



# **INTRODUCTION TO RADIATION ONCOLOGY**

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Assist Prof Marija Živković Radojević MD PhD**

**WHEN PEOPLE HEAR THE WORD „RADIATION“  
THEY OFTEN THINK...**

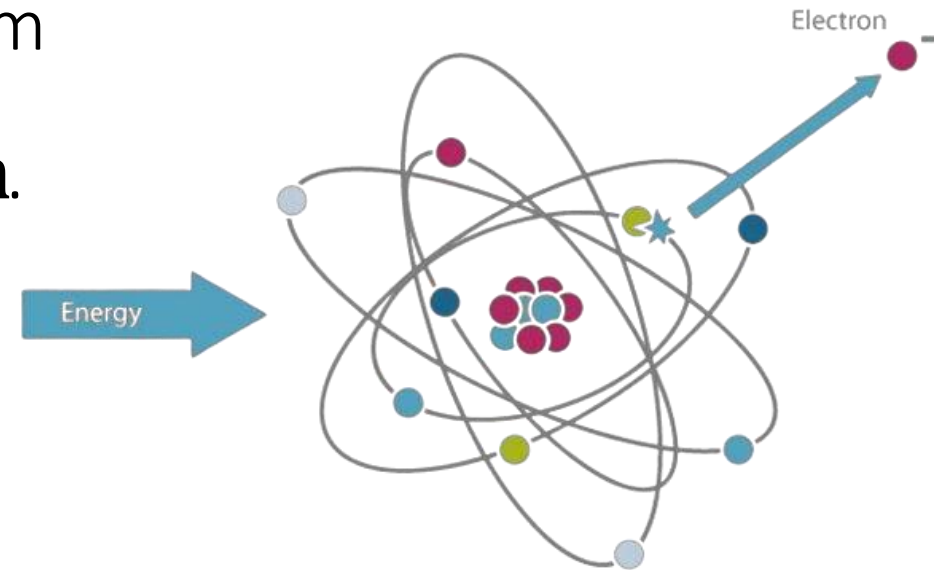


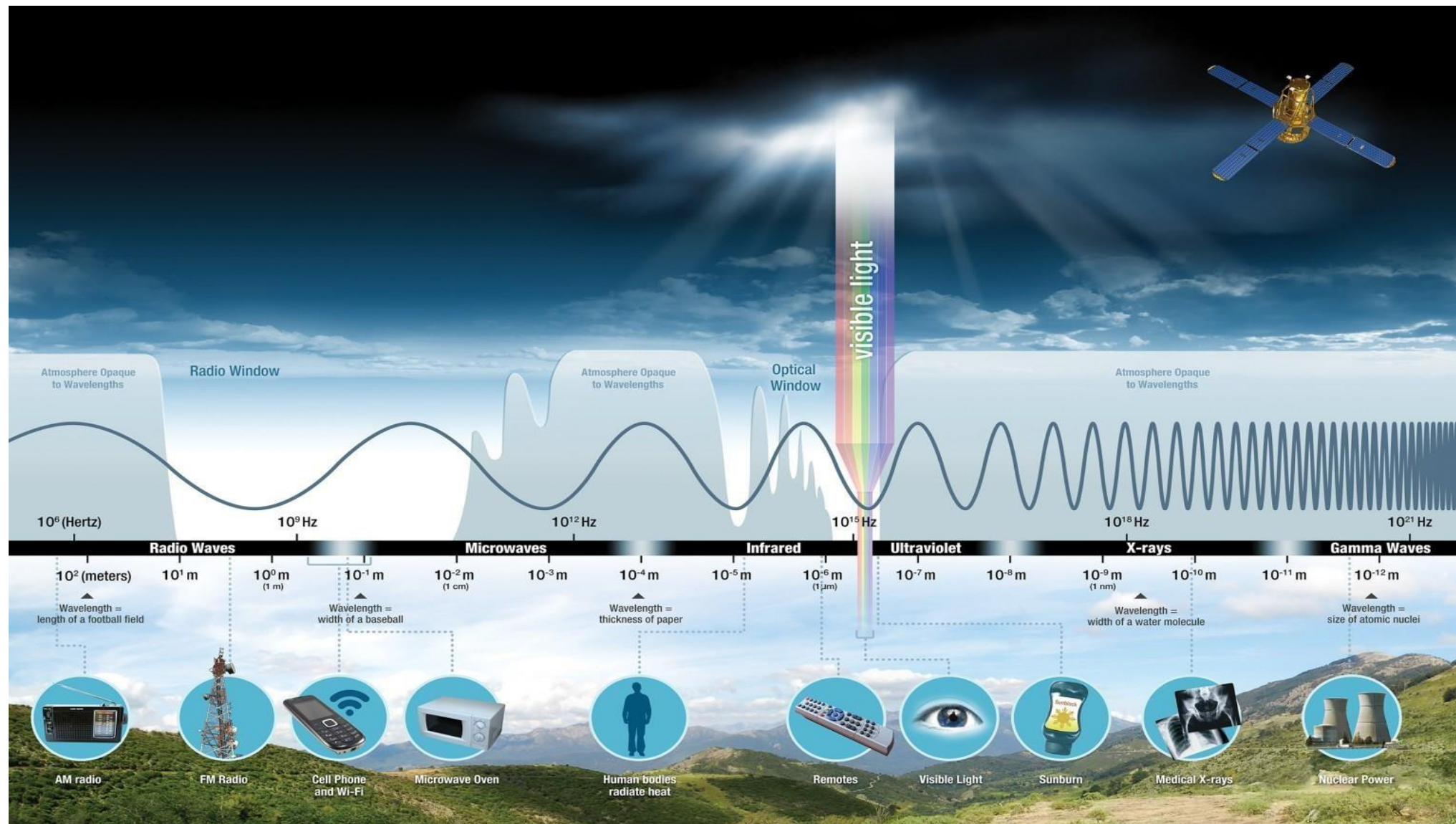
**The reality of medical use of radiation therapy is very  
different**



# RADIATION BIOLOGY AND PHYSICS

The propagation of energy from a radiative source to another medium is termed **radiation**.





# COMMON FEATURES OF ELECTROMAGNETIC RADIATION

- It propagates in a straight line.
- It travels at the speed of light (nearly 300,000 km/s).
- It transfers energy to the medium through which it passes, and the amount of energy transferred correlates positively with the frequency and negatively with the wavelength of the radiation.
- The energy of the radiation decreases as it passes through a material, due to absorption and scattering, and this decrease in energy is negatively correlated with the square of the distance traveled through the material.

# SUBDIVISION OF ELECTROMAGNETIC RADIATION

- Ionizing radiation (Electrons are knocked out of their atomic and molecular orbits when high-energy radiation interacts with matter)
- Nonionizing radiation

# NONIONIZING RADIATION

- Radio waves
- Microwaves
- Infrared light
- Visible light
- Ultraviolet light

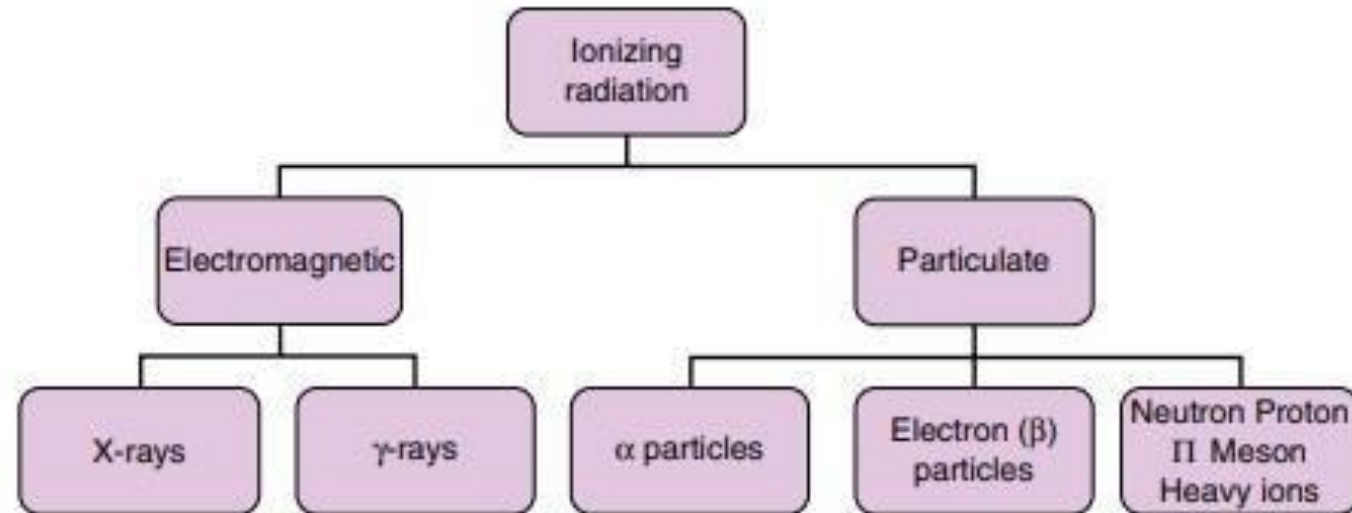


# Radiotherapy

- The treatment of disease with ionizing radiation.
- Included in oncology multidisciplinary treatment approach – radiation oncology
- Treatment of malignant diseases and certain benign conditions (vascular disorders, degenerative diseases...)
- Local/Locoregional treatment method
- *Abscopal effect*
- More than 50% of all oncology patient undergo radiotherapy during treatment.



# IONIZING RADIATION



# SOURCES OF IONIZING RADIATION

## Photons

- Gamma Rays  
Emitted from a nucleus of a radioactive atom  
Cobalt treatment machine  
Radioisotopes used in brachytherapy
- X-rays  
Generated by a linear accelerator when  
accelerated electrons hit a target

## Particle Beams

- Protons
- Neutrons
- Electrons

# INTERACTION OF IONIZING RADIATION WITH MATTER

The radiation effects - through a series of physical and chemical reactions:

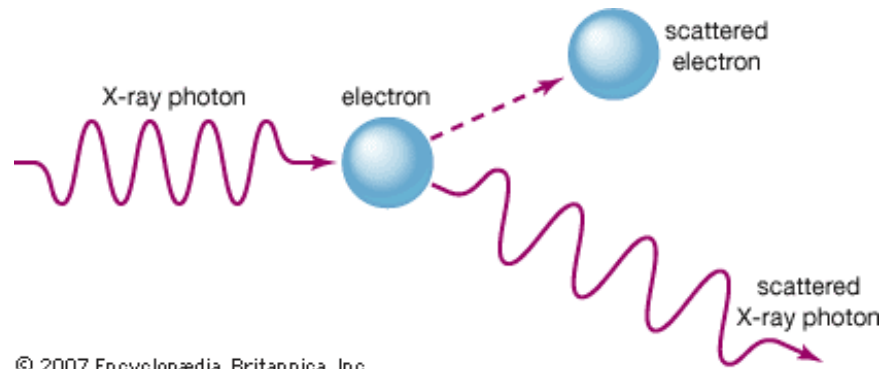
In the physical stage - ionization and excitation of atoms of living matter molecules.

Chemical stage - by direct and indirect action of ionizing radiation

Biological stage – inactivation of any subcellular structures

# PHYSICAL STAGE

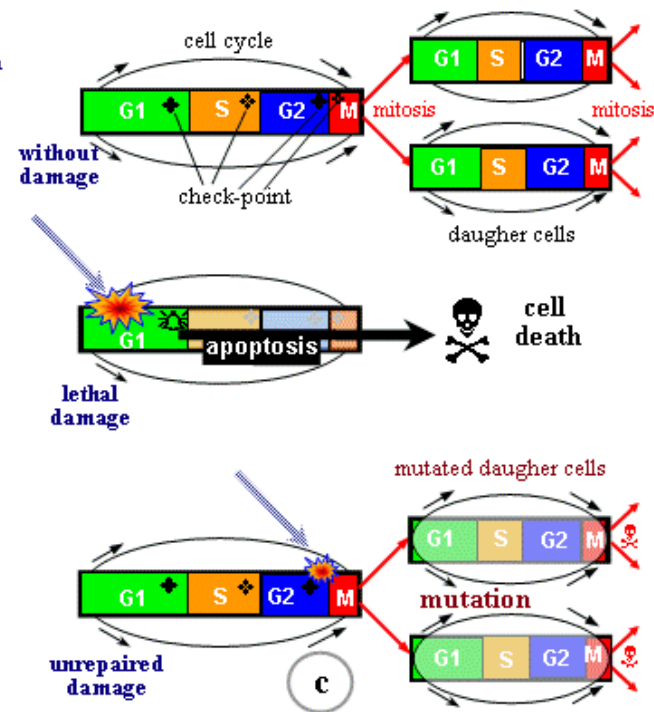
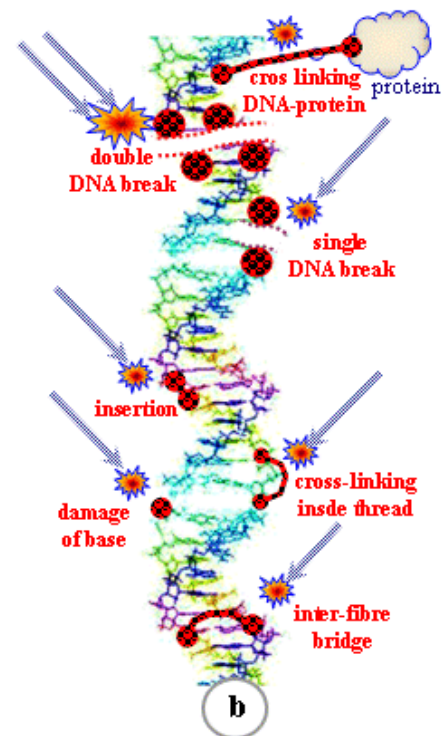
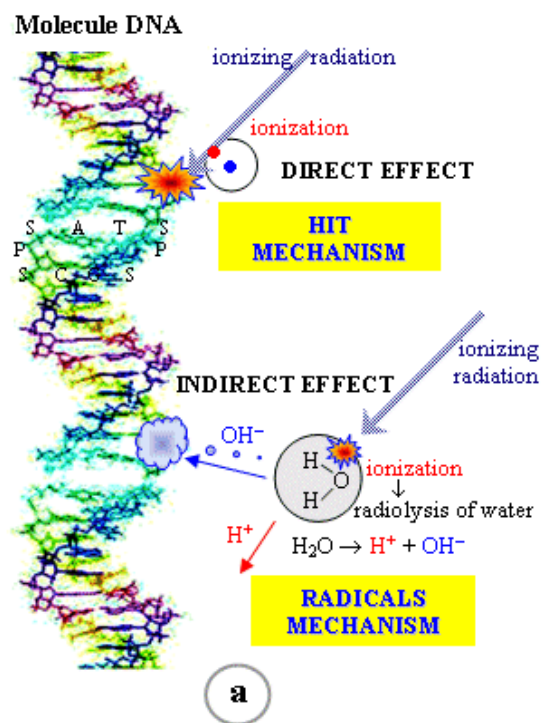
- Compton effect
- Photoelectric effect
- Pair production



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# CHEMICAL STAGE

- Direct action (**target theory**): the target can be a cell, or any of its structures (DNA, RNA, enzyme).
- In interaction with radiation, structures can be reversibly or irreversibly damaged.
- Indirect action (**free radical theory**): effect on extracellular and intracellular fluid, formation of free radicals (dominant mechanism of action on biological systems)



