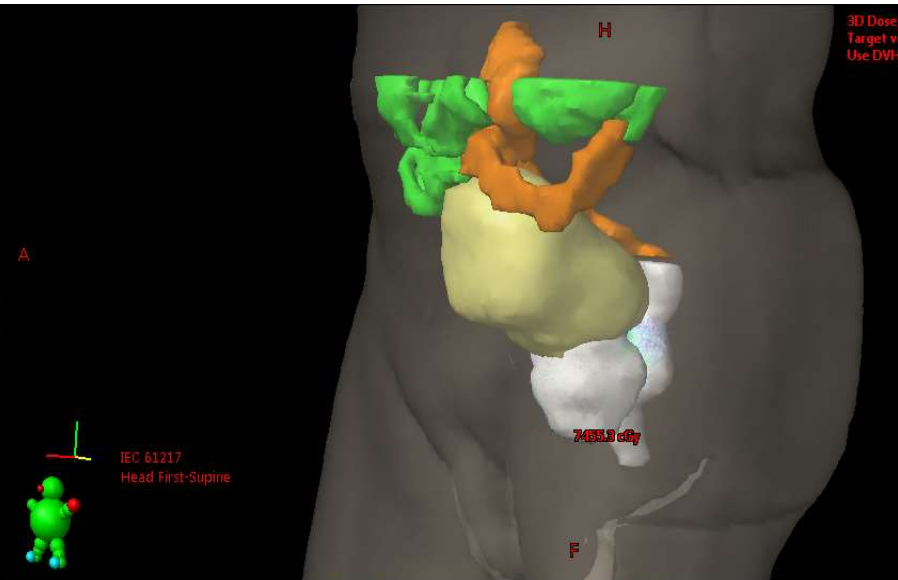


72Gy - Sagittal - CT_1

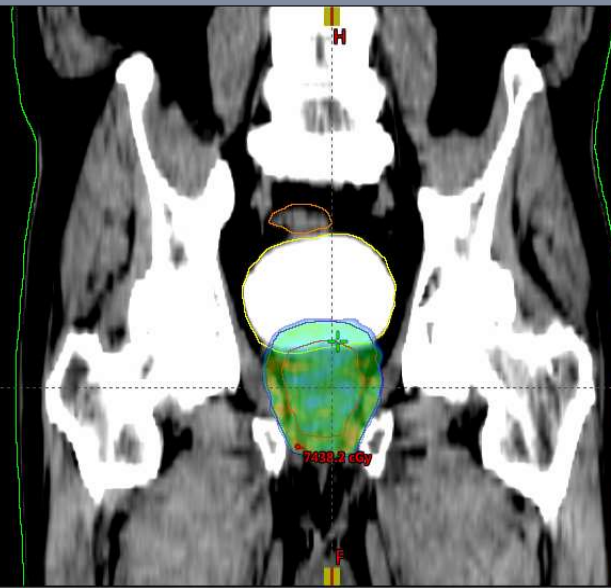


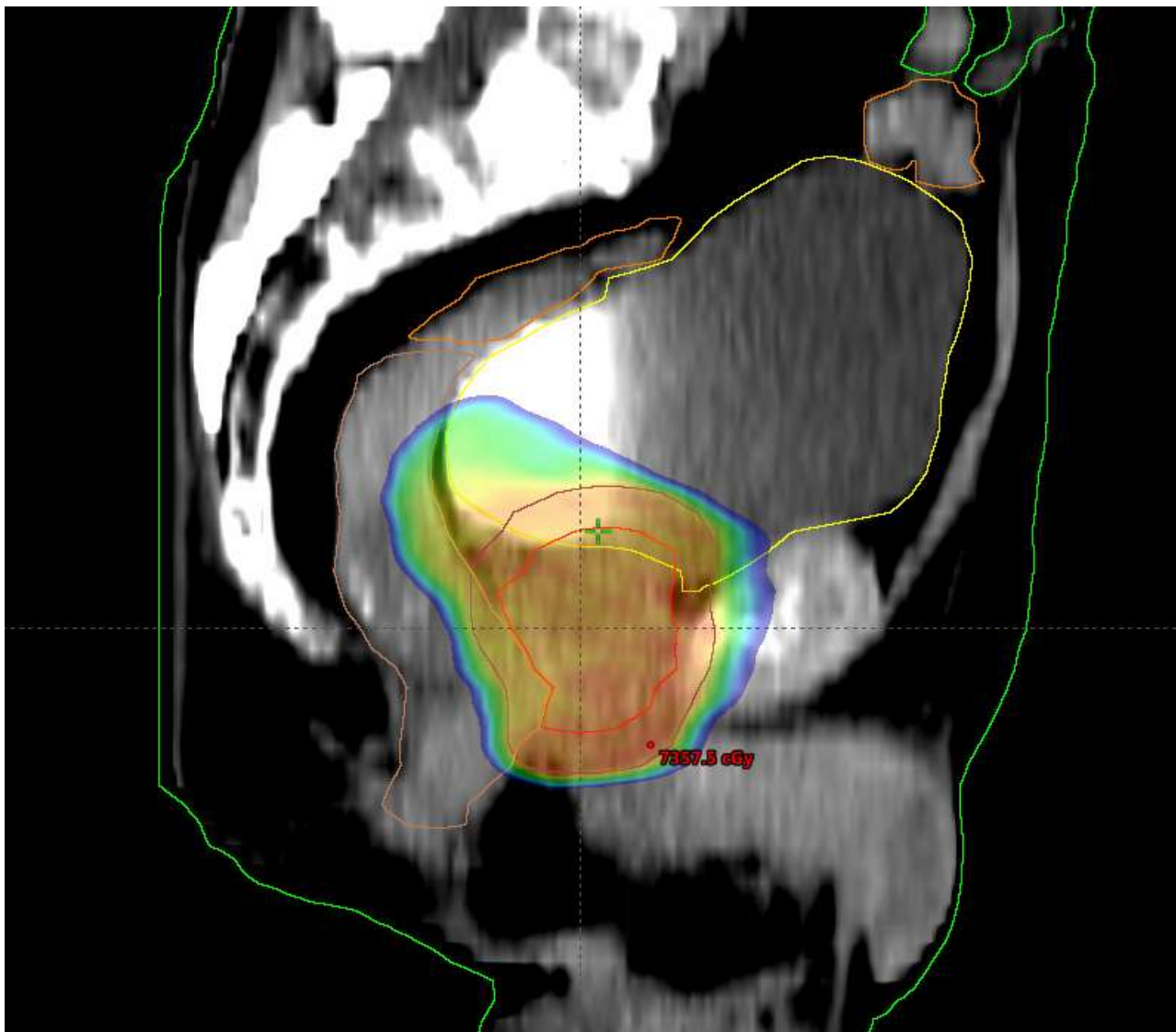


72Gy - Frontal - CT_1



72Gy - Sagittal - CT_1





OAR constrains

Bladder	V65 < 50% V70 < 35% V75 < 25% V80 < 15%
Sigmoid colon	V50 < 50% V60 < 35% V65 < 25% V70 < 20% V75 < 15%
Rectum	V50 < 50% V60 < 35% V65 < 25% V70 < 20% V75 < 15%
Bowel	V45 < 195 cm ³ V15 < 120 cm ³
Femur	V40 < 40% V45 < 25% V50 < 10%

- Kang SW, Chung JB, Kim JS, Kim IA, Eom KY, Song C, Lee JW, Kim JY, Suh TS. Optimal planning strategy among various arc arrangements for prostate stereotactic body radiotherapy with volumetric modulated arc therapy technique. *Radiol Oncol*. 2017 Jan 15;51(1):112-120.



Karavido010421

- 1
- PD_6Gy
- PD_66Gy
- 72Gy
- PTV66 : R0
- 66Gy
- PTV72 : R0
- 6Gy

72Gy

CT_1

Registered Images

CT_1

Bladder

BODY

Bowel

CTV

CTV_p+sv

FemHeadNeck_L

FemHeadNeck_R

NS_Ring

NS_Ring1

PTV_6600

PTV_7200

Rectum

SeminalVesicle

Sigma

User Origin

Reference Points

PTV_6600

PTV_7200

Verification

Verification1

Dose

66Gy

Fields

Isocenter Group I

P0

P270

CBCT

G181-179

G179-181

6Gy

Fields

72Gy - Transversal - CT_1

Color wash [cGy]