**X-rays interact with water**

**radiolysis**

**free radicals**

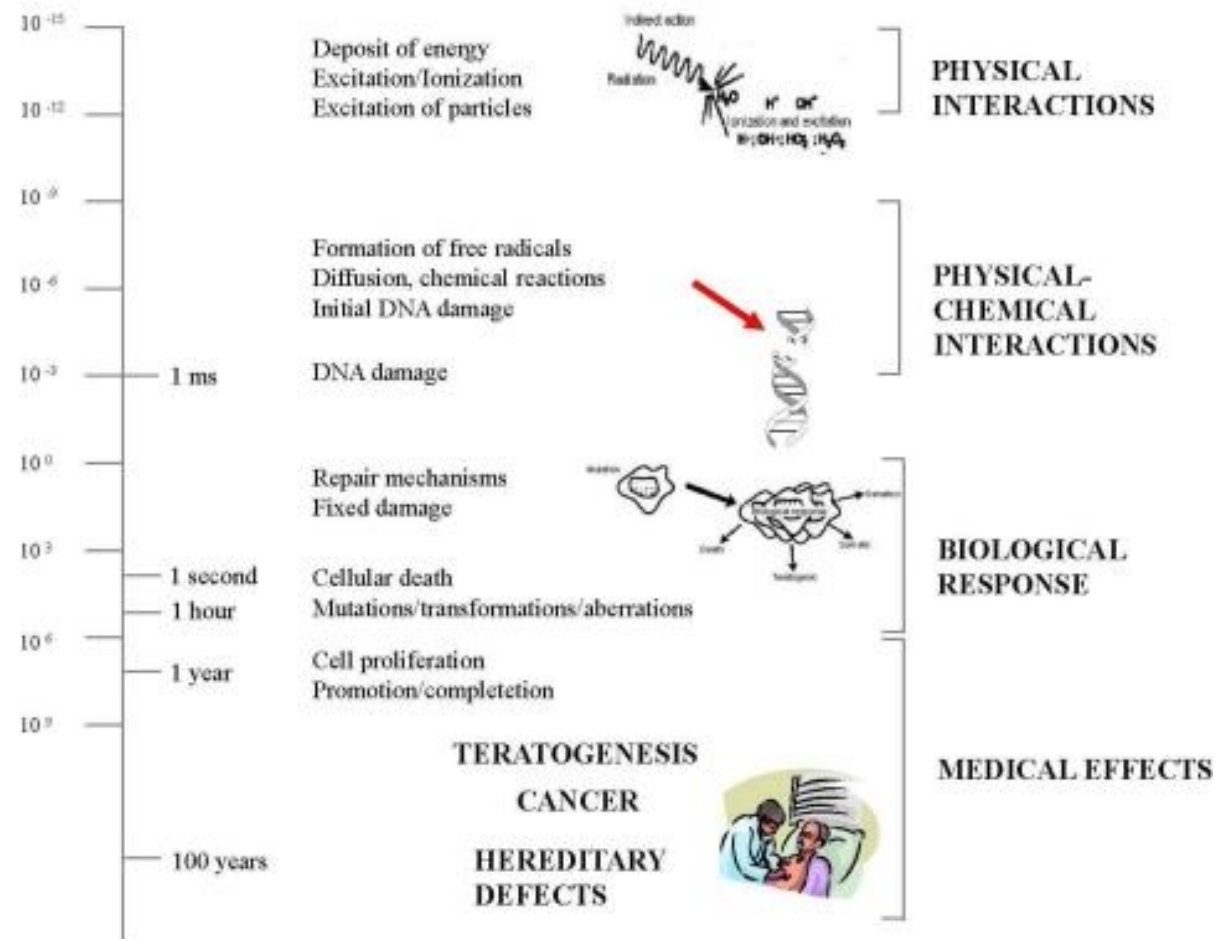
**bind to and damage DNA**

**cell death**

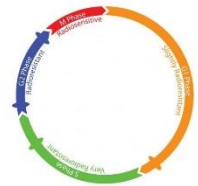
**(by mitotic catastrophe)**

# BIOLOGICAL STAGE

- DNA damaged and to what extent?
- Repair mechanisms/cell death
- Damage can be lethal (irreversible damage), sub-lethal, when recovery of the damaged cell is possible (reversible damage) and potentially lethal damage.







## 5R - factors influencing the response of tumor and normal tissue to ionizing radiation

- **Repair** - after each RT, interaction of radiation with cellular structures and repair of damage occurs within a few hours. Cells of different tissue – different dynamics of the repair process, depending on the proliferative potential.
- **Repopulation** - approximately the same percentage of vital tumor cells and healthy tissue is eliminated during radiation with each fraction. The loss of cells stimulates the surviving cells to divide more intensively. The final effect of repopulation is a tumor mass increase before each new fraction, but also the recovery of damaged healthy cells.
- **Redistribution** - tumor cells and healthy tissue show the highest radioresistance in the S and G1 phase of the cell cycle, while they are most sensitive in the M (mitosis) and late G2 phase, where there is a difference in radiosensitivity between tumor cells and healthy tissue.
- Irradiation of cells that are in different phases of the cell cycle results in the devitalization of those in the radiosensitive phase - immediately after irradiation cycle, the largest number of surviving cells are in the radioresistant phase.
- **Reoxygenation** - increased oxygen concentration increases, and decreased concentration decreases the radiosensitivity of cells. With their growth, solid tumors often exceed the capacity of the existing vascularization, so zones of hypoxia and necrosis appear in the tumor tissue.
- By applying fractionated radiation regimens during the interfraction interval, reoxygenation of previously hypoxic cells is achieved, thereby increasing their radiosensitivity.

# Radiosensitivity

- Malignant tumor cells are dedifferentiated and have increased mitotic activity, which makes them more radiosensitive compared to the cells of healthy tissues from which they arise (*Bergonié-Tribondeau* law).
- The greater the difference in radiosensitivity between the cells of normal tissues and the tumor, the greater the possibility of treating the tumor with radiotherapy.
- **Radiosensitive** tumors: lymphomas, leukosis, germinal tumors (seminoma, disgerminoma), nephroblastoma, Wilms' tumor, Ewing's sarcoma;
- **Moderately radiosensitive** tumors: tumors of the head and neck region (cancers of the skin, lips, paranasal cavities, epipharynx, oropharynx, hypopharynx, larynx), GI tumors (cancer of the esophagus, anus, rectum), gynecological tumors (cancer of the cervix, endometrium, vulva , vagina), urological tumors (prostate cancer, bladder cancer, non-seminoma testicular tumors), lung, breast, thyroid gland and brain tumors
- **Radioresistant** tumors: bone and soft tissue tumors (osteosarcoma, chondrosarcoma, fibrosarcoma, synoviosarcoma, liposarcoma, angiosarcoma, etc.), kidney adenocarcinoma, GI adenocarcinomas (stomach, pancreas, liver, bile ducts) and melanoma.

# Radiosensitisers

Hyperbaric oxygen

Carbogen

Nicotinamide

Metronidazole and its analogs (misonidazole, etanidazole, nimorazole)

Hypoxic cell cytotoxic agents (Mitomycin-C, Tirapazamine)

Membrane active agents (procaine, lidocaine, chlorpromazine)

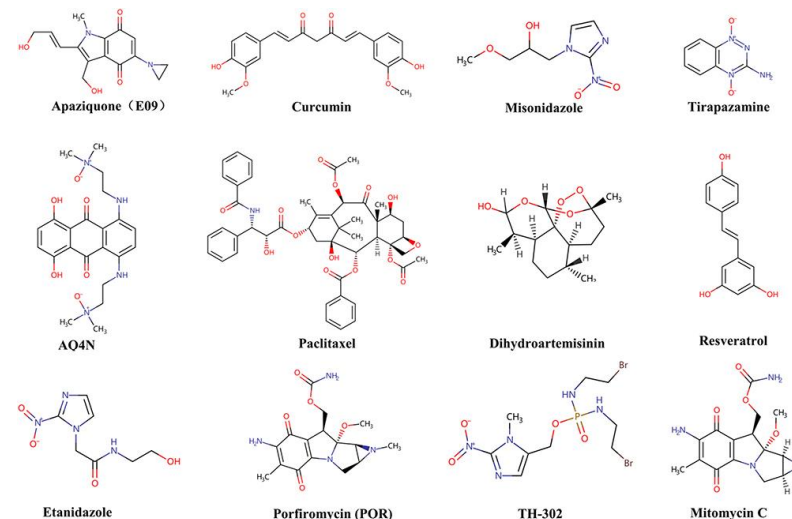
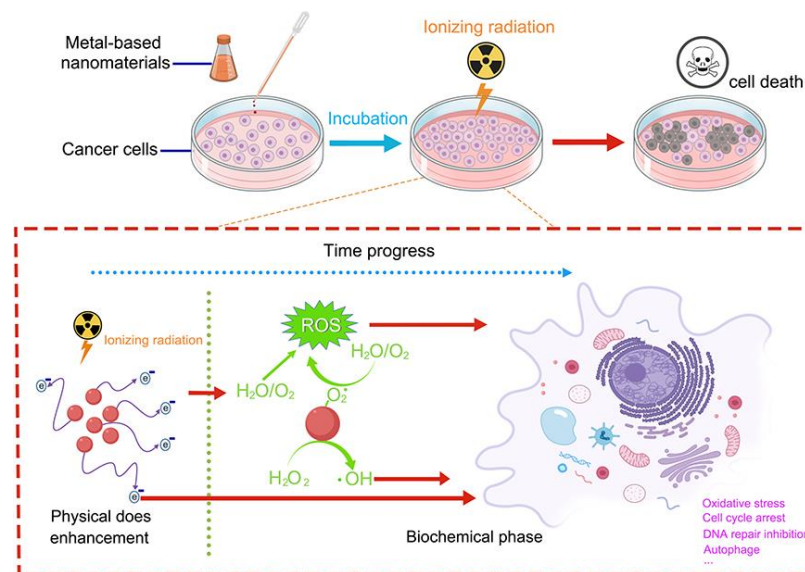
Radiosensitizing nucleosides (5-Fluorouracil, Fluorodeoxyuridine, Bromodeoxyuridine, Iododeoxyuridine, Hydroxyurea, Gemcitabine, Fludarabine)

Texaphyrins (motexafin gadolinium)

Supressors of sulfhydryl groups (N- Ethylmaleimide, Diamide and Diethylmaleate)

Hyperthermia

Novel radiosensitizers (paclitaxel, docetaxel, irinotecan)



# Radioprotectors

## Radiation mitigators

Palifermin

Halofuginone

TGF- $\beta$

Keratinocyte growth factor

ACE inhibitors (Captopril, Enalapril, ramipril)

COX-2 inhibitors/NSAIDS (celecoxib, aspirin, il

### ● Systemic/Overall Survival

Tetracyclin/derivatives (Antibiotic and unknown mechanism)  
Ciprofloxacin (Supportive care)  
Levofloxacin (Supportive care)

### ● Central Nervous System/Brain

Rampril (ACE inhibitor)  
Atorvastatin (Statin)  
EUK 189, 207, 423, 451 (MnSOD-catalase mimetic)

### ● Renal

Atorvastatin (Statin)  
Captopril (ACE inhibitor)  
EUK 207 (MnSOD-catalase mimetic)

### ● Gastrointestinal

SOM230 (Somatostatin Analog)  
Li2 CO3 (Lithium carbonate)  
Mesenchymal stem cells  
CBLB-502  
EUK 207, 451 (MnSOD-catalase mimetic)

### ● Skin

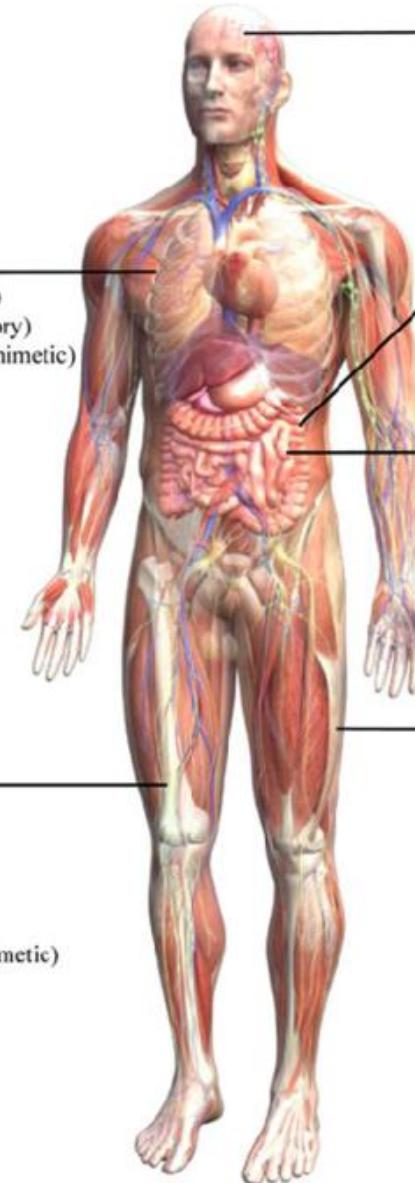
Curcumin (Anti-inflammatory, inhibits NFkB)  
EsA (Anti-inflammatory)  
Mesenchymal stem cells  
Pentoxifylline (Anti-oxidant)  
Cox inhibitors (Anti-inflammatory-Cox2 inhibitor)  
Cu/Zn-SOD (Anti-oxidant)  
EUK 207, 423, 451 (MnSOD-catalase mimetic)

### ● Lung

Genistein (Protein tyrosine kinase inhibitor)  
h-Esculentoside-A (h-EsA) (Anti-inflammatory)  
EUK 189, 207, 423, 451 (MnSOD-catalase mimetic)  
Statins  
ACE inhibitors  
A II Blockers  
Cox Inhibitors  
MnTnHex-2-PyP5+ (MnSOD mimetics)

### ● Bone Marrow

Mesenchymal stem cells  
Myeloid progenitor cells  
Bone marrow stem cells  
Cord blood  
Endothelial cells  
EUK 451 (MnSOD-catalase mimetic)



- Coleman S. N. ALERT. 2014.

# DOSE FRACTIONATION IN RADIATION ONCOLOGY

- The total dose of radiation applied in one fraction or divided with a time gap in between does not give the same radiobiological effect.
- If the total dose is applied in one fraction or a smaller number of fractions, the radiation effect on the biological system is greater than if the same dose is applied in a larger number of fractions – TDF (Time Dose Fraction) or EQD2 (biologically equivalent doses).
- The longer the irradiation time, the higher the total dose required to achieve a radiobiological effect.

# Fractionation regimes

- Standard (conventional) fractionated radiation – previously the most frequently applied radiation regimen in daily clinical practice. Therapeutic dose 1.8 to 2 Gy per day.
- Hyperfractionated radiation - radiation fractions are applied, with a minimum time interval of 4 to 6 hours in one day. The aim is to improve local control, expected higher acute adverse events.
- Hypofractionated radiation - application of the total tumor dose in a smaller number of fractions, whereby a dose of 3 to 6 Gy, or greater per fraction is applied.
- Single radiation fraction - applying therapeutic dose in one fraction (SRS, IORT, palliative single shoot).
- Continuous radiation - in brachytherapy, with Low Dose Rate (LDR).

# Radiotherapy treatment aim can be:

- Radical - in order to achieve a complete and permanent remission of the disease (the application of a radical dose of radiation is often limited by the radiotolerance of healthy tissue)
- Prophylactic (elective) - by irradiating a region that is not clinically affected, but the subclinical presence of malignant cells is possible
- Palliative - in order to control symptoms and improve the quality of life (pain reduction, prevention of bleeding, compression symptoms)
- Preoperative - goal: downstaging, downsizing. Precedes surgical treatment, intent - reduction of biological potential.
- Postoperative (adjuvant) - eradication of possibly remaining malignant cells in order to reduce the local relapse rate (LRR). Clearly defined indications by localization.
- Intraoperative radiotherapy (IORT) - direct irradiation of the tumor bed during the surgical procedure.
- Chemoradiotherapy (CRT) - to improve treatment results, can be a concomitant therapeutic regimen - simultaneous application or in a sequential therapeutic regimen - applying chemotherapy after completed radiotherapy, or vice versa. Synergism of two methods. More frequent treatment complications.

# PART II



# 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)



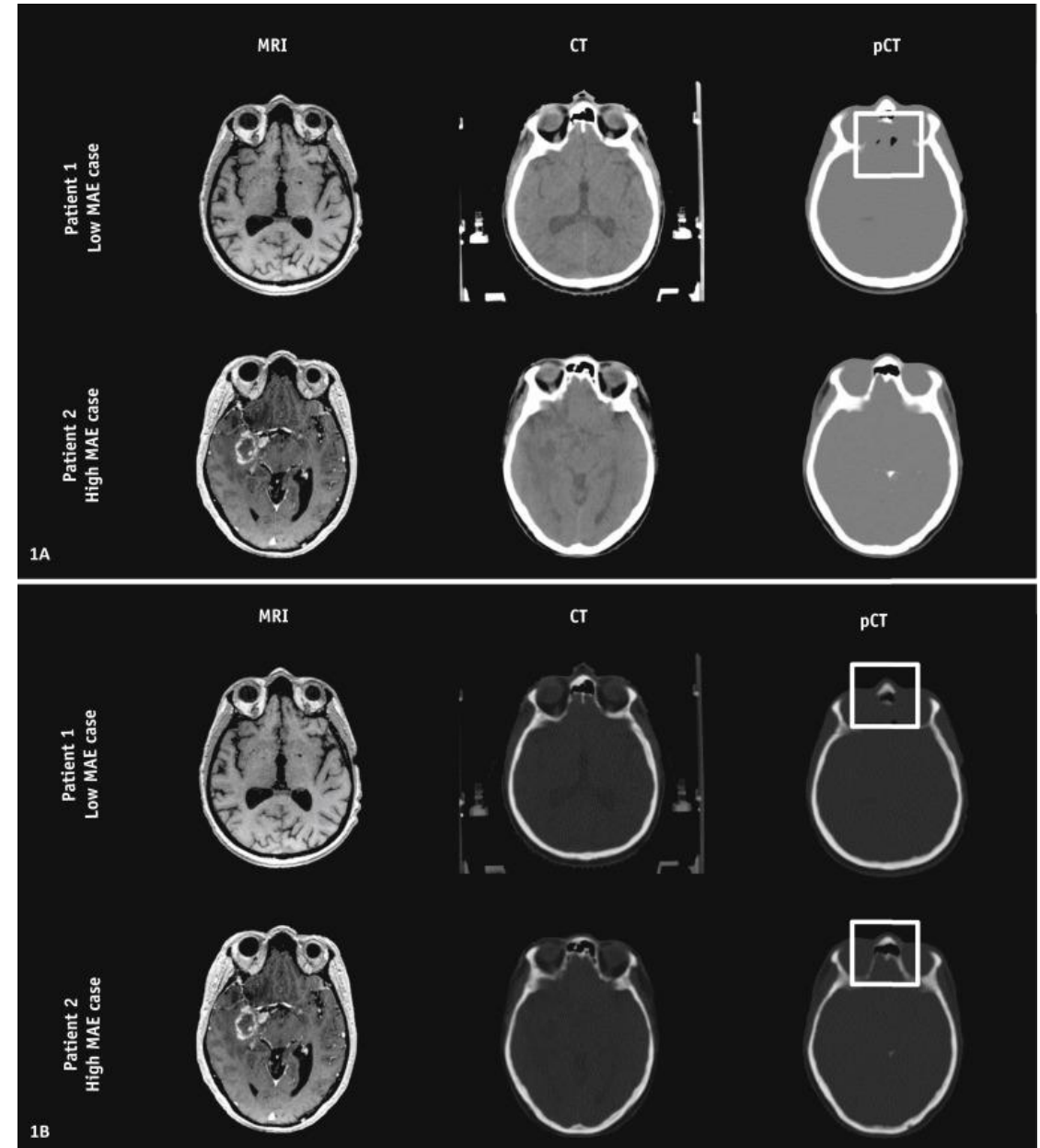
# Conventional simulator (fluoroscopic planning machine)



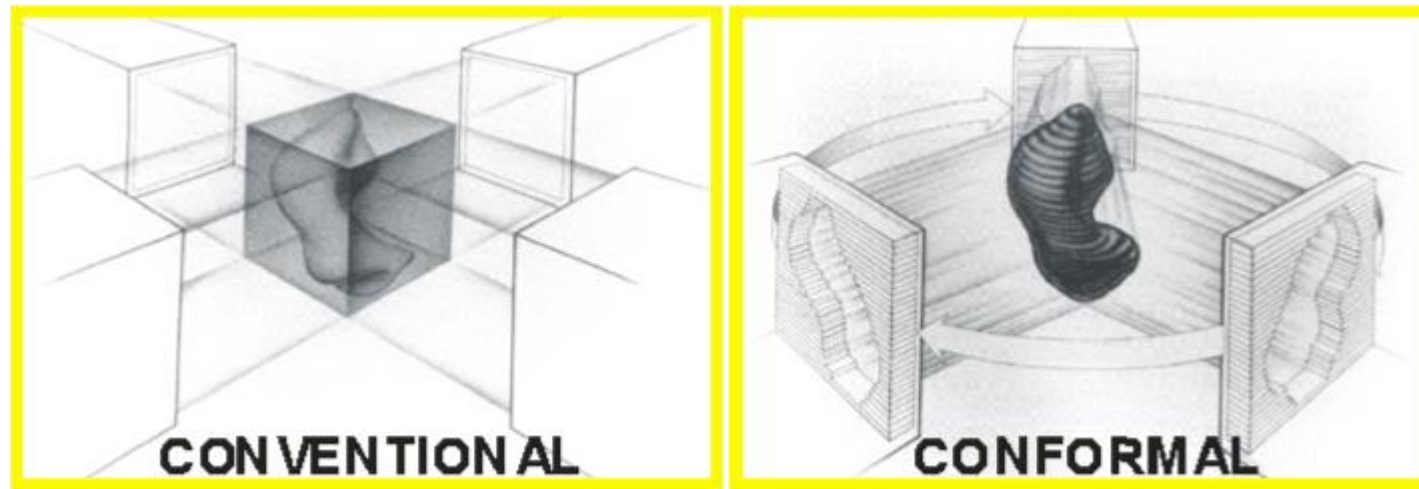
# CT/MRI simulator

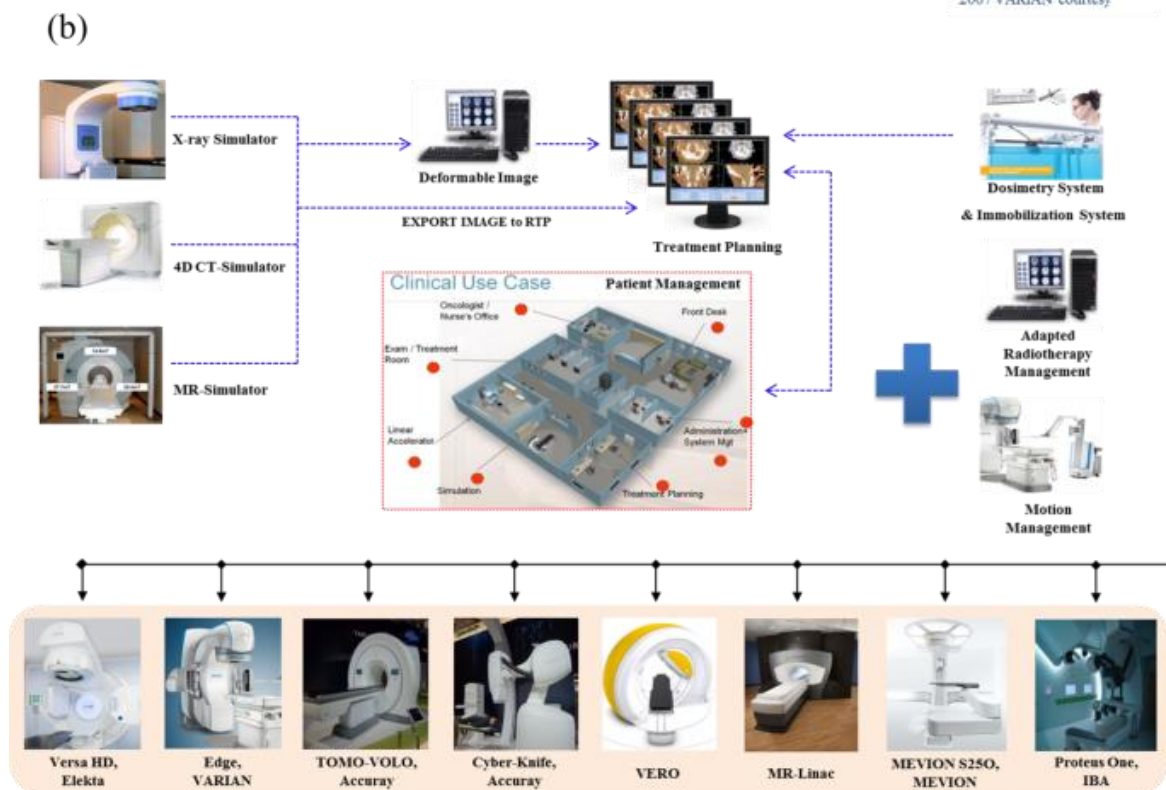
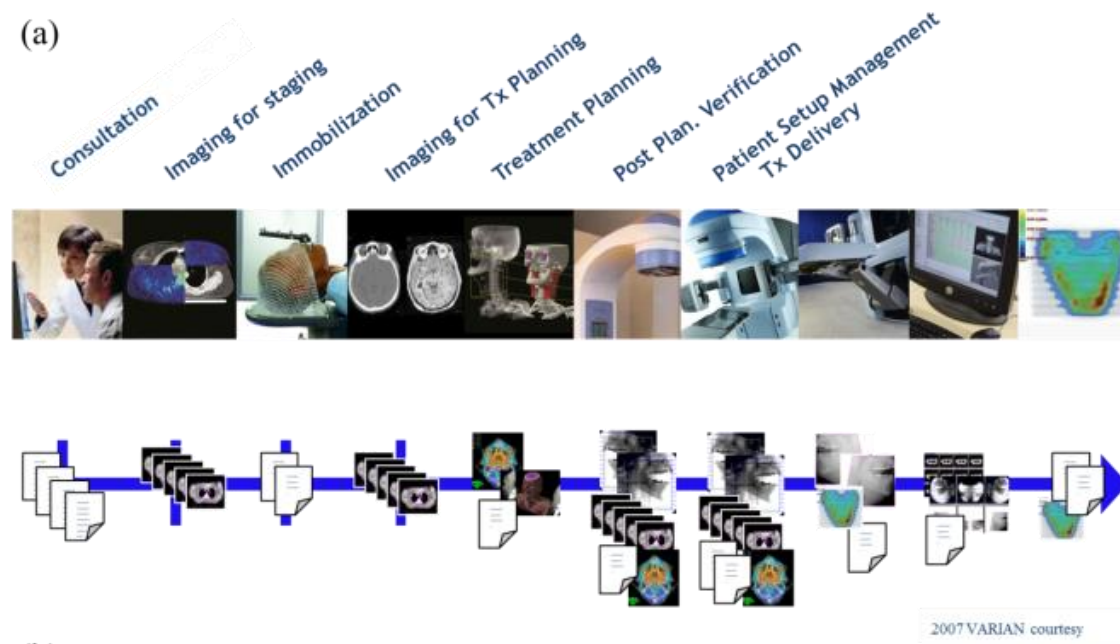


- Andres A. E. Int J of Radiation Oncology, Biology, Physics. , 2020.



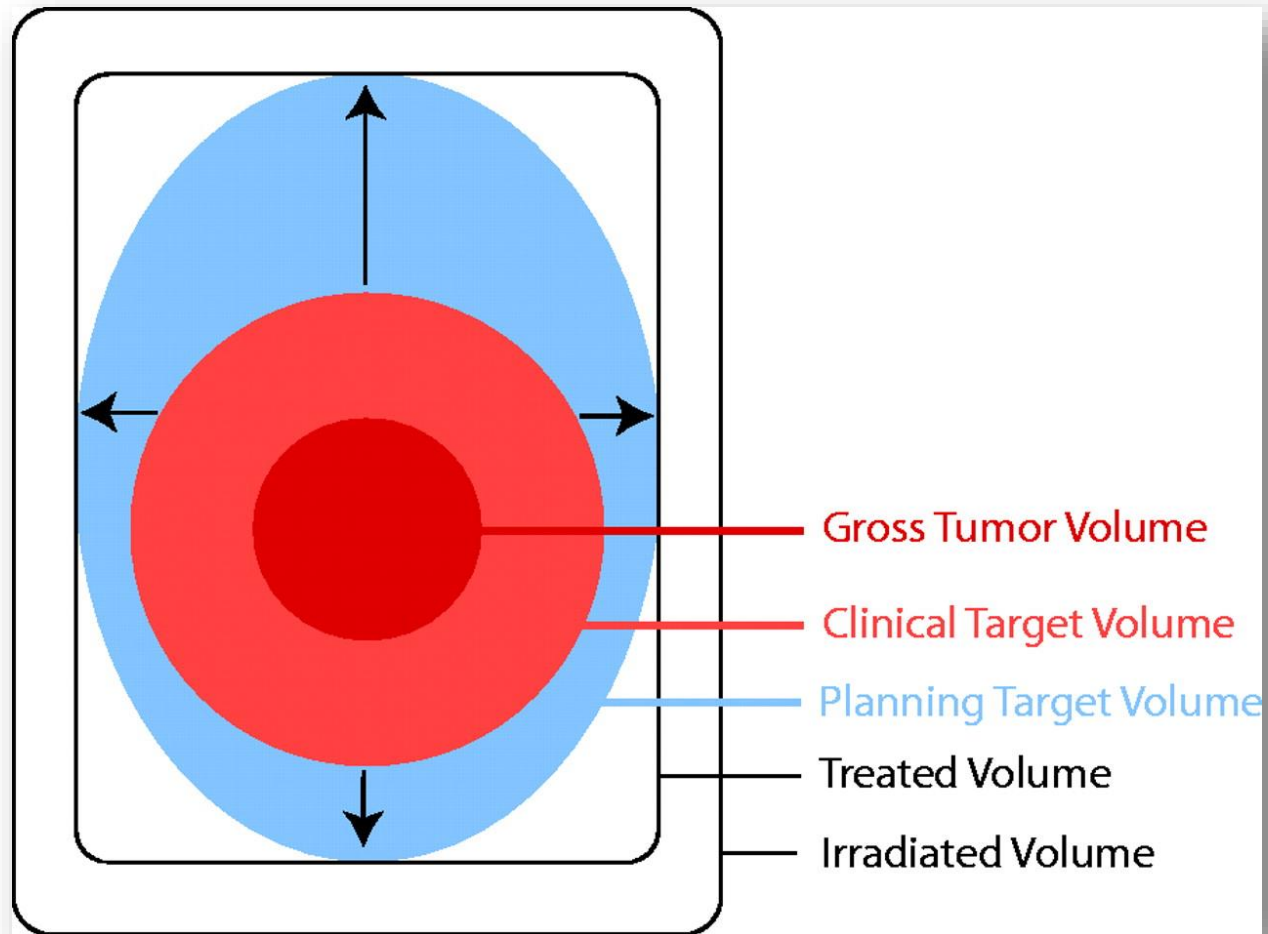
# PRECISE DELIVERY OF THERAPEUTIC RADIATION DOSE IN THE TUMOR TISSUE WITH MINIMAL DAMAGE TO THE SURROUNDING, HEALTHY TISSUE





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.