7200.0

7000.0

6500.0

6000.0

5800.0

5600.0

5400.0

5200.0

5000.0

4800.0

4600.0

4400.0

4200.0

4000.0

3800.0

3600.0

3400.0

3200.0

3000.0

2800.0

2600.0

2400.0

2200.0

2000.0

1800.0

1600.0

1400.0

1200.0

1000.0

800.0

600.0

400.0

200.0

0.0

-200.0

-400.0

-600.0

-800.0

-1000.0

-1200.0

-1400.0

-1600.0

-1800.0

-2000.0

-2200.0

-2400.0

-2600.0

-2800.0

-3000.0

-3200.0

-3400.0

-3600.0

-3800.0

-4000.0

-4200.0

-4400.0

-4600.0

-4800.0

-5000.0

-5200.0

-5400.0

-5600.0

-5800.0

-6000.0

-6200.0

-6400.0

-6600.0

-6800.0

-7000.0

-7200.0

-7400.0

-7600.0

-7800.0

-8000.0

-8200.0

-8400.0

-8600.0

-8800.0

-9000.0

-9200.0

-9400.0

-9600.0

-9800.0

-10000.0

-10200.0

-10400.0

-10600.0

-10800.0

-11000.0

-11200.0

-11400.0

-11600.0

-11800.0

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-12200.0

-12400.0

-12600.0

-12800.0

-13000.0

-13200.0

-13400.0

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-20000.0

-20200.0

-20400.0

-20600.0

-20800.0

-21000.0

-21200.0

-21400.0

-21600.0

-21800.0

-22000.0

-22200.0

-22400.0

-22600.0

-22800.0

-23000.0

-23200.0

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-30800.0

-31000.0

-31200.0

-31400.0

-31600.0

-31800.0

-32000.0

-32200.0

-32400.0

-32600.0

-32800.0

-33000.0

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-37600.0

-37800.0

-38000.0

-38200.0

-38400.0

-38600.0

-38800.0

-39000.0

-39200.0

-39400.0

-39600.0

-39800.0

-40000.0

-40200.0

-40400.0

-40600.0

-40800.0

-41000.0

-41200.0

-41400.0

-41600.0

-41800.0

-42000.0

-42200.0

-42400.0

-42600.0

-42800.0

-43000.0

-43200.0

-43400.0

-43600.0

-43800.0

-44000.0

-44200.0

-44400.0

-44600.0

-44800.0

-45000.0

-45200.0

-45400.0

-45600.0

-45800.0

-46000.0

-46200.0

-46400.0

-46600.0

-46800.0

-47000.0

-47200.0

-47400.0

-47600.0

-47800.0

-48000.0

-48200.0

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-48600.0

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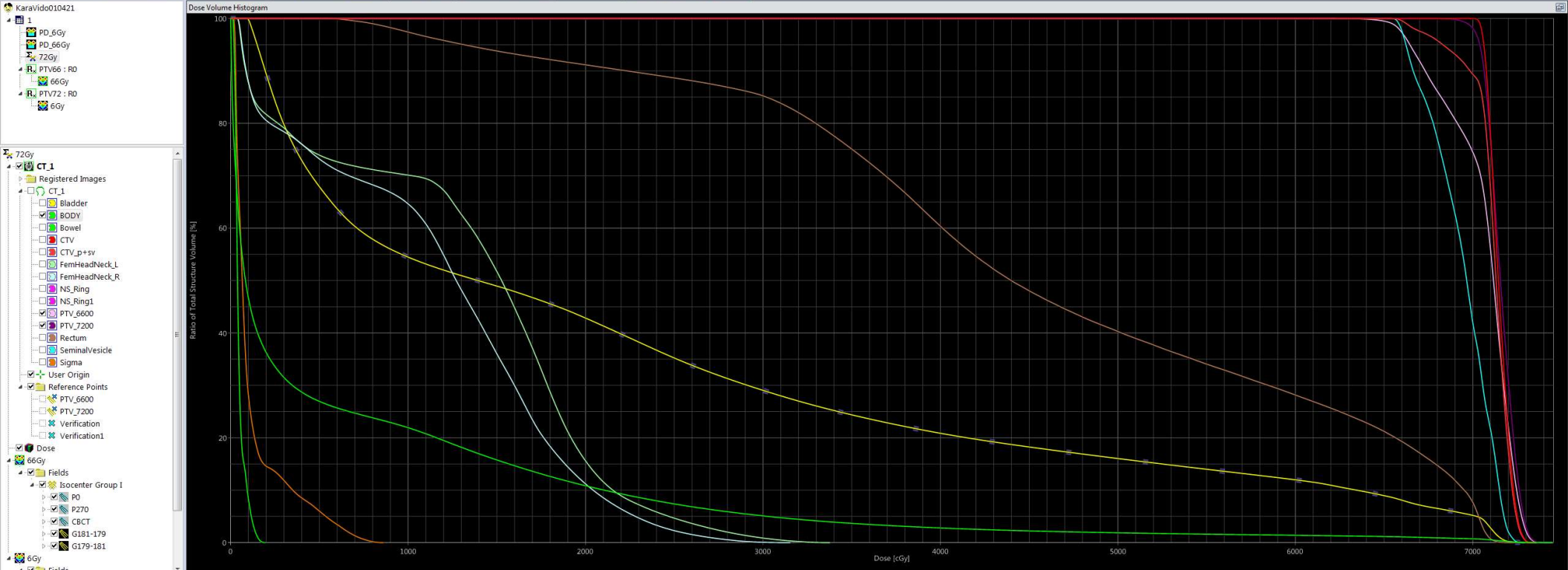
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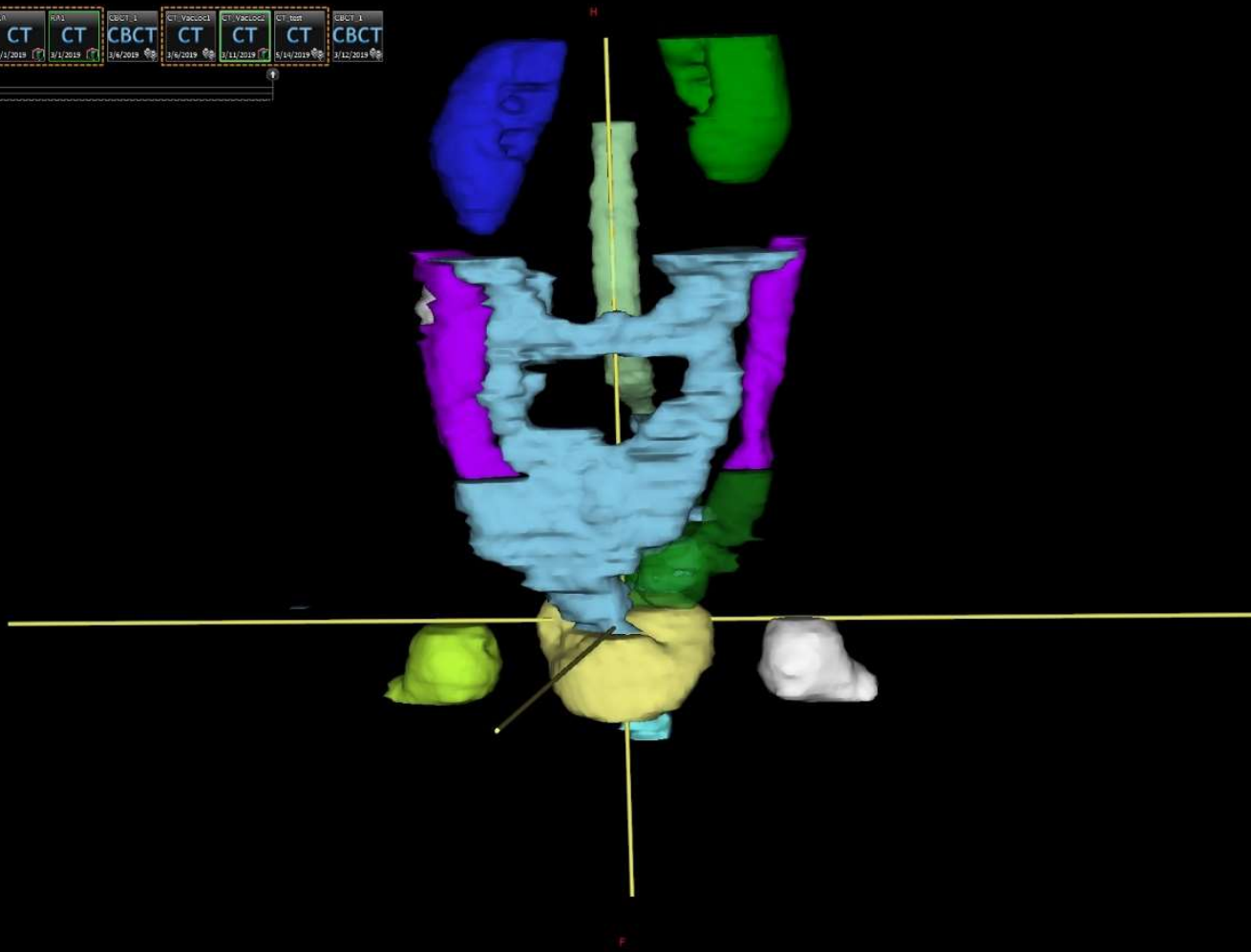
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Show DVH	Structure	Approval Status	Plan	Course	Volume [cm³]	Dose Cover [%]	Sampling Cover [%]	Min Dose [cGy]	Max Dose [cGy]	Mean Dose [cGy]	
<input checked="" type="checkbox"/>	BODY	Approved	72Gy	1	28289.4	100.0	100.0	100.1	0.0	7455.3	641.7
<input checked="" type="checkbox"/>	Bladder	Approved	72Gy	1	709.0	100.0	100.0	100.0	91.5	7365.6	2229.9
<input checked="" type="checkbox"/>	Bowel	Approved	72Gy	1	202.4	100.0	100.0	100.0	11.0	198.3	48.2
<input checked="" type="checkbox"/>	CTV	Approved	72Gy	1	62.0	100.0	100.0	100.0	6992.7	7351.4	7149.1
<input checked="" type="checkbox"/>	CTV_p+sv	Approved	72Gy	1	77.4	100.0	100.0	100.0	6534.5	7351.4	7110.4
<input checked="" type="checkbox"/>	FemHeadNeck_L	Approved	72Gy	1	292.8	100.0	100.0	100.0	36.1	3381.7	1311.8
<input checked="" type="checkbox"/>	FemHeadNeck_R	Approved	72Gy	1	289.6	100.0	100.0	100.0	38.2	3156.0	1155.8
<input checked="" type="checkbox"/>	NS_Ring	Approved	72Gy	1							
<input checked="" type="checkbox"/>	NS_Ring1	Approved	72Gy	1	2500.9	100.0	100.0	100.0	128.5	7271.6	2781.2
<input checked="" type="checkbox"/>	PTV_6600	Approved	72Gy	1	261.1	100.0	100.0	100.0	6007.9	7455.3	7059.8
<input checked="" type="checkbox"/>	PTV_7200	Approved	72Gy	1	184.7	100.0	100.0	100.0	6732.3	7455.3	7158.5
<input checked="" type="checkbox"/>	Rectum	Approved	72Gy	1	88.7	100.0	100.0	100.0	548.2	7236.5	4599.9
<input checked="" type="checkbox"/>	SeminalVesicle	Approved	72Gy	1	14.2	100.0	100.0	100.1	6534.5	7294.2	6939.7
<input checked="" type="checkbox"/>	Sigma	Approved	72Gy	1	197.3	100.0	100.0	100.0	17.3	865.8	123.2