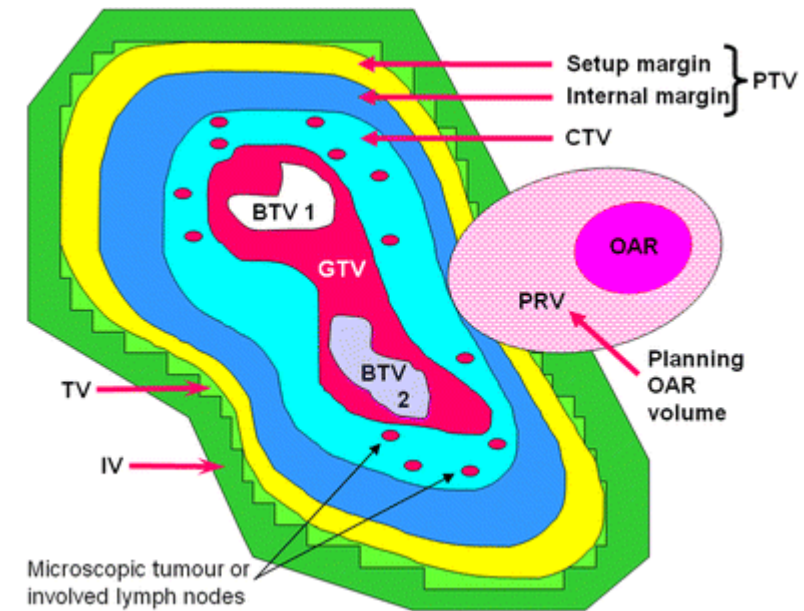


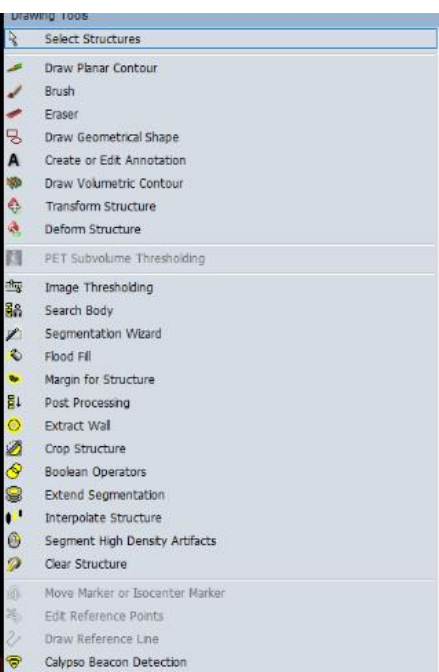
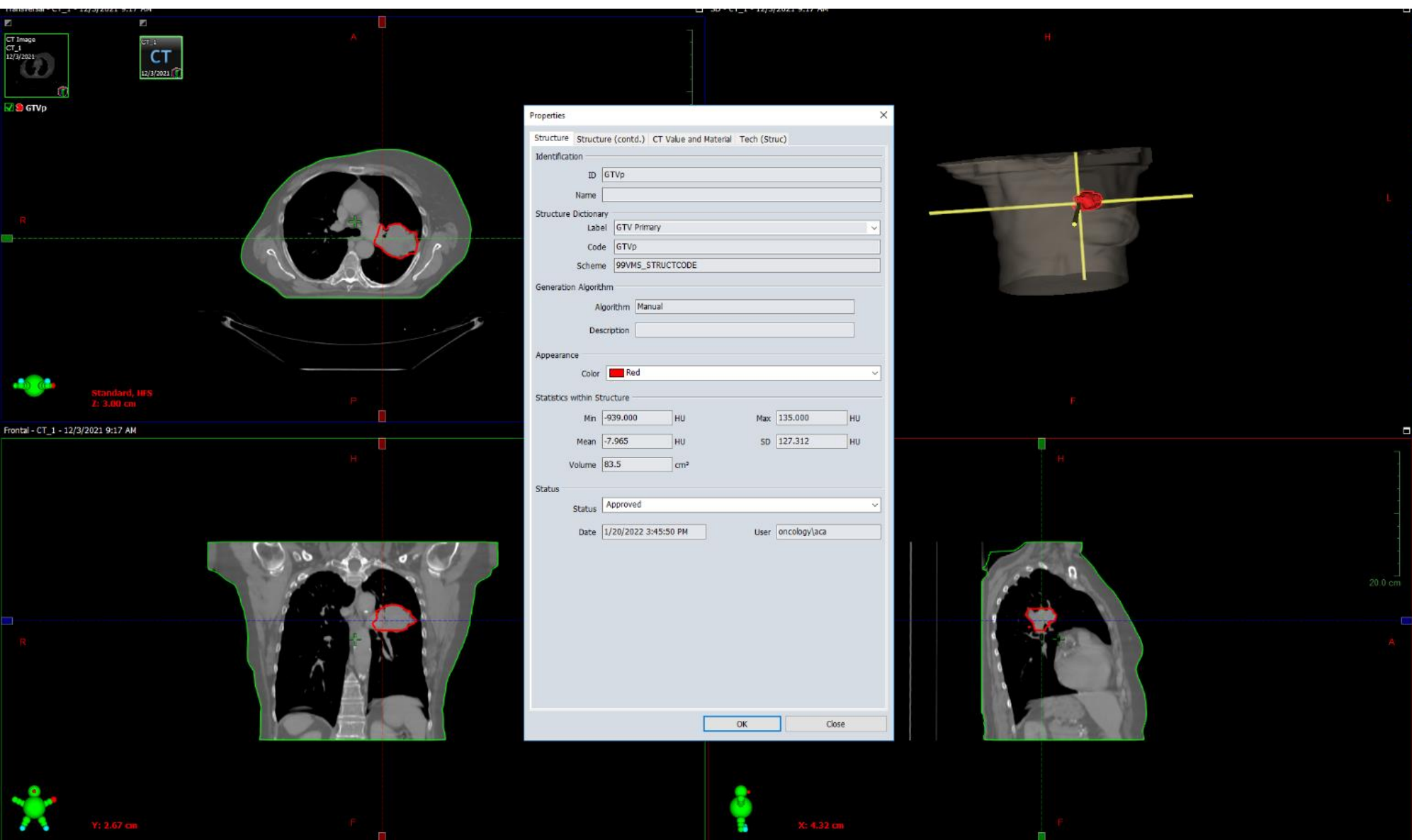
# Organs at Risk (OAR)

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

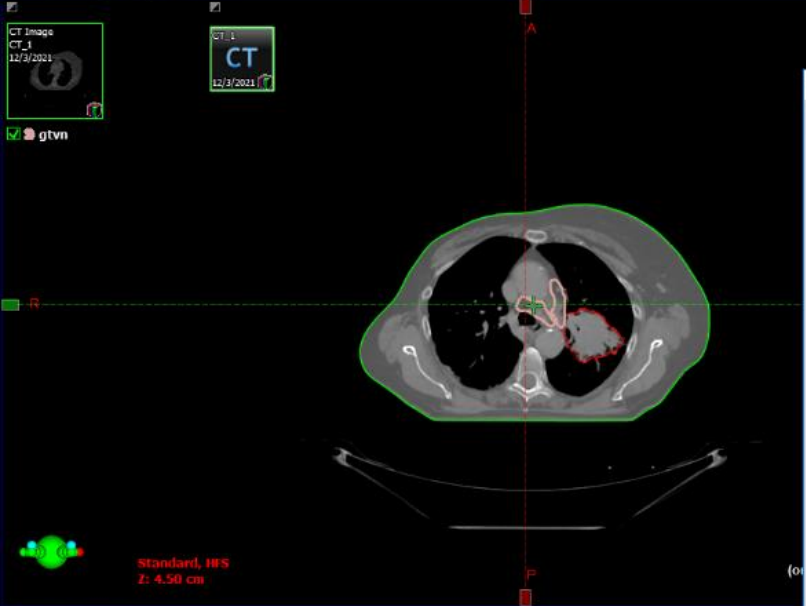
Additional volume around OAR (PRV - Planning Risk Volume)

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

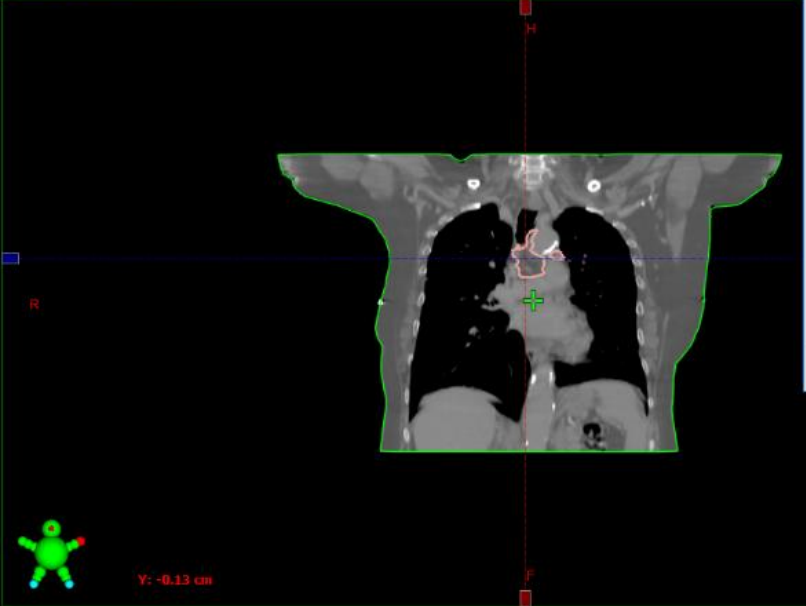




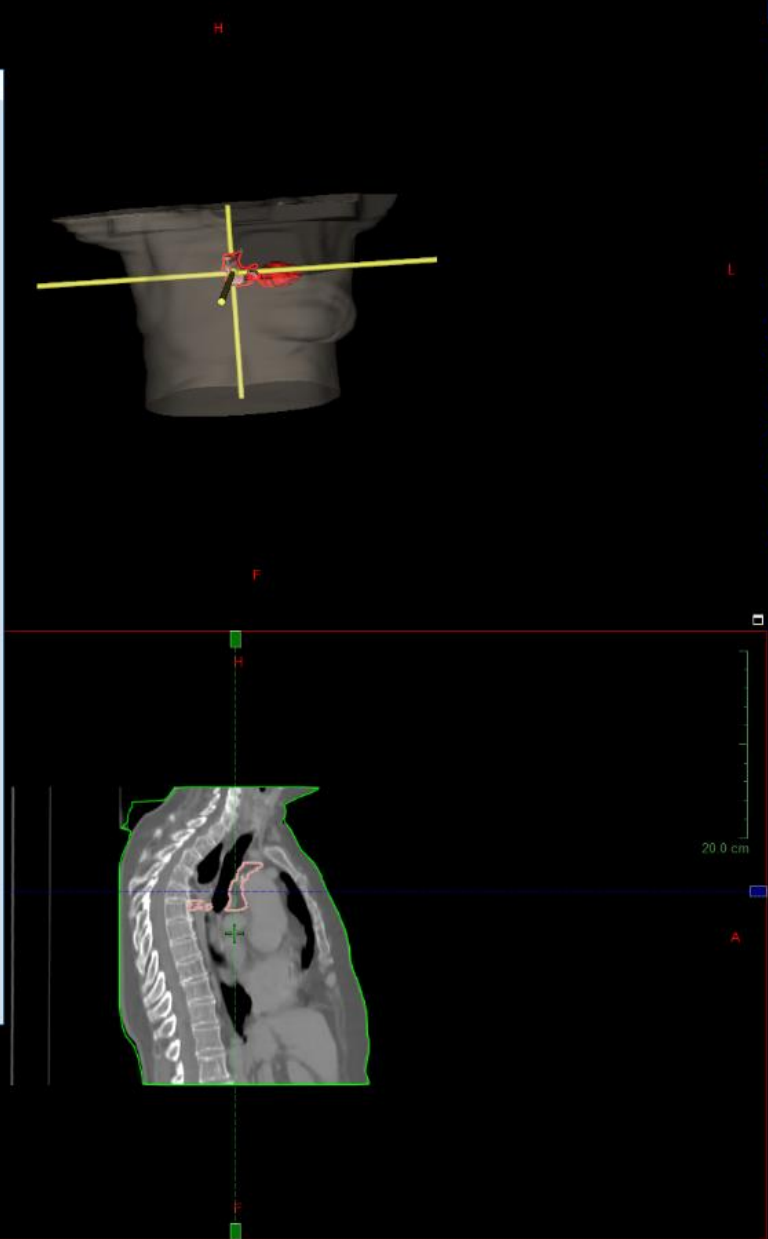
Transversal - CT\_1 - 12/3/2021 9:17 AM



Frontal - CT\_1 - 12/3/2021 9:17 AM



3D - CT\_1 - 12/3/2021 9:17 AM



Properties

Structure Structure (contd.) CT Value and Material Tech (Struc)

Identification

ID gtvn

Name

Structure Dictionary

Label GTV Nodal

Code GTVn

Scheme 99VMS\_STRUCTURECODE

Generation Algorithm

Algorithm Manual

Description

Appearance

Color RGB223166159

Statistics within Structure

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Mean	-52.123	HU	SD	118.084	HU
Volume	27.3	cm³			

Status

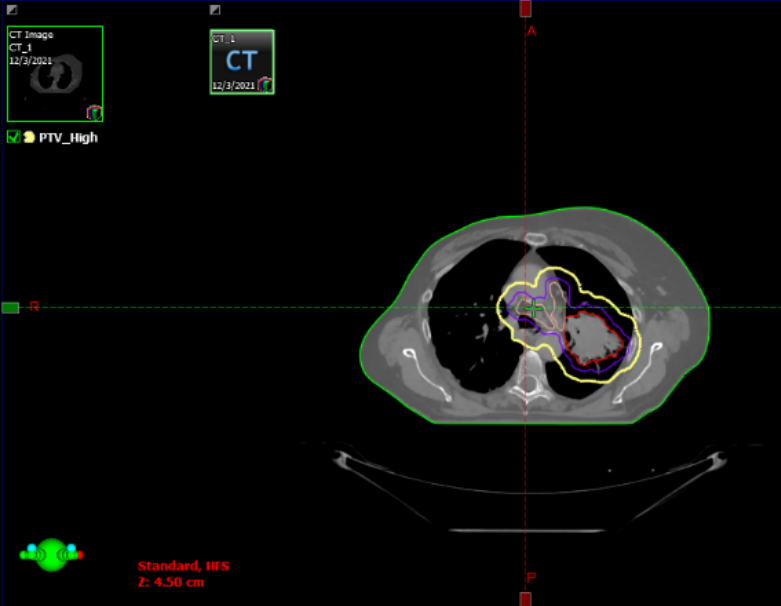
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Date 1/20/2022 3:45:50 PM User oncology\jaca

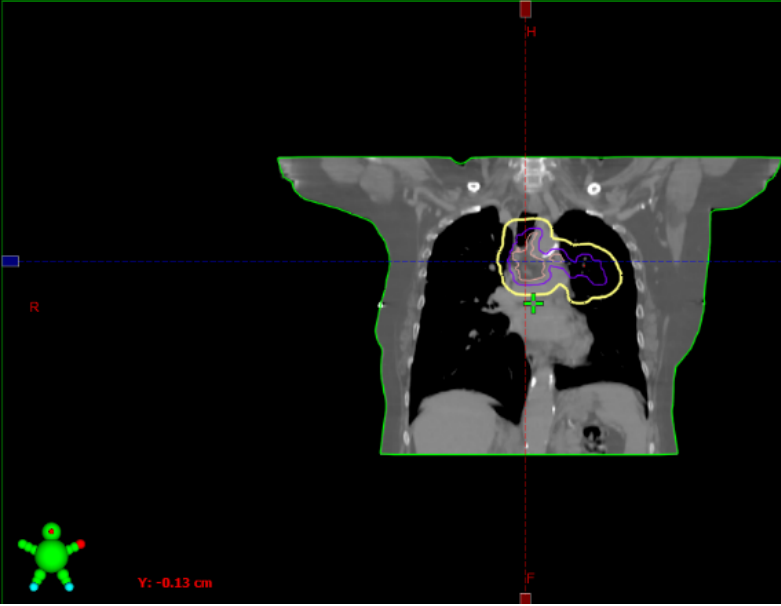
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- Drawing Tools
- Select Structures
  - Draw Planar Contour
  - Brush
  - Eraser
  - Draw Geometrical Shape
  - Create or Edit Annotation
  - Draw Volumetric Contour
  - Transform Structure
  - Deform Structure
  - PET Subvolume Thresholding
  - Image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

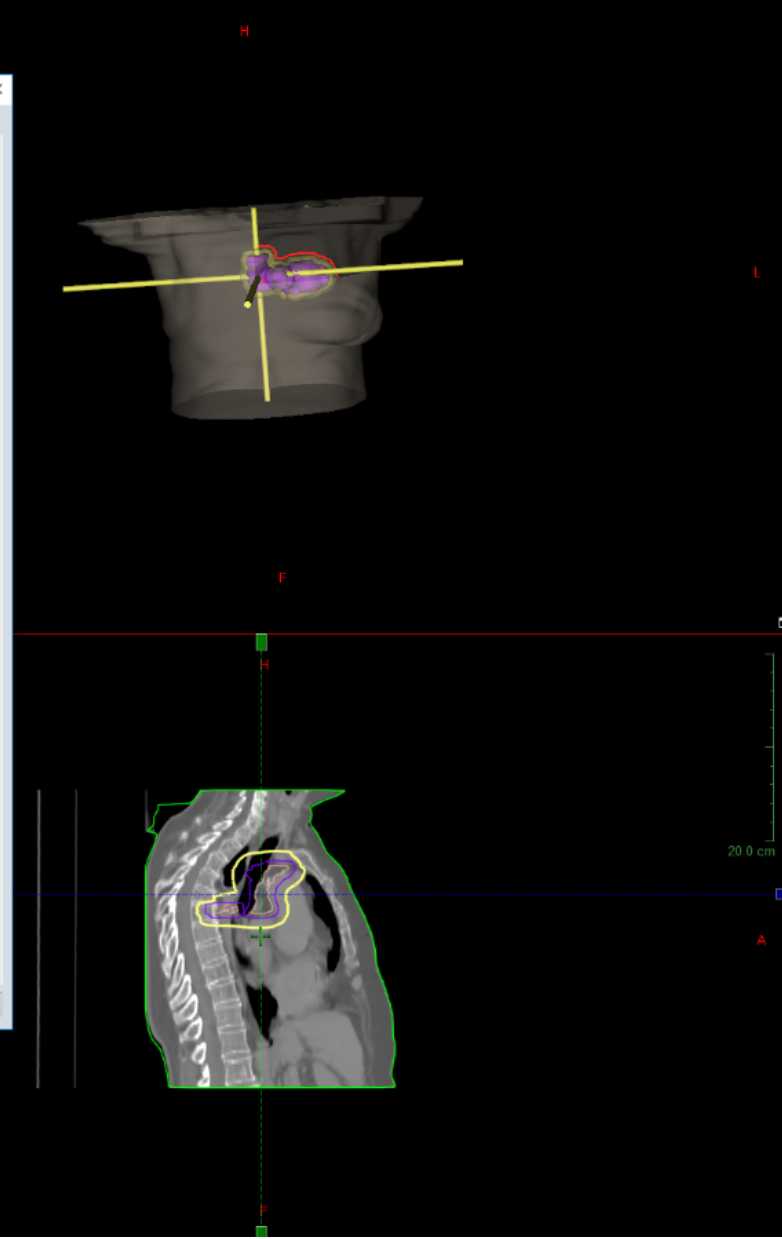
Transversal - CT\_1 - 12/3/2021 9:17 AM



Frontal - CT\_1 - 12/3/2021 9:17 AM



3D - CT\_1 - 12/3/2021 9:17 AM



Properties

Structure (contd.) CT Value and Material Tech (Struc)

Identification

ID PTV\_High

Name

Structure Dictionary

Label PTV High Risk

Code PTV\_High

Scheme 99VMS\_STRUCTCODE

Generation Algorithm

Algorithm Manual

Description

Appearance

Color Translucent : Yellow

Statistics within Structure

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Mean	-317.710	HU	SD	403.285	HU
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Status

Status Approved

Date 1/20/2022 3:45:50 PM

User oncology\aca

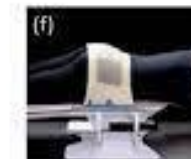
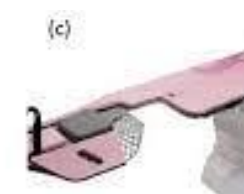
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- Initial diagnostic work up (pathology and diagnostics)
- Disease staging and disease characterization (e.g. Tumor molecular profile)
- Multidisciplinary oncology team – treatment decision
- Initial exam, informed decision and patient consent
- Positioning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

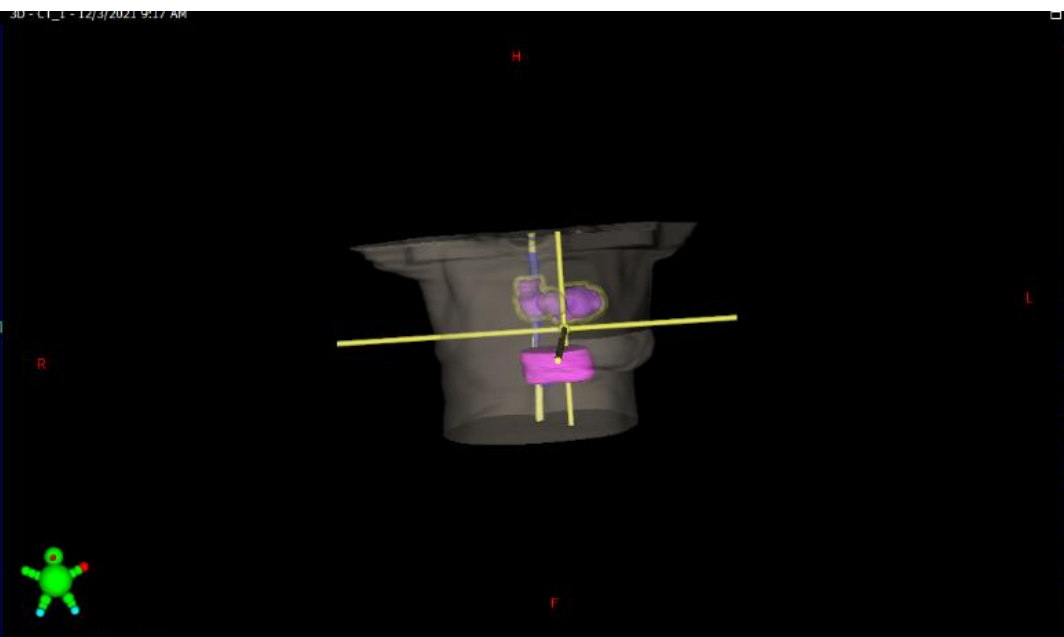


# POSITIONING AND IMMOBILIZATION

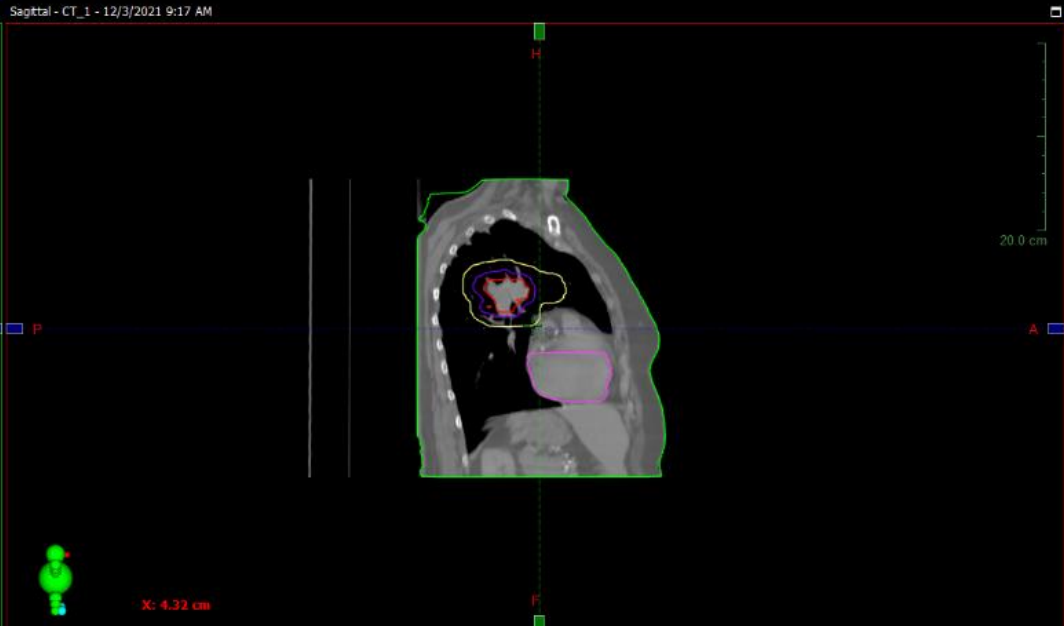
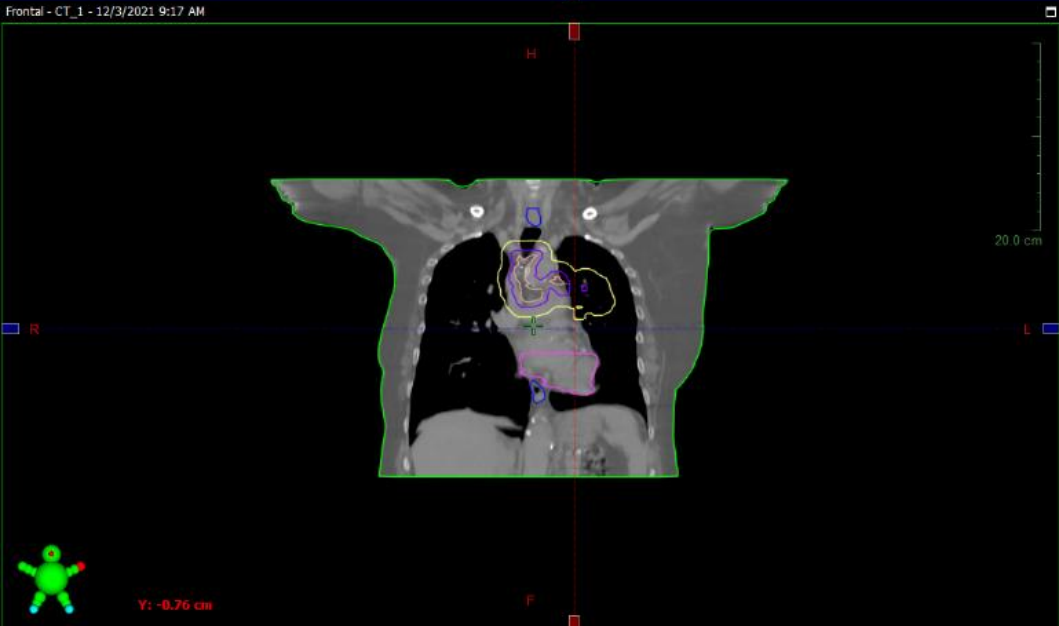


# Three-dimensional conformal radiation, 3D-CRT

- 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



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  - Draw Reference Line
  - Calypso Beacon Detection





1

1: R0

Plan\_1

Plan\_1

CT\_1

Registered Images

CT\_1

BODY

CouchInterior

CouchSurface

CTV\_High

Esophagus

gtvn

GTVvp

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)

MLC

79.0

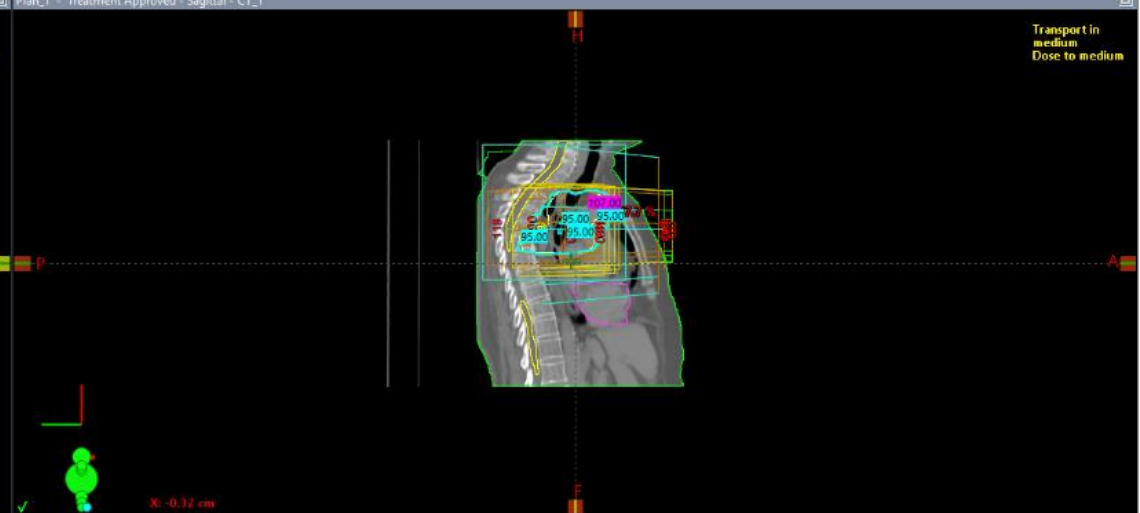
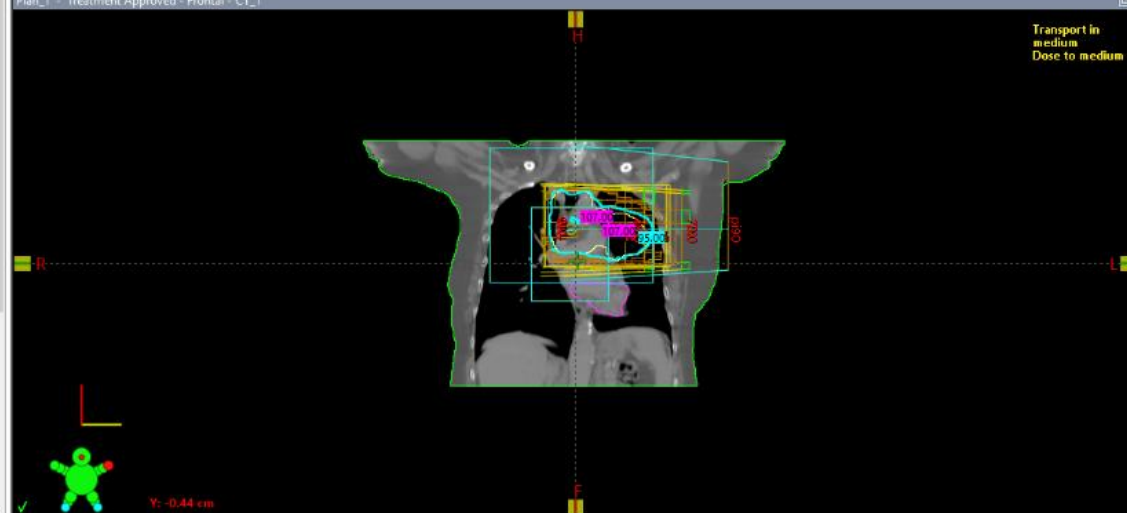
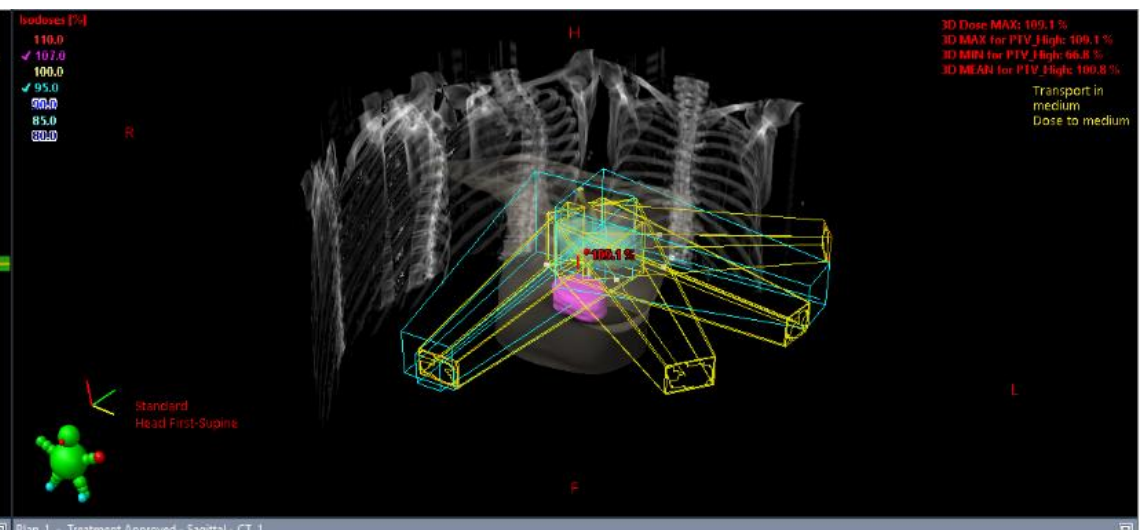
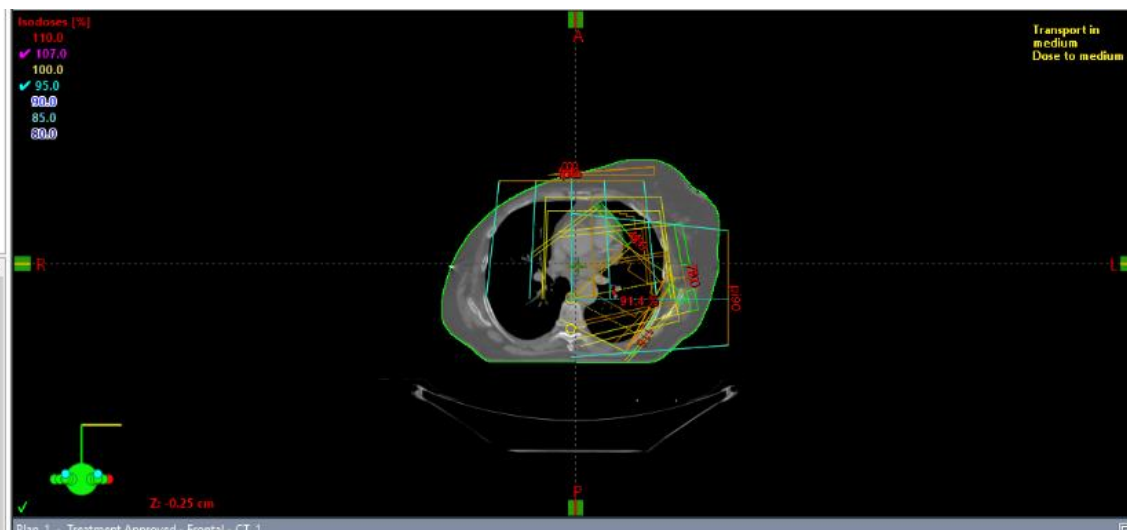
Field 5--DRR (Live)