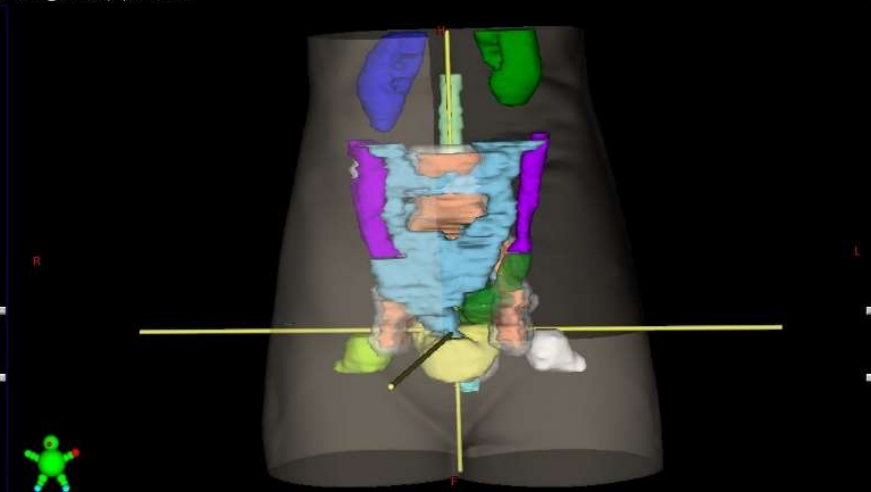


Drawing Tools

- Select Structures
- Draw Planar Contour
- Brush
- Eraser
- Draw Geometrical Shape
- Create or Edit Annotation
- Draw Volumetric Contour
- Transform Structure
- Deform Structure
- PET Subvolume Thresholding
- Image Thresholding
- Search Body
- Segmentation Wizard
- Flood Fill
- Margin for Structure
- Post Processing
- Extract Wall
- Crop Structure
- Boolean Operators
- Extend Segmentation
- Interpolate Structure
- Segment High Density Artifacts
- Clear Structure
- Move Marker or Isocenter Marker
- Edit Reference Points
- Draw Reference Line
- Calypso Beacon Detection



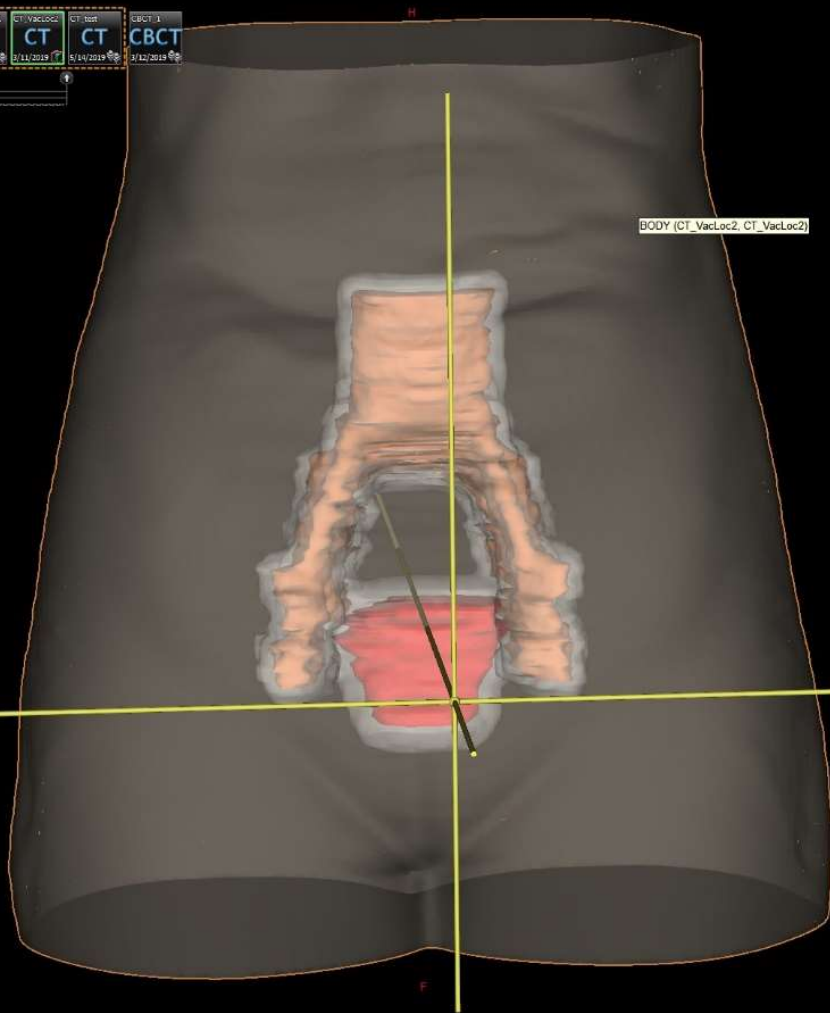
3D - CT_VadLoc2 - 3/11/2019 9:16 AM



Sagittal - CT_VadLoc2 - 3/11/2019 9:16 AM

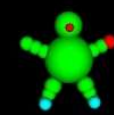


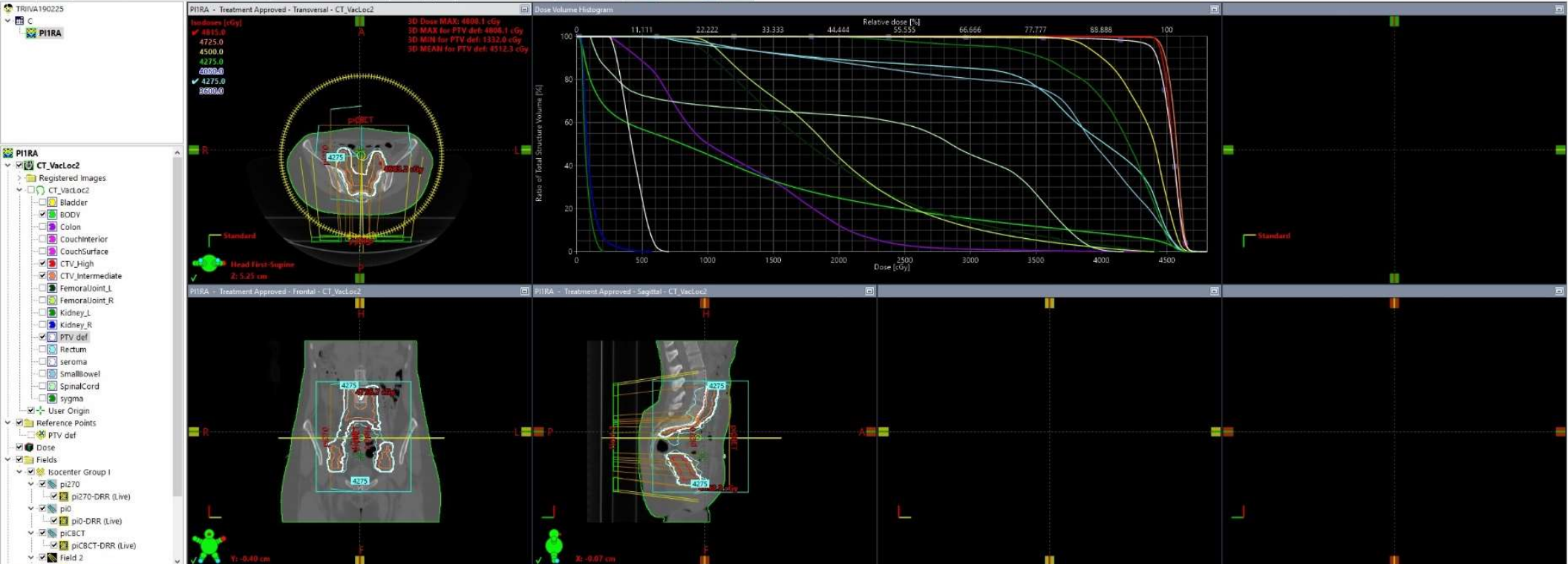
- Drawing Tools
- Select Structures
 - Draw Planar Contour
 - Brush
 - Erase
 - Draw Geometrical Shape
 - Create or Edit Annotation
 - Draw Volumetric Contour
 - Transform Structure
 - Deform Structure
 - PET Subvolume Thresholding
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Drawing Tools