Fields

Dose

Reference Points

Dose Statistics



Group	Field ID	Technique	Machine/Energy	MLC	Field Weight	Scale	Gantry Angle [deg]	Coll Rtn [deg]	Iso Rtn [deg]	Wedge	Field X [cm]	X1 [cm]	X2 [cm]	Field Y [cm]	Y1 [cm]	Y2 [cm]	X [cm]	Y [cm]	Z [cm]	Calculated SSD [cm]	MU	Ref. D [cGy]
I	pi0	STATIC-I	Elekta3 - 6X		0.000	IEC61217	0.0	0.0	0.0	None	22.0	-11.0	+11.0	18.1	-7.1	+11.0	-0.85	4.05	4.09	85.8		
I	pi90	STATIC-I	Elekta3 - 6X		0.000	IEC61217	90.0	0.0	0.0	None	18.5	-11.0	+7.5	17.5	-6.5	+11.0	-0.85	4.05	4.09	80.8		
I	foto	STATIC-I	Elekta3 - 6X		0.000	IEC61217	0.0	0.0	0.0	None	10.4	-5.4	+5.0	12.6	-9.6	+3.0	-0.85	4.05	4.09	85.8		
I	48	STATIC-I	Elekta3 - 6X	Static	0.419	IEC61217	48.7	0.0	0.0	None	18.3	-7.8	+10.5	11.2	-5.5	+5.7	-0.85	4.05	4.09	81.3	38	56.8
I	48.0	STATIC-I	Elekta3 - 6X	Static	0.081	IEC61217	48.7	0.0	0.0	None	18.2	-7.3	+10.9	12.0	-6.0	+6.0	-0.85	4.05	4.09	81.3	7	11.1
I	79	STATIC-I	Elekta3 - 6X	Static	0.329	IEC61217	79.2	0.0	0.0	None	15.0	-8.8	+6.2	10.5	-5.0	+5.5	-0.85	4.05	4.09	80.1	37	56.4
I	79.0	STATIC-I	Elekta3 - 6X	Static	0.071	IEC61217	79.2	0.0	0.0	None	13.3	-8.1	+5.2	12.0	-6.0	+6.0	-0.85	4.05	4.09	80.1	8	12.6



JOVVER211203

- 1
- R 1: R0
- Plan\_1

Plan\_1

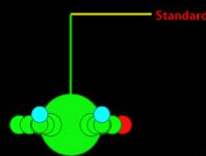
- CT\_1
  - Registered Images
    - CT\_1
      - BODY
      - CouchInterior
      - CouchSurface
      - CTV\_High
      - Esophagus
      - gtvn
      - GTVp
      - Heart
      - Lung\_L
      - Lung\_R
      - PTV\_High
      - SpinalCord
    - User Origin
  - Reference Points
    - PTV\_High
  - Dose
    - Fields
      - Isocenter Group 1
        - 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)
        - MLC

Plan\_1 - Treatment Approved - Transversal - CT\_1

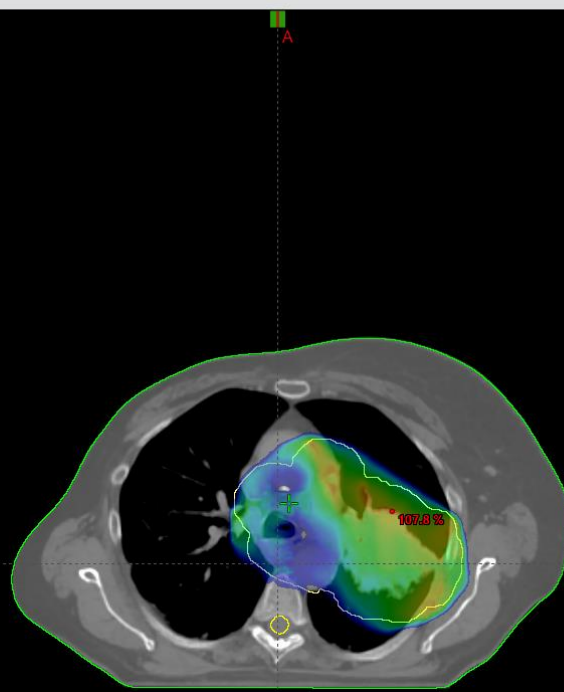
Color wash [%]



R



Head First-Supine  
Z: 4.09 cm

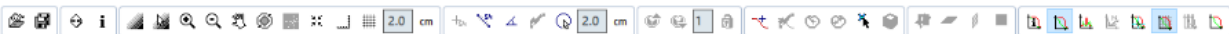


3D Dose MAX: 109.1 %  
3D MAX for PTV\_High: 109.1 %  
3D MIN for PTV\_High: 66.8 %  
3D MEAN for PTV\_High: 100.8 %

Transport in  
medium  
Dose to medium

Fields Dose Reference Points Dose Statistics

Plan ID	Dose per Fraction [cGy]	Number of Fractions	Total Dose [cGy]	Treatment Percentage [%]	Target Volume	Primary Reference Point			Plan Normalization Mode	Plan Normalization Value [%]
						ID	Planned Dose per Fraction [cGy]	Planned Total Dose [cGy]		
Plan_1	200.0	32	6400.0	100.00	PTV_High	PTV_High	200.0	6400.0	95.00% covers 95.00% of Target Volume	319.5



JOVVER211203

1  
1 : R0  
Plan\_1

Plan\_1

- CT\_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 4.5-DRR (Live)

Dose Volume Histogram

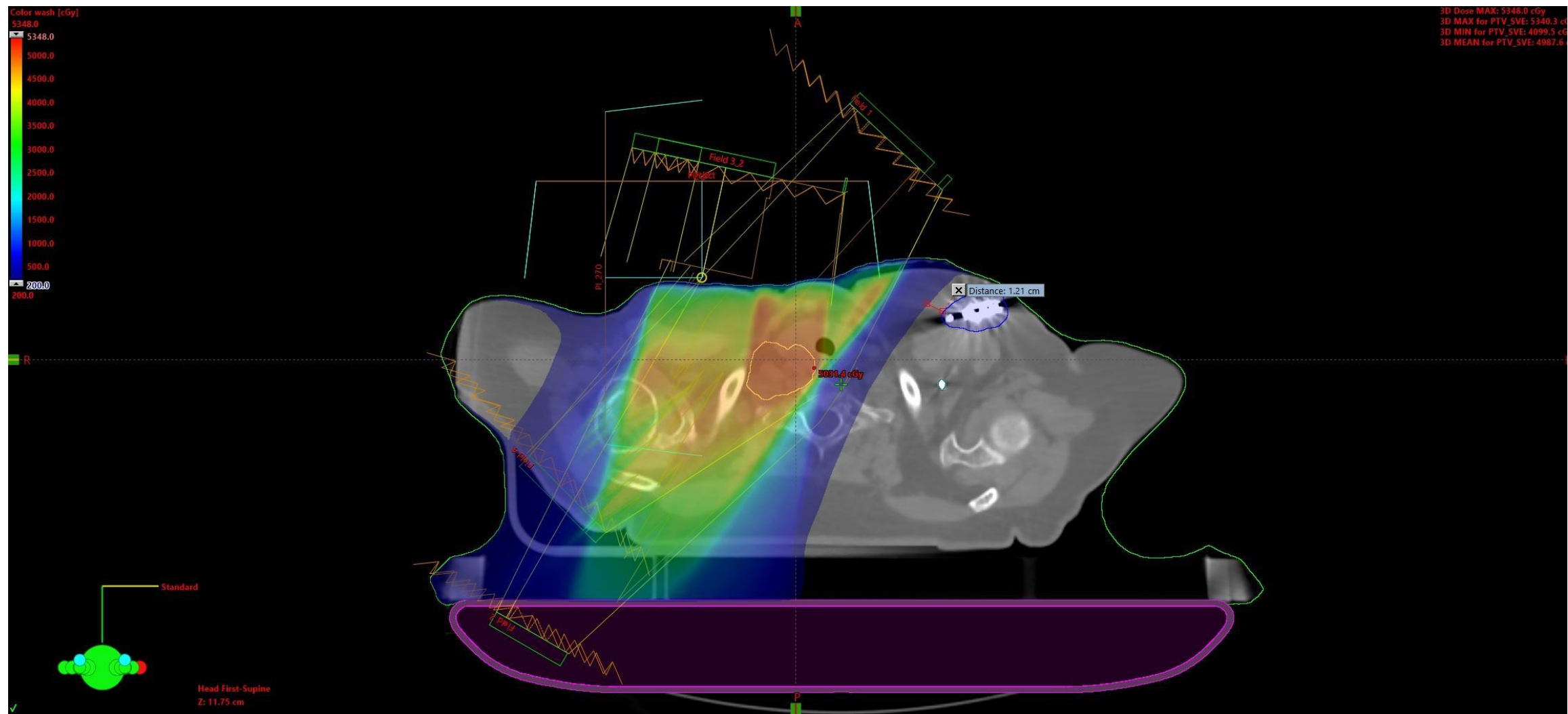


Dose Reference Points Dose Statistics

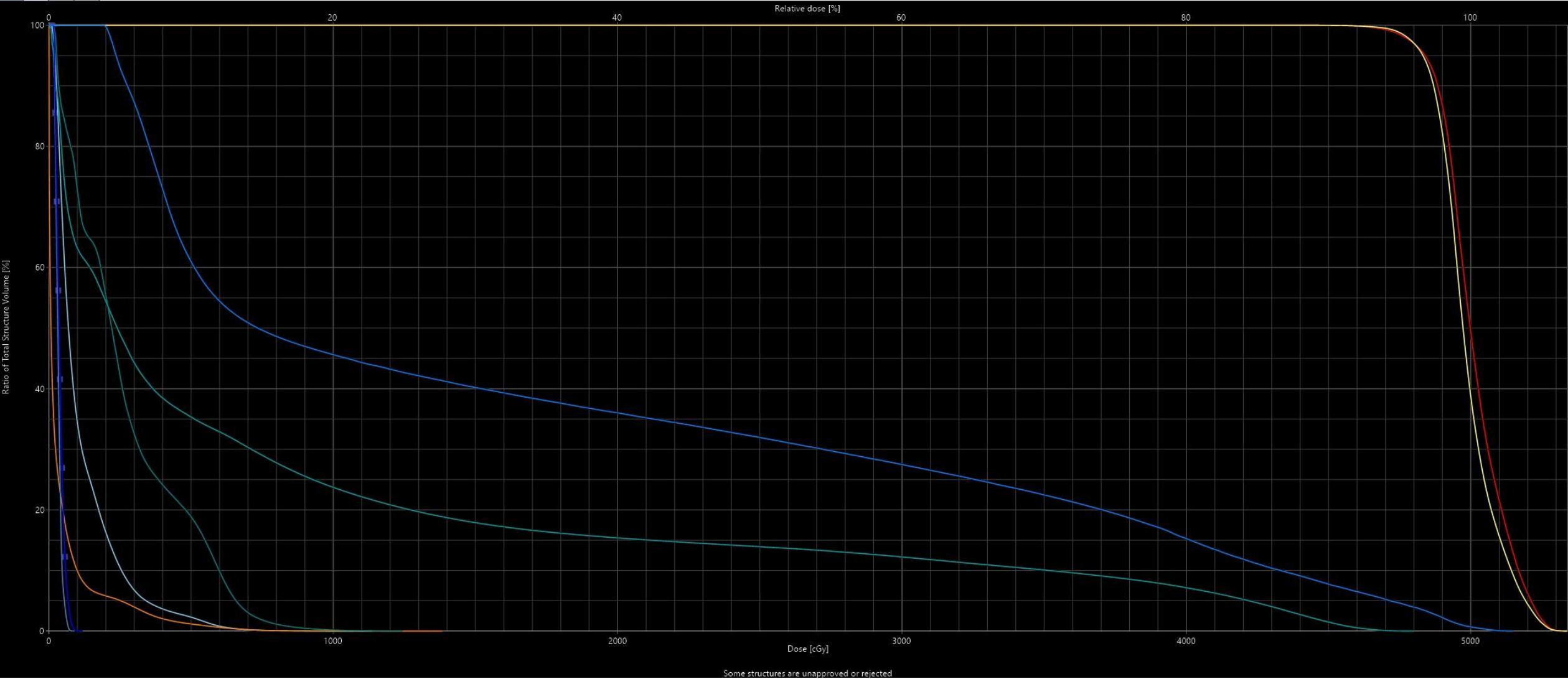
Show DVH	Structure	Approval Status	Plan	Course	Volume [cm <sup>3</sup> ]	Dose Cover [%]	Sampling Cover [%]	Min Dose [cGy]	Max Dose [cGy]	Mean Dose [cGy]	D5985.0% [%]	V95.0 [%]	V107.0 [%]	V107.0% [cm <sup>3</sup> ]	V5320.0cGy [%]	V5985.0cGy [%]	V5992.0cGy [%]	V6650.0cGy [%]
<input checked="" type="checkbox"/>	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	100.2	100.1	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	5604.9	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.#QNB	1.5	1.5	1.5	1.5

# 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]

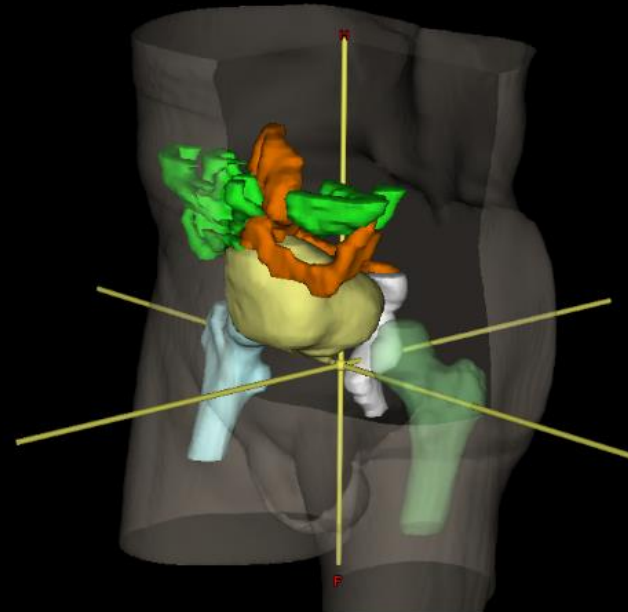
# Volumetric Modulated Arc Therapy, VMAT

- 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



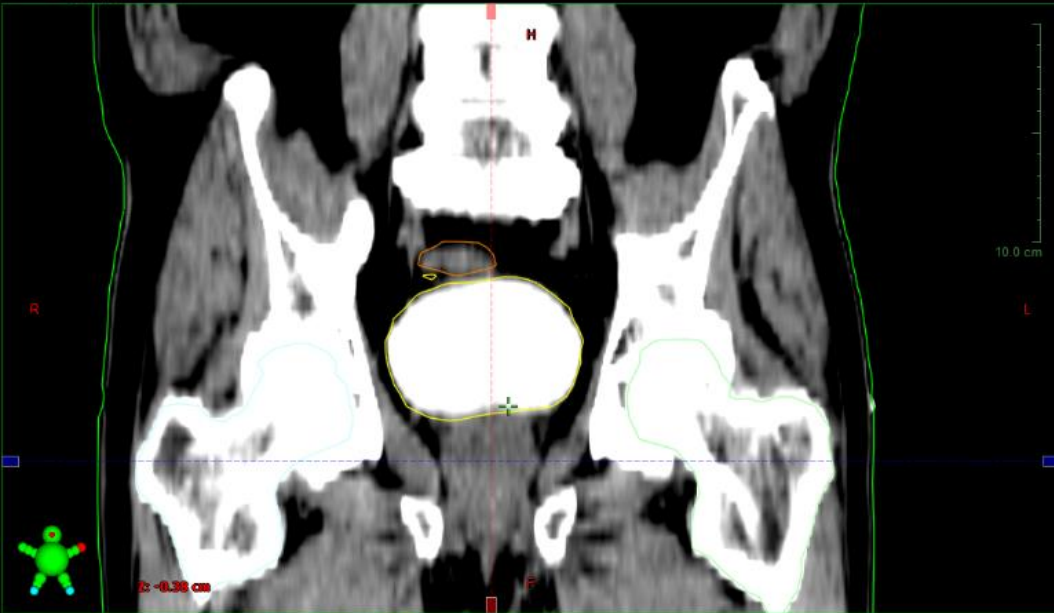
3D - CT\_1 - 4/6/2021 8:55 AM



Drawing Tools

- Select Structures
- Draw Planar Contour
- Brush
- Eraser
- Draw Geometrical Shape
- Create or Edit Annotation
- Draw Volumetric Contour
- Transform Structure
- Deform Structure
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- Segment High Density Artifacts
- Clear Structure
- Move Marker or Isocenter Marker
- Edit Reference Points
- Draw Reference Line
- Calypso Beacon Detection