- Select Structures
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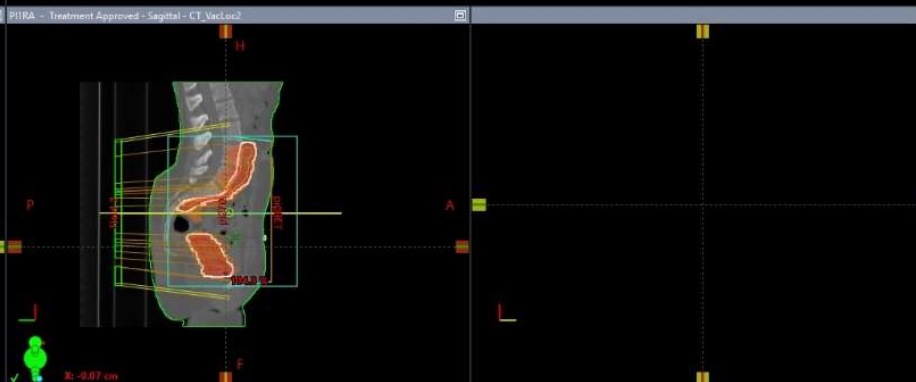
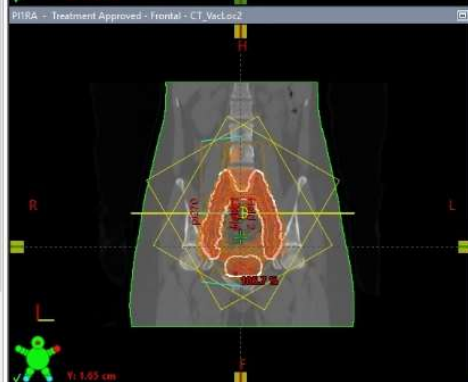
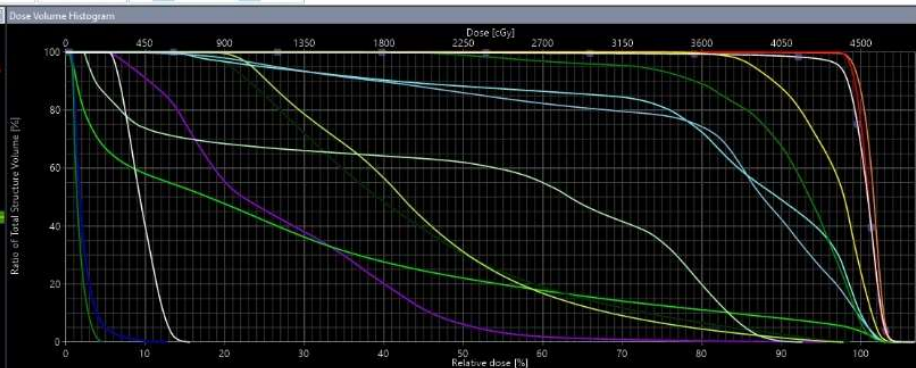
Fields	Dose	Reference Points	Dose Statistics								
Show DVH	Structure	Approval Status	Plan	Course	Volume [cm³]	Dose Cover [%]	Sampling Cover [%]	Min Dose [cGy]	Max Dose [cGy]	Mean Dose [cGy]	
<input checked="" type="checkbox"/>	CTV_Intermediate	Approved	PIIRA	C	257.2	100.0	100.0	3499.8	4723.9	4562.7	
<input checked="" type="checkbox"/>	CTV_High	Approved	PIIRA	C	57.0	100.0	100.0	4363.2	4731.2	4539.7	
<input checked="" type="checkbox"/>	Colon	Approved	PIIRA	C	69.0	100.0	100.1	211.2	4309.5	1195.4	
<input checked="" type="checkbox"/>	Bladder	Approved	PIIRA	C	81.7	100.0	100.0	3276.2	4724.5	4334.9	
<input checked="" type="checkbox"/>	BODY	Approved	PIIRA	C	17716.9	100.0	100.0	9.6	4808.1	1294.2	
<input checked="" type="checkbox"/>	FemoralJoint_L	Approved	PIIRA	C	42.5	100.0	100.0	759.6	4437.9	1966.9	
<input checked="" type="checkbox"/>	FemoralJoint_R	Approved	PIIRA	C	43.1	100.0	100.0	782.3	4402.4	2012.0	
<input checked="" type="checkbox"/>	Kidney_R	Approved	PIIRA	C	114.4	100.0	99.8	18.0	582.2	99.5	
<input checked="" type="checkbox"/>	Rectum	Approved	PIIRA	C	36.1	100.0	100.0	992.7	4641.3	3706.6	
<input checked="" type="checkbox"/>	SmallBowel	Approved	PIIRA	C	335.8	100.0	100.1	0.0	4703.3	3616.6	
<input checked="" type="checkbox"/>	SpinalCord	Approved	PIIRA	C	34.3	100.0	100.1	102.2	4168.7	2252.3	
<input checked="" type="checkbox"/>	Sigma	Approved	PIIRA	C	117.9	100.0	100.0	1901.5	4677.4	4082.4	
<input checked="" type="checkbox"/>	Kidney_L	Approved	PIIRA	C	84.7	100.0	99.8	16.6	216.8	74.0	
<input checked="" type="checkbox"/>	seroma	Approved	PIIRA	C	37.1	100.0	100.0	242.5	707.5	425.2	
<input checked="" type="checkbox"/>	PTV def	Approved	PIIRA	C	880.1	100.0	100.0	1332.0	4808.1	4512.3	

TRIIVA190225

PIIRA

PIIRA

- CT_VacLoc2
 - Registered Images
 - CT_VacLoc2
 - Bladder
 - BODY
 - Colon
 - CouchInterior
 - CouchSurface
 - CTV_High
 - CTV_Intermediate
 - FemoralJoint_L
 - FemoralJoint_R
 - Kidney_L
 - Kidney_R
 - PTV_def
 - Rectum
 - seroma
 - SmallBowel
 - SpinalCord
 - Sigma
 - User Origin
 - Reference Points
 - PTV_def
 - Dose
 - Fields
 - Isocenter Group I
 - pi270
 - pi270-DRR (Live)
 - pi0
 - pi0-DRR (Live)
 - piCBCT
 - piCBCT-DRR (Live)
 - Field 2



Fields Dose Reference Points Dose Statistics

Show DVH	Structure	Approval Status	Plan	Course	Volume [cm³]	Dose Cover [%]	Sampling Cover [%]	Min Dose [%]	Max Dose [%]	Mean Dose [%]
<input checked="" type="checkbox"/>	CTV_Intermediate	Approved	PIIRA	C	257.2	257.2	100.0	77.8	105.0	101.4
<input checked="" type="checkbox"/>	CTV_High	Approved	PIIRA	C	57.0	57.0	100.0	97.0	105.1	100.9
<input checked="" type="checkbox"/>	Colon	Approved	PIIRA	C	69.0	69.0	100.0	100.1	95.8	26.6
<input checked="" type="checkbox"/>	Bladder	Approved	PIIRA	C	81.7	81.7	100.0	100.0	72.8	96.3
<input checked="" type="checkbox"/>	BODY	Approved	PIIRA	C	17716.9	17716.9	100.0	100.0	0.2	28.8
<input checked="" type="checkbox"/>	FemoralJoint_L	Approved	PIIRA	C	42.5	42.5	100.0	100.0	16.9	43.7
<input checked="" type="checkbox"/>	FemoralJoint_R	Approved	PIIRA	C	43.1	43.1	100.0	100.0	17.4	44.7
<input checked="" type="checkbox"/>	Kidney_R	Approved	PIIRA	C	114.4	114.4	100.0	99.8	0.4	2.2
<input checked="" type="checkbox"/>	Rectum	Approved	PIIRA	C	36.1	36.1	100.0	100.0	13.2	82.4
<input checked="" type="checkbox"/>	SmallBowel	Approved	PIIRA	C	335.8	335.8	100.0	100.1	0.0	80.4
<input checked="" type="checkbox"/>	SpinalCord	Approved	PIIRA	C	34.3	34.3	100.0	100.1	2.3	50.1
<input checked="" type="checkbox"/>	Sigma	Approved	PIIRA	C	117.9	117.9	100.0	100.0	42.3	90.7
<input checked="" type="checkbox"/>	Kidney_L	Approved	PIIRA	C	84.7	84.7	100.0	99.8	0.4	1.6
<input checked="" type="checkbox"/>	seroma	Approved	PIIRA	C	37.1	37.1	100.0	100.0	5.4	9.4
<input checked="" type="checkbox"/>	PTV_def	Approved	PIIRA	C	880.1	880.1	100.0	100.0	29.6	100.3

Ready

User: dr. Nedžad Milosavljevic

Group: Oncologist

Site: Main

CAP. NUM. SCRL

1:09 PM

5/8/2020



TRIVA190225

CT

PI1RA

PI1RA

CT_VacLoc2

Registered Images

CT_VacLoc2

Bladder

BODY

Colon

CouchInterior

CouchSurface

CTV_High

CTV_Intermediate

FemoralJoint_L

FemoralJoint_R

Kidney_L

Kidney_R

PTV def

Rectum

seroma

SmallBowel

SpinalCord

sygma

User Origin

Reference Points

PTV def

Dose

Fields

Isocenter Group I

pi270

pi270-DRR (Live)

pi0

pi0-DRR (Live)

piCBCT

piCBCT-DRR (Live)

Field 2

Field 2-DRR (Live)

MLC

Field 1

Field 1-DRR (Live)

MLC

MLC

MLC

MLC

MLC

MLC

MLC

MLC

MLC

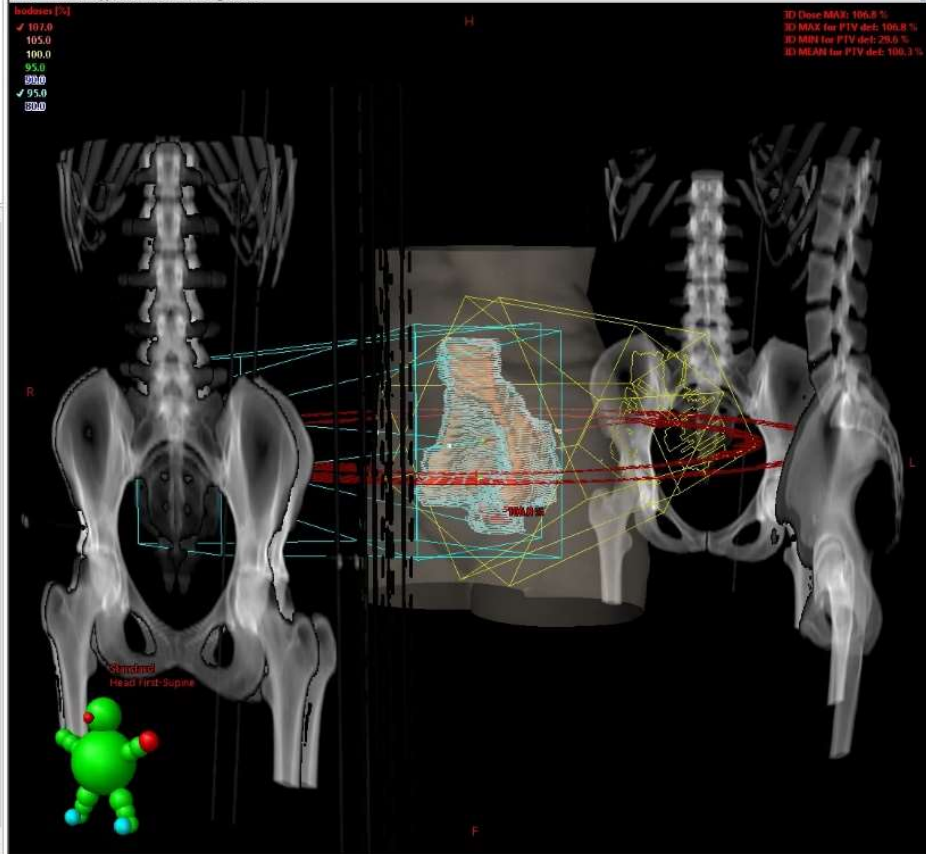
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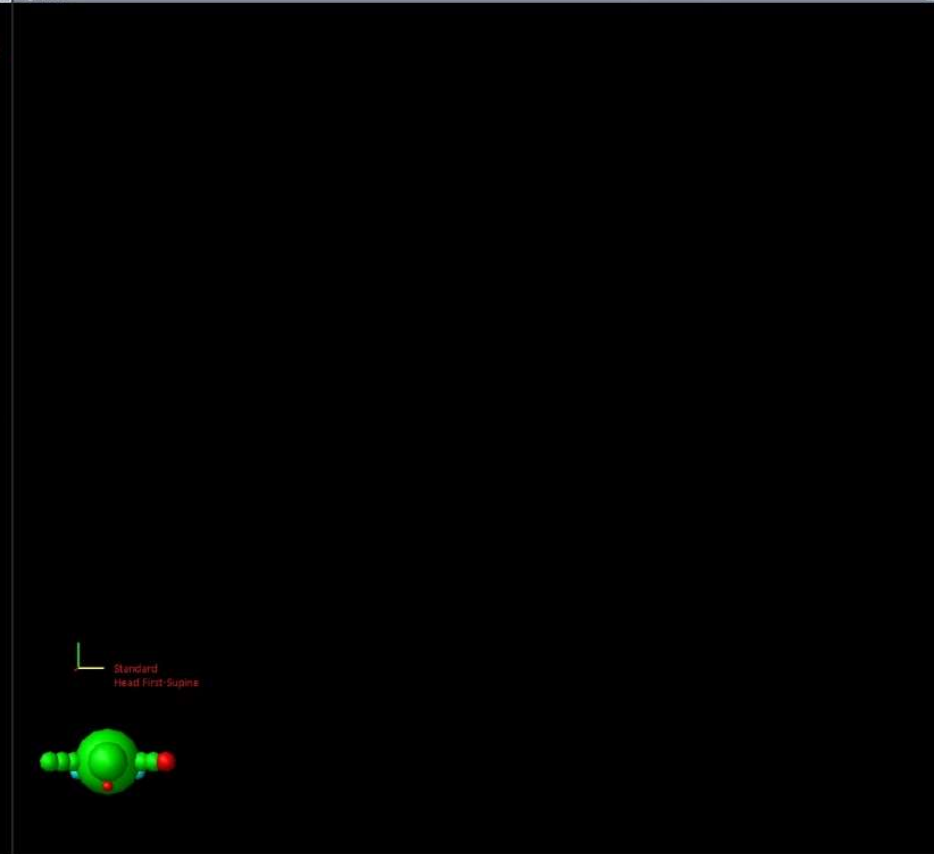
MLC

MLC

PI1RA - Treatment Approved - Model View - CT_VacLoc2



CT_VacLoc2



Fields Dose Reference Points Dose Statistics

Show DVH	Structure	Approval Status	Plan	Course	Volume [cm ³]	Dose Cover [%]	Sampling Cover [%]	Min Dose [%]	Max Dose [%]	Mean Dose [%]
	CTV_Intermediate	Approved	PI1RA	C						
	CTV_High	Approved	PI1RA	C						
	Colon	Approved	PI1RA	C						
	Bladder	Approved	PI1RA	C						
	BODY	Approved	PI1RA	C						
	FemoralJoint_L	Approved	PI1RA	C						
	FemoralJoint_R	Approved	PI1RA	C						
	Kidney_R	Approved	PI1RA	C						

Ready

User: dr Neda Milosavljevic

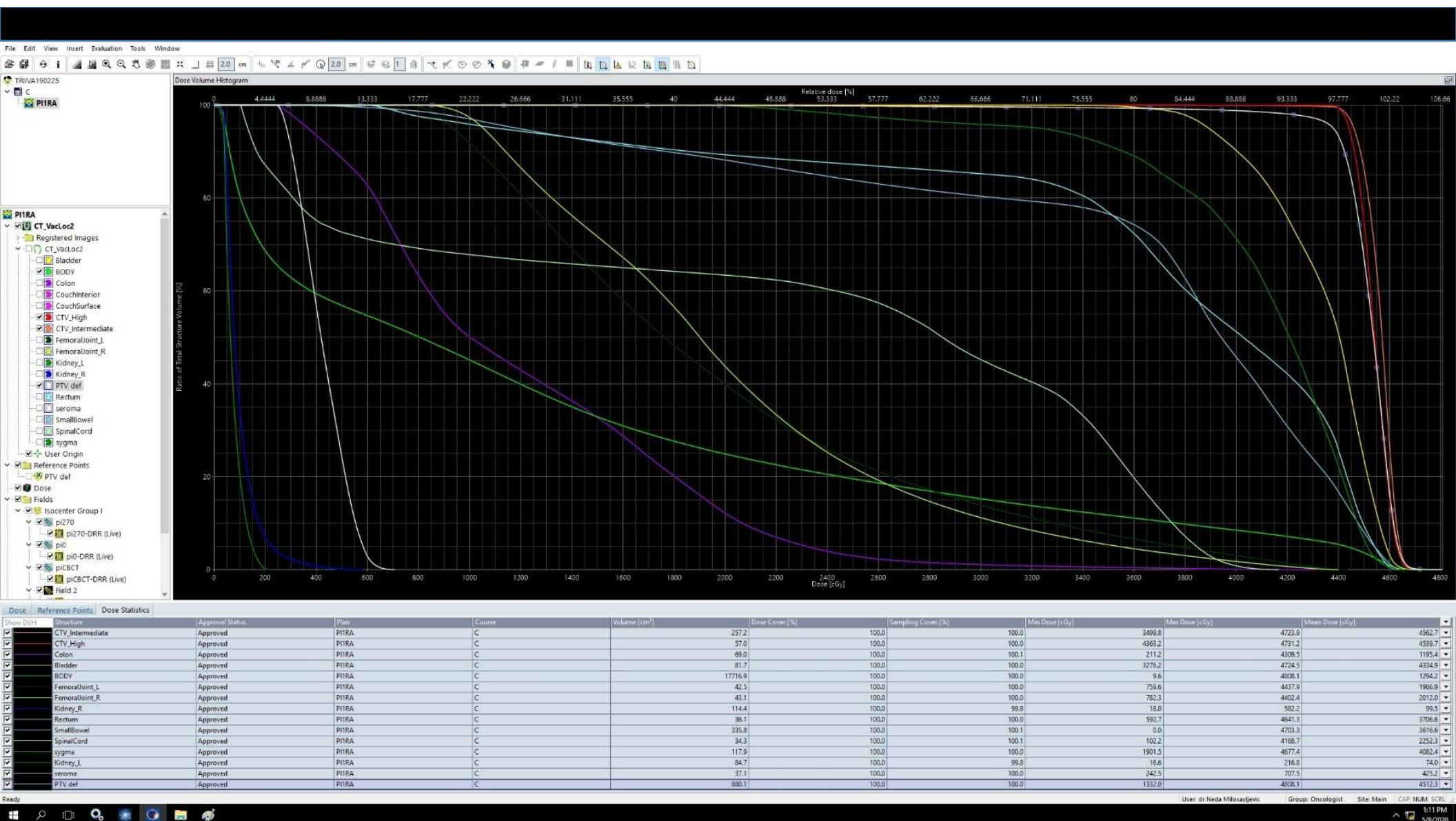
Group: Oncologist

Site: Main

CAP: NUM

SCR: 12:59 PM

5/8/2020



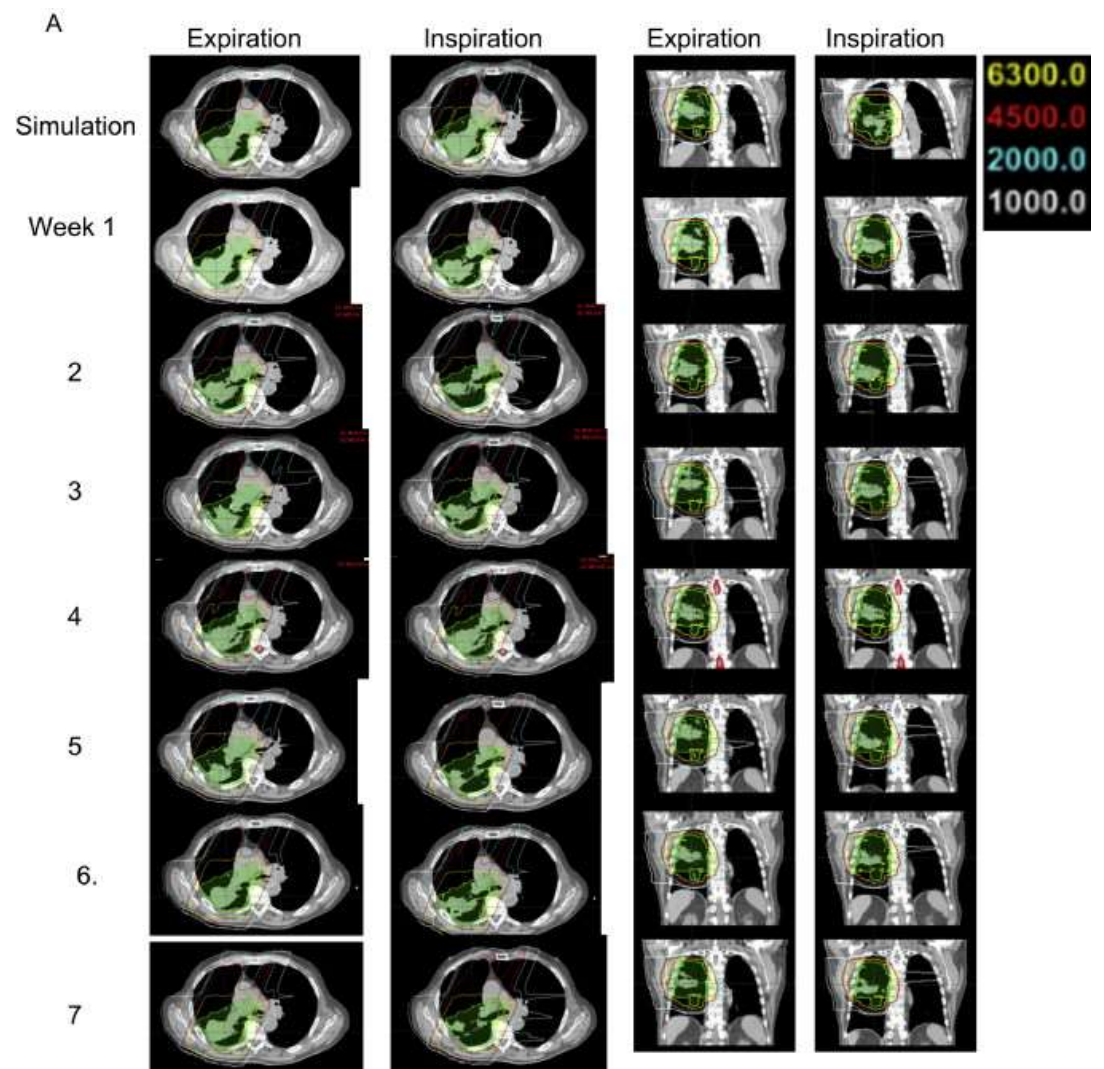
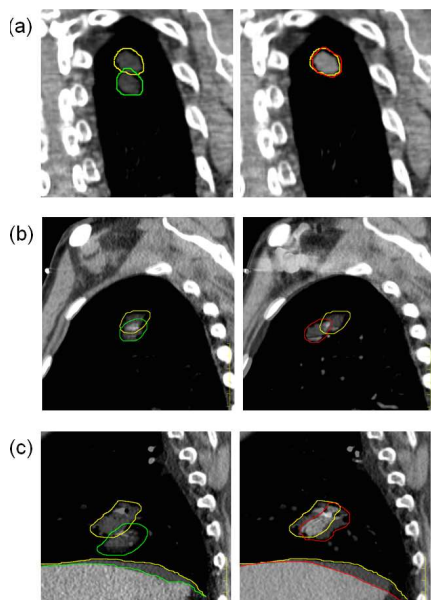
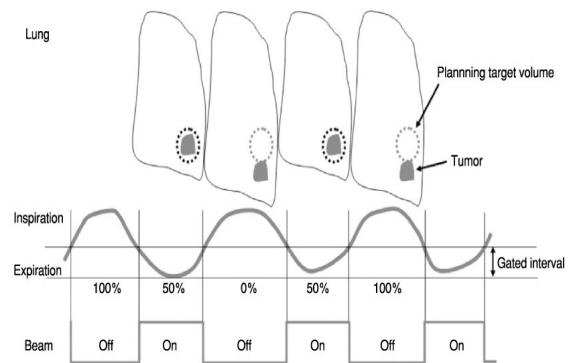
Show DVH	Structure	Approval Status	Plan	Course	Volume [cm³]	Dose Cover [%]	Sampling Cover [%]	Min Dose [cGy]	Max Dose [cGy]	Mean Dose [cGy]
<input checked="" type="checkbox"/>	CTV_Intermediate	Approved	PIIRA	C	257.2	100.0	100.0	100.0	3499.8	4723.9
<input checked="" type="checkbox"/>	CTV_High	Approved	PIIRA	C	57.0	100.0	100.0	100.0	4363.2	4731.2
<input checked="" type="checkbox"/>	Colon	Approved	PIIRA	C	69.0	100.0	100.0	100.1	211.2	4309.5
<input checked="" type="checkbox"/>	Bladder	Approved	PIIRA	C	81.7	100.0	100.0	100.0	3276.2	4724.5
<input checked="" type="checkbox"/>	BODY	Approved	PIIRA	C	17716.9	100.0	100.0	100.0	9.6	4808.1
<input checked="" type="checkbox"/>	FemoralJoint_L	Approved	PIIRA	C	42.5	100.0	100.0	100.0	759.6	4437.9
<input checked="" type="checkbox"/>	FemoralJoint_R	Approved	PIIRA	C	43.1	100.0	100.0	100.0	782.3	4402.4
<input checked="" type="checkbox"/>	Kidney_R	Approved	PIIRA	C	114.4	100.0	100.0	99.8	18.0	582.2
<input checked="" type="checkbox"/>	Rectum	Approved	PIIRA	C	36.1	100.0	100.0	100.0	992.7	4641.3
<input checked="" type="checkbox"/>	SmallBowel	Approved	PIIRA	C	335.8	100.0	100.0	100.1	0.0	4703.3
<input checked="" type="checkbox"/>	SpinalCord	Approved	PIIRA	C	34.3	100.0	100.0	100.1	102.2	4168.7
<input checked="" type="checkbox"/>	sygma	Approved	PIIRA	C	117.9	100.0	100.0	100.0	1901.5	4677.4
<input checked="" type="checkbox"/>	Kidney_L	Approved	PIIRA	C	84.7	100.0	100.0	99.8	16.6	216.8
<input checked="" type="checkbox"/>	seroma	Approved	PIIRA	C	37.1	100.0	100.0	100.0	242.5	707.5
<input checked="" type="checkbox"/>	PTV_def	Approved	PIIRA	C	880.1	100.0	100.0	100.0	1332.0	4512.3

IMAGE GUIDED RADIOTHERAPY - IGRT

- IGRT allows assessment of geometric accuracy of the “patient model” during treatment.
- Provides a method where deviations of anatomy from initial plan are determined and this information is used for updates.
 - *Interfractional variations*
 - *Positioning*
 - *Organ mobility*
 - *Anatomic variations during treatment*
 - *Intrafractional motion*

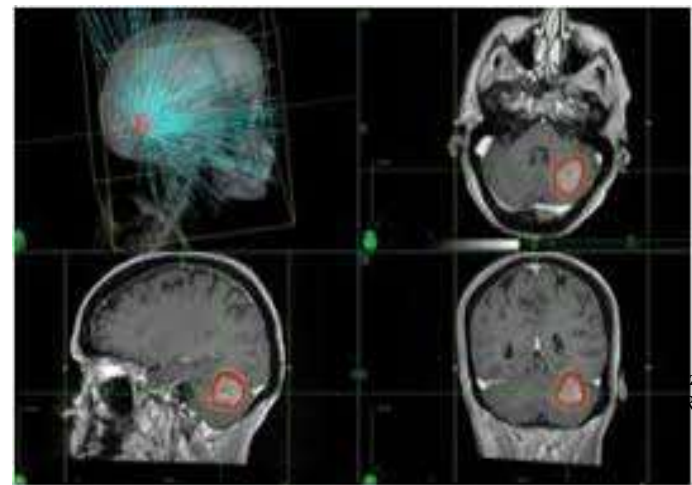
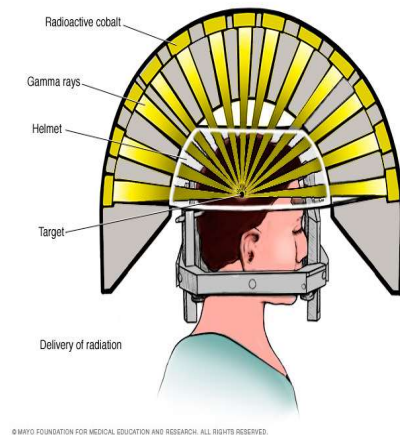
RESPIRATORY GATING

- improvement in the irradiation of tumor sites affected by respiratory motion such as lung, breast, and liver tumors
- decreased radiation related toxicity to organs at risk
 - *integration of respiratory movements into treatment planning,*
 - *forced shallow breathing with abdominal compression,*
 - *breath-hold techniques,*
 - *respiratory gating techniques,*
 - *tracking techniques*



Stereotactic radiotherapy

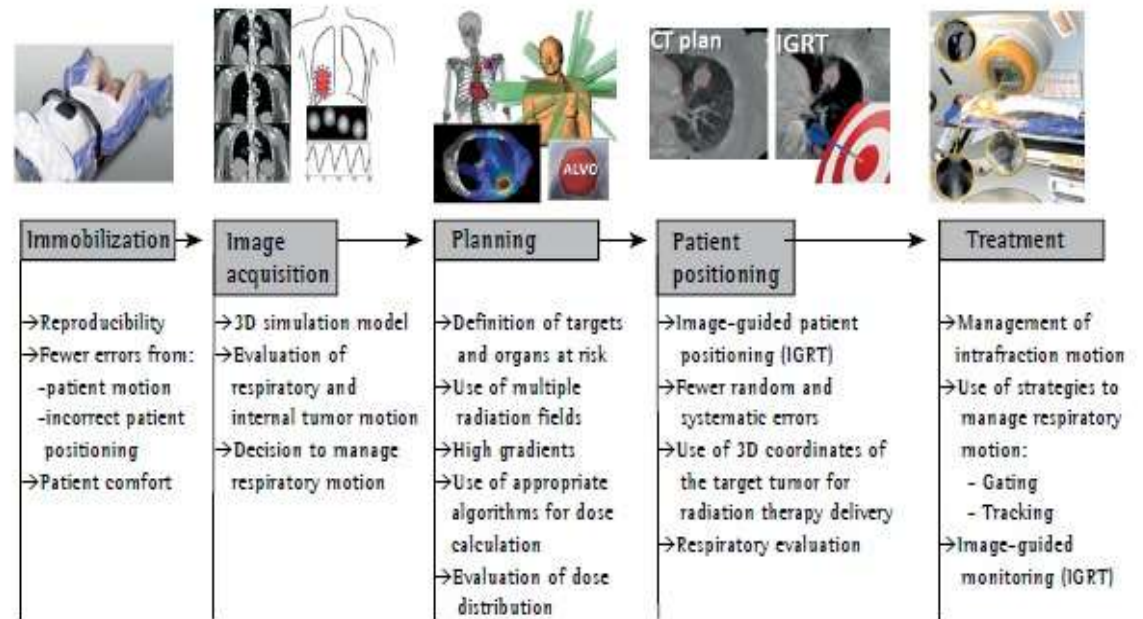
- high-precision radiotherapy technique that utilises high doses of radiation in a few or single fractions
- Stereotactic radiosurgery (SRS); Stereotactic body radiation therapy (SBRT) or stereotactic ablative radiotherapy (SABR)
- Numbers of indications



zvor: Mayo Clinic. SRS.
Radiosurgery.gr

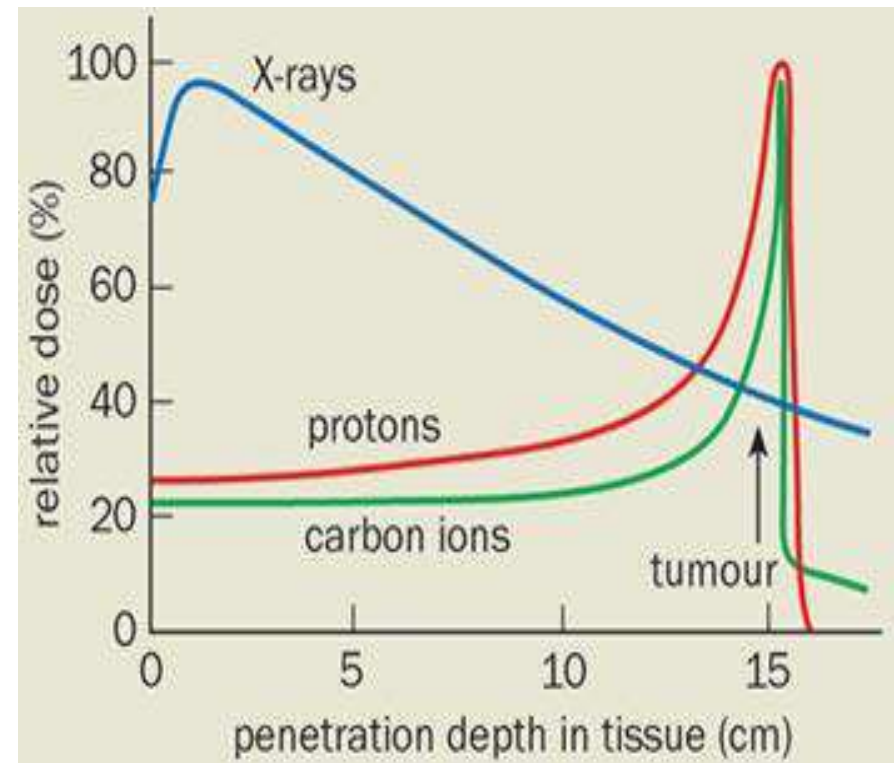
Stereotactic Body Radiotherapy, SBRT

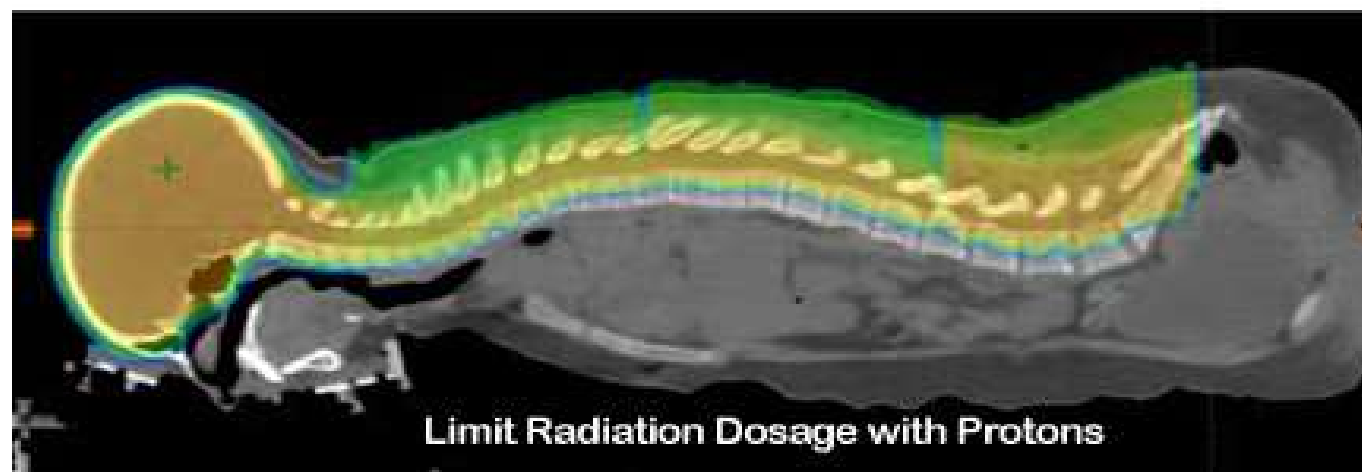
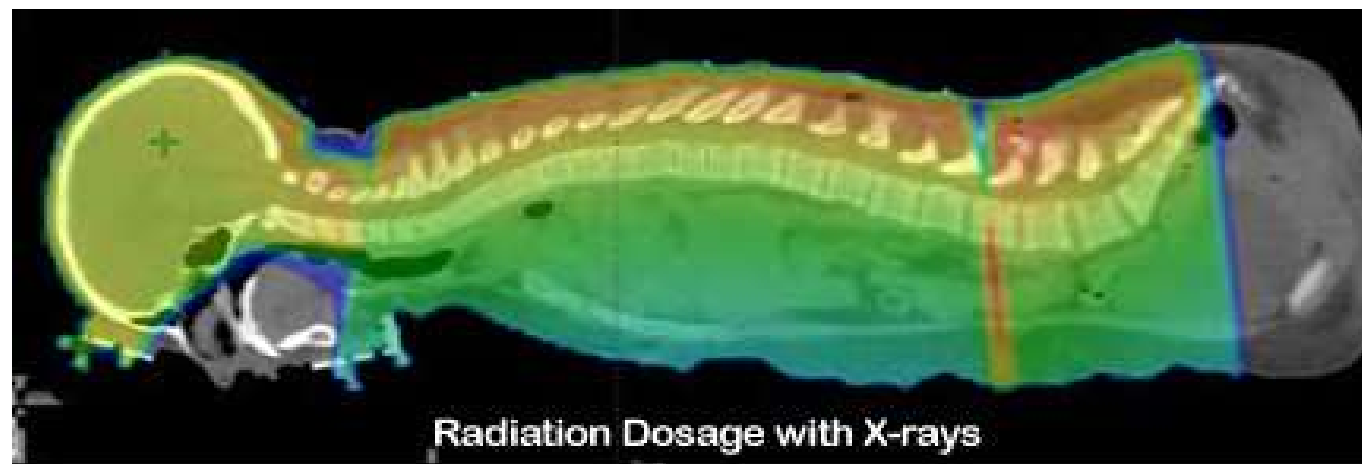
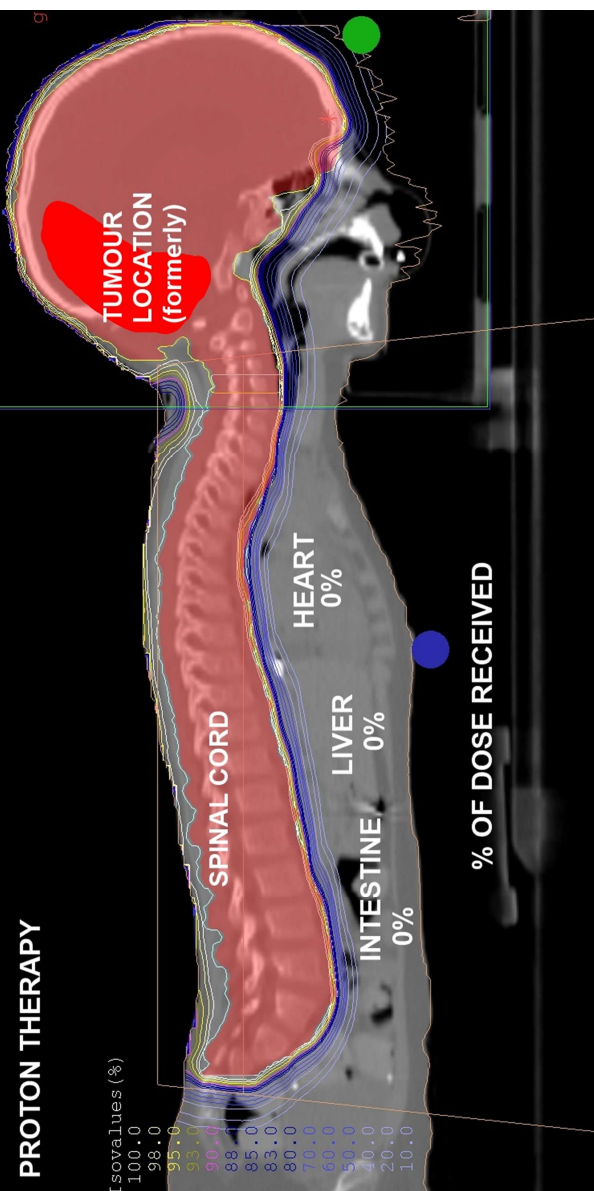
- The use of ablative doses delivered in a small number of fractions, and whose biologically equivalent dose (BED) is >100 Gy.
- It prevents tumor repopulation, causes vascular damage, apoptosis of the endothelium, remodeling of the microvasculature, induces an immune response to the tumor.



Proton Therapy

- physical properties of a proton beam - modulating the Bragg peak of protons
- sparing the surrounding normal tissues - ideal when organ preservation is a priority
- Availability and cost of treatment?





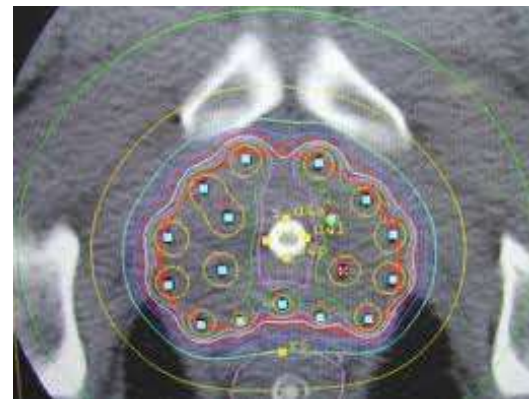
INTRAOPERATIVE RADIOTHERAPY (IORT)

- Precise delivery of a large dose of ionising radiation to the tumour or tumour bed during surgery.
- Direct visualisation of the tumour bed and ability to space out the normal tissues from the tumour bed - maximisation of the dose to the tumour/ minimising the dose to normal tissues.
- Electrons, low-kV X-rays and HDR brachytherapy
- for dose escalation (retroperitoneal sarcoma), EBRT dose de-escalation (paediatric tumours), as sole radiation modality (early breast cancers) and as a re-irradiation modality (recurrent rectal and gynaecological cancers)

Brachytherapy

- By precisely positioning the radioactive source in the immediate vicinity of the tumor (up to 2 cm), it is possible to apply a high dose of radiation to the target volume.
- Due to the peripheral dose drop, healthy tissue in the immediate vicinity is spared.
- The volume dose is lower than that in EBRT, so the risks for local and systemic radiotoxicity are significantly lower.

- Surface (contact) brachytherapy is performed by bringing the source into close proximity, for the irradiation of tumors localized on the skin and visible mucous membranes.
- Intracavitary (intraluminal/endoluminal) - by introducing radioisotopes into natural body cavities using a guide/applicator.
- Interstitial brachytherapy where radiation sources are introduced directly into the tumor, through guides inserted into the tumor tissue or by inserting radioactive grains into the tumor.



- MA S. Cancer men. And res. 2019.; Prostate Cancer Brachytherapy. UCLA Health