Frontal - CT\_1 - 4/6/2021 8:55 AM

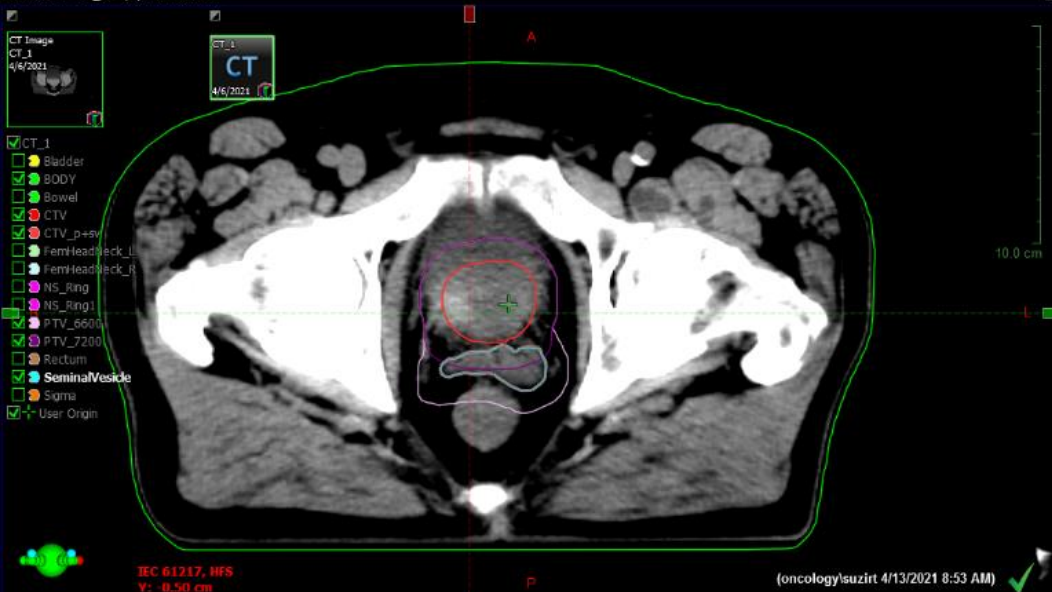


Sagittal - CT\_1 - 4/6/2021 8:55 AM

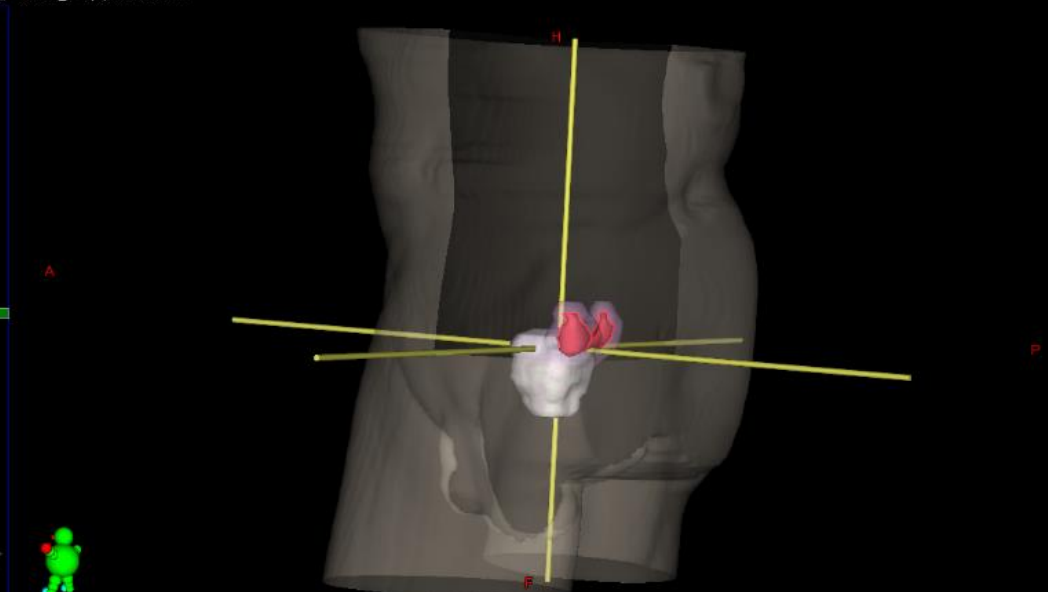




Transversal - CT\_1 - 4/6/2021 8:55 AM



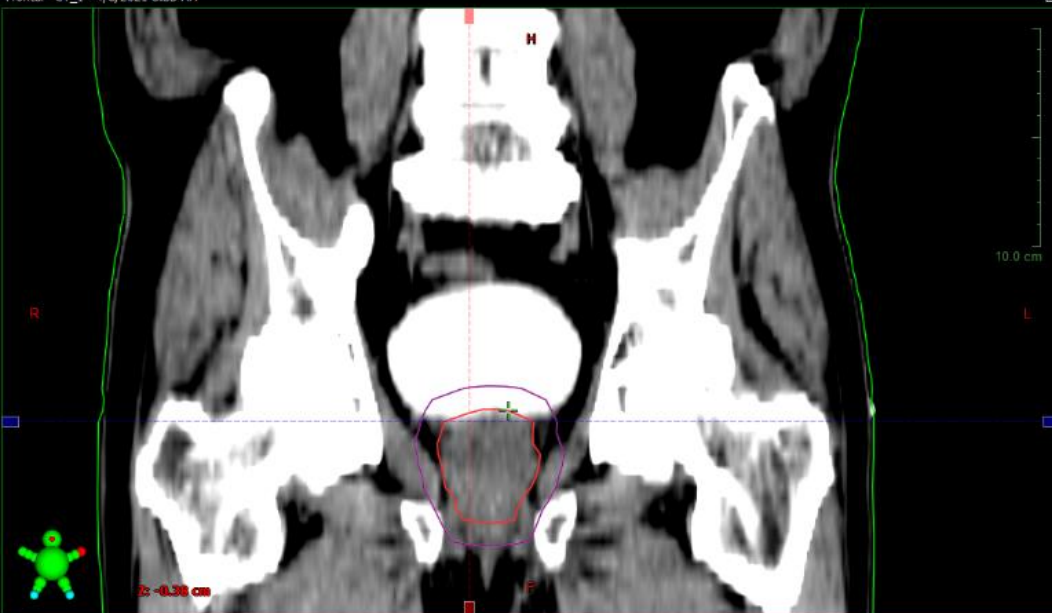
3D - CT\_1 - 4/6/2021 8:55 AM



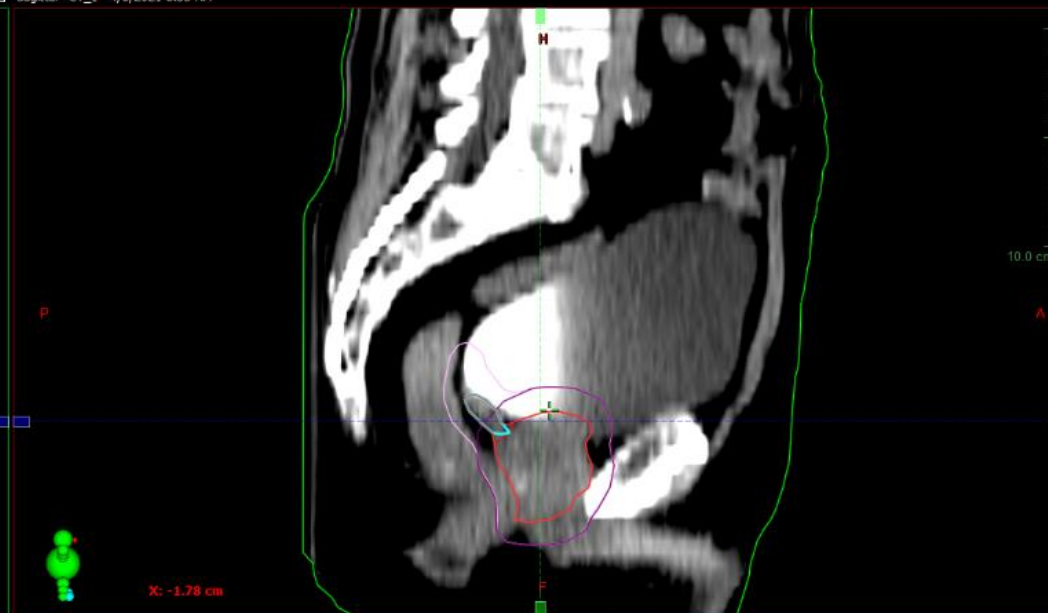
Drawing Tools

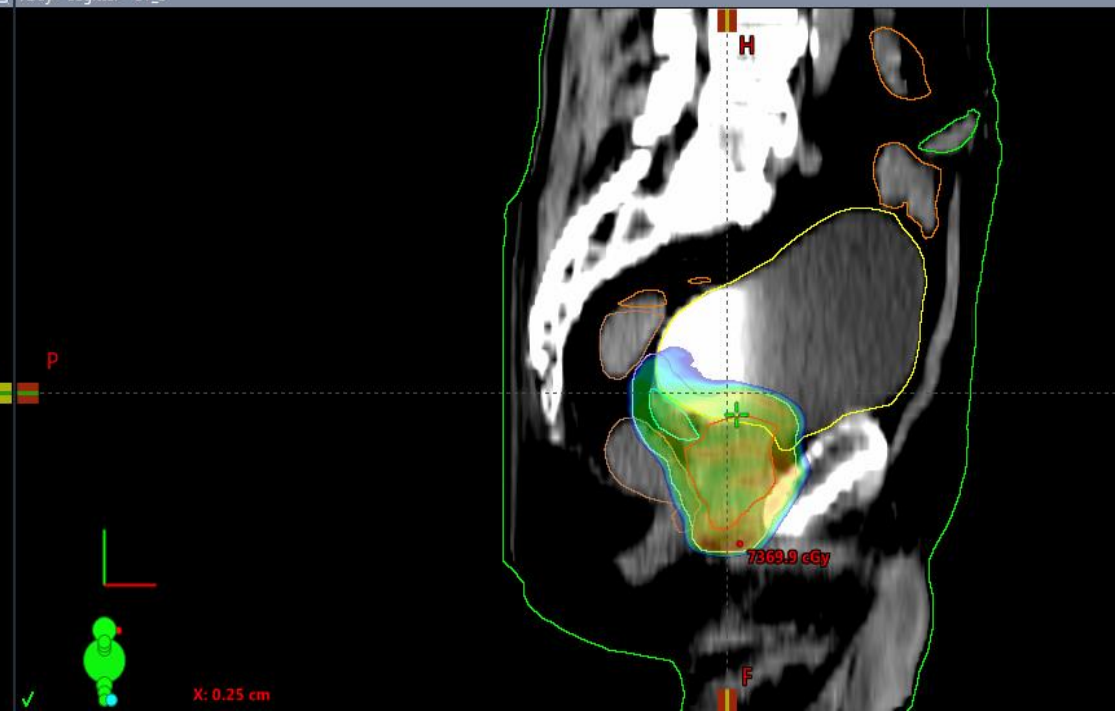
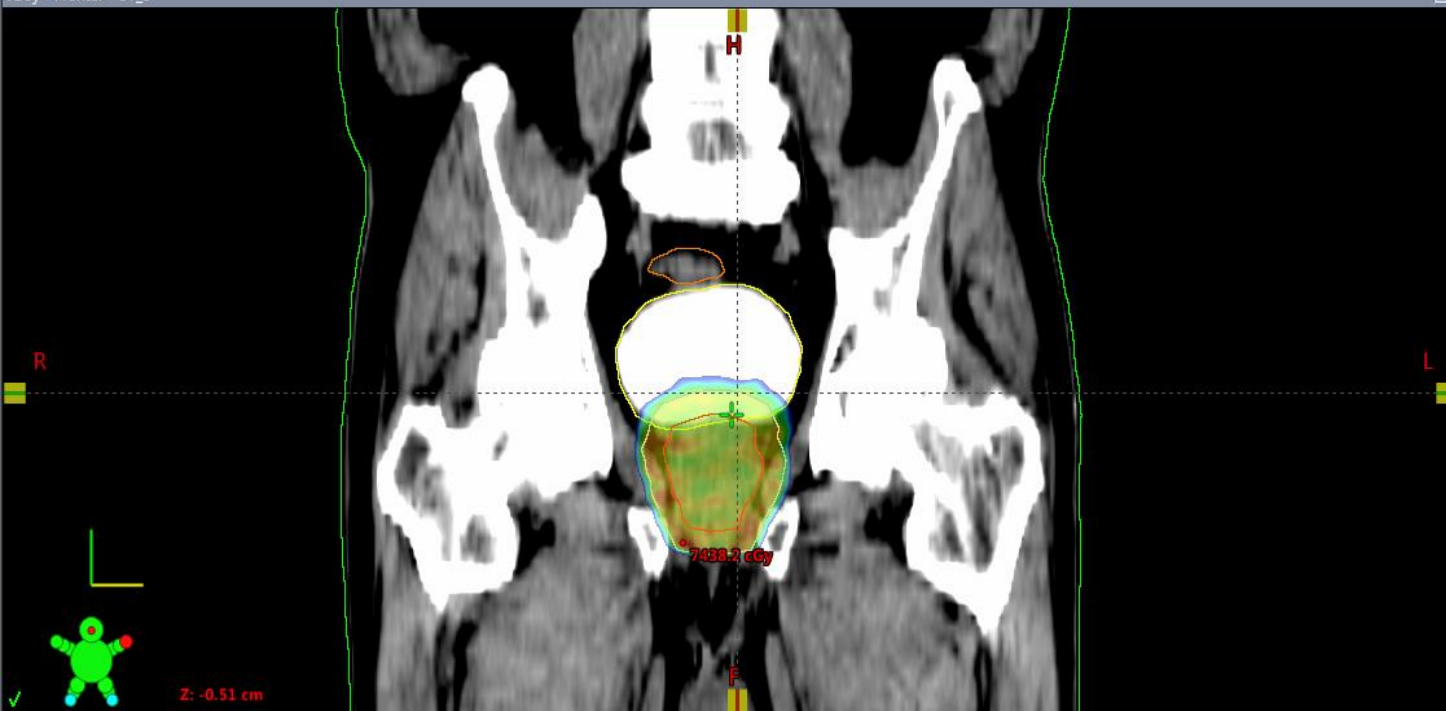
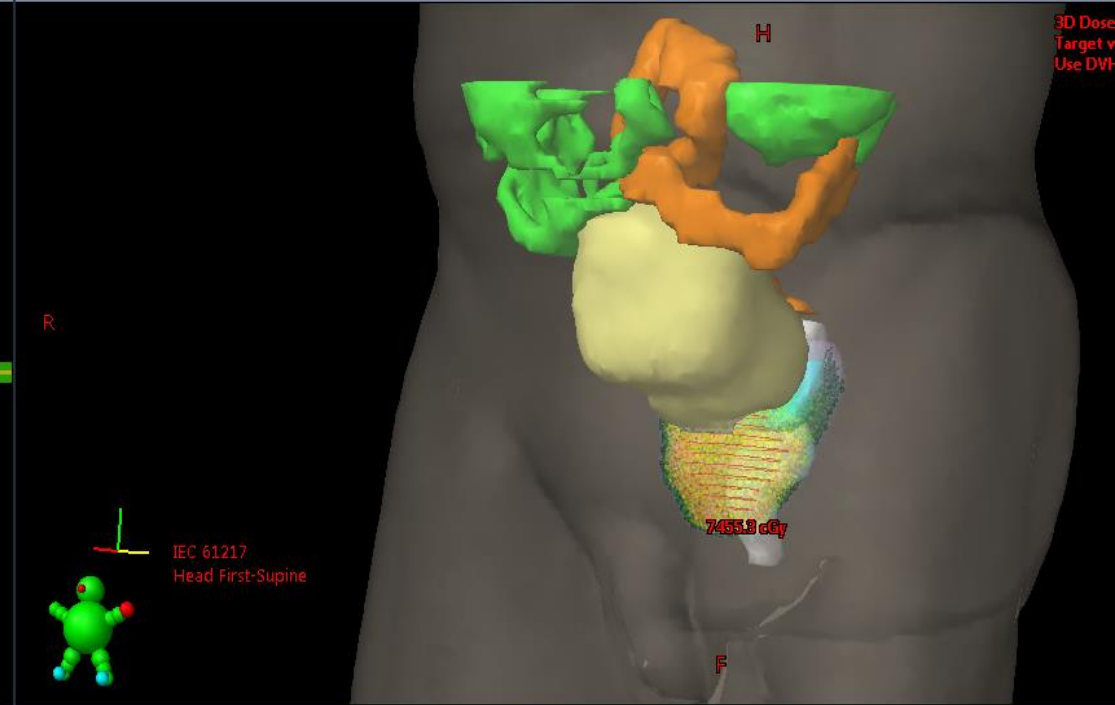
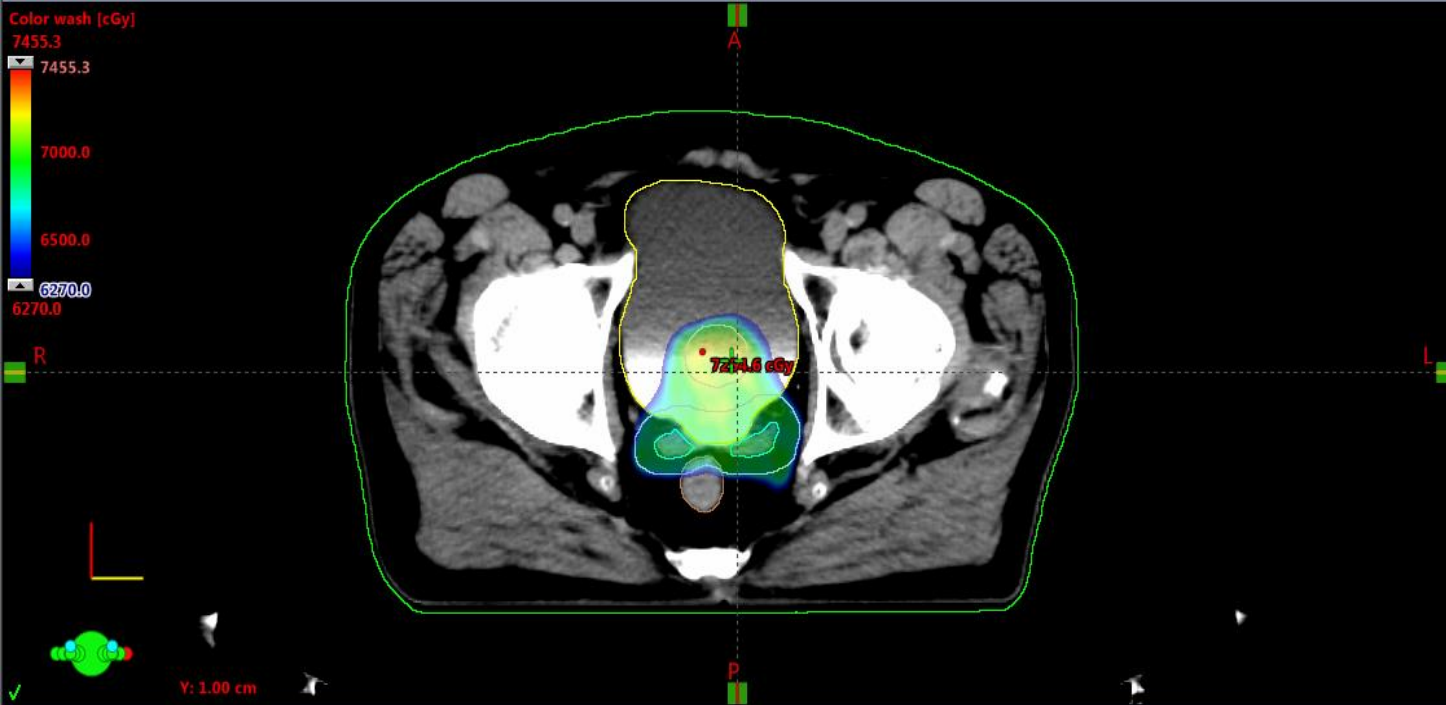
- Select Structures
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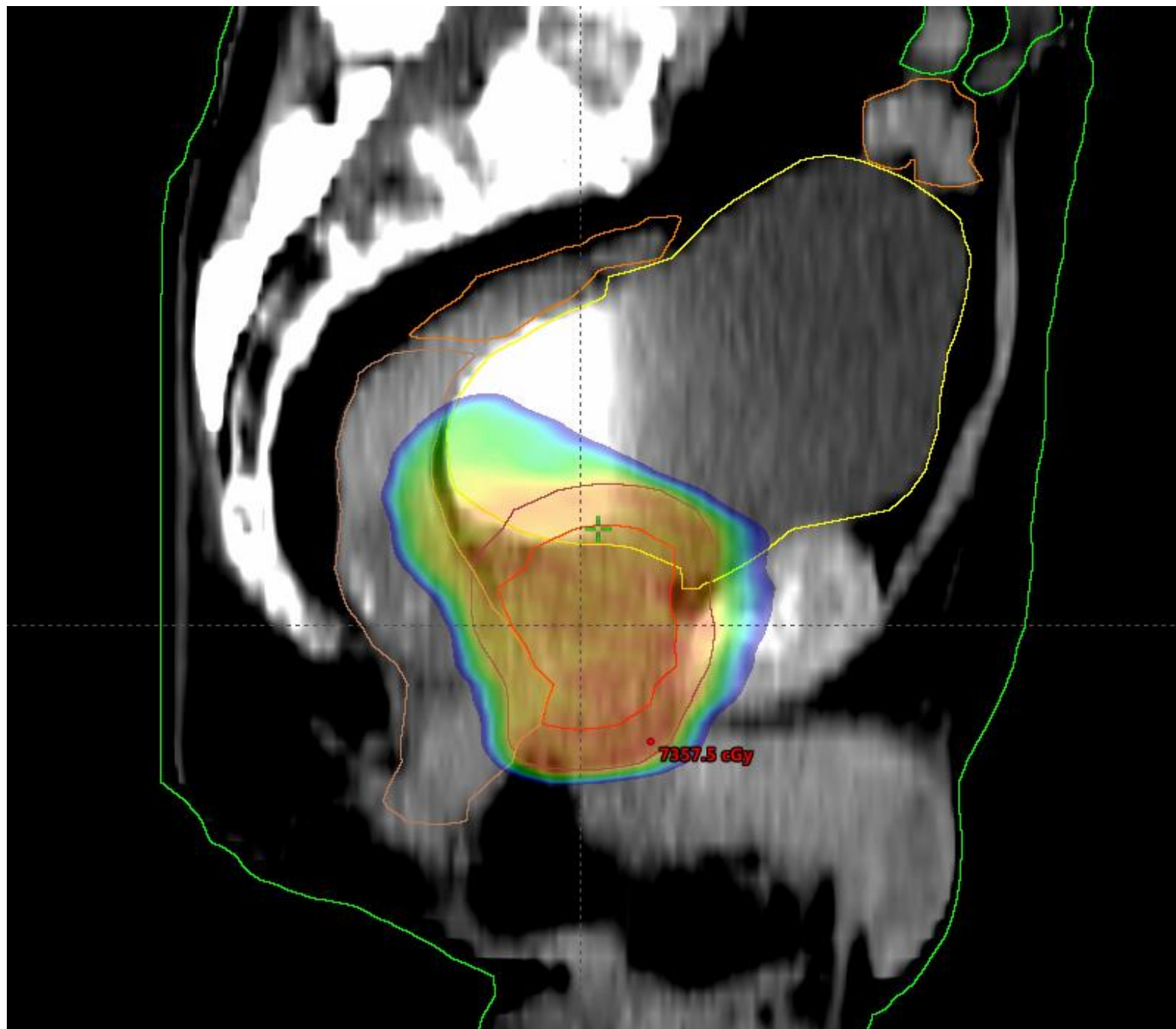
Frontal - CT\_1 - 4/6/2021 8:55 AM



Sagittal - CT\_1 - 4/6/2021 8:55 AM









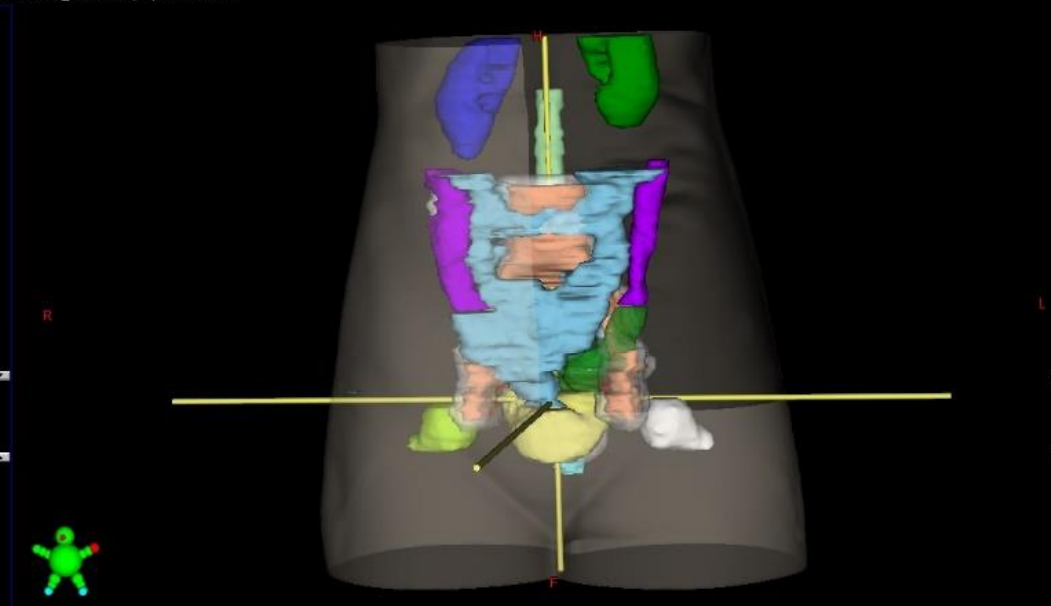


Fields	Dose	Reference Points	Dose Statistics	Plan Sum										
Show DVH	Structure	Approval Status	Plan	Course	Volume [cm <sup>3</sup> ]	Dose Cover.[%]	Sampling Cover.[%]	Min Dose [cGy]	Max Dose [cGy]	Mean Dose [cGy]				
<input checked="" type="checkbox"/>	BODY	Approved	72Gy	1	28289.4	100.0	100.0	100.1	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			

Transversal - CT\_VadLoc2 - 3/11/2019 9:16 AM



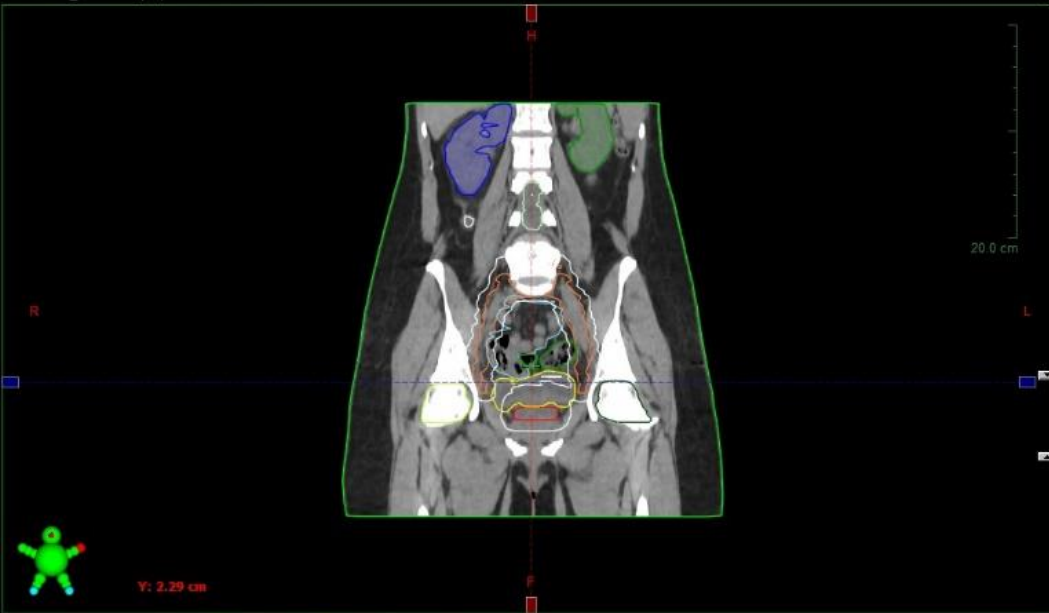
3D - CT\_VadLoc2 - 3/11/2019 9:16 AM



Drawing Tools

- Select Structures
- Draw Planar Contour
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- Eraser
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- Move Marker or Isocenter Marker
- Edit Reference Points
- Draw Reference Line
- Calypso Beacon Detection

Frontal - CT\_VadLoc2 - 3/11/2019 9:16 AM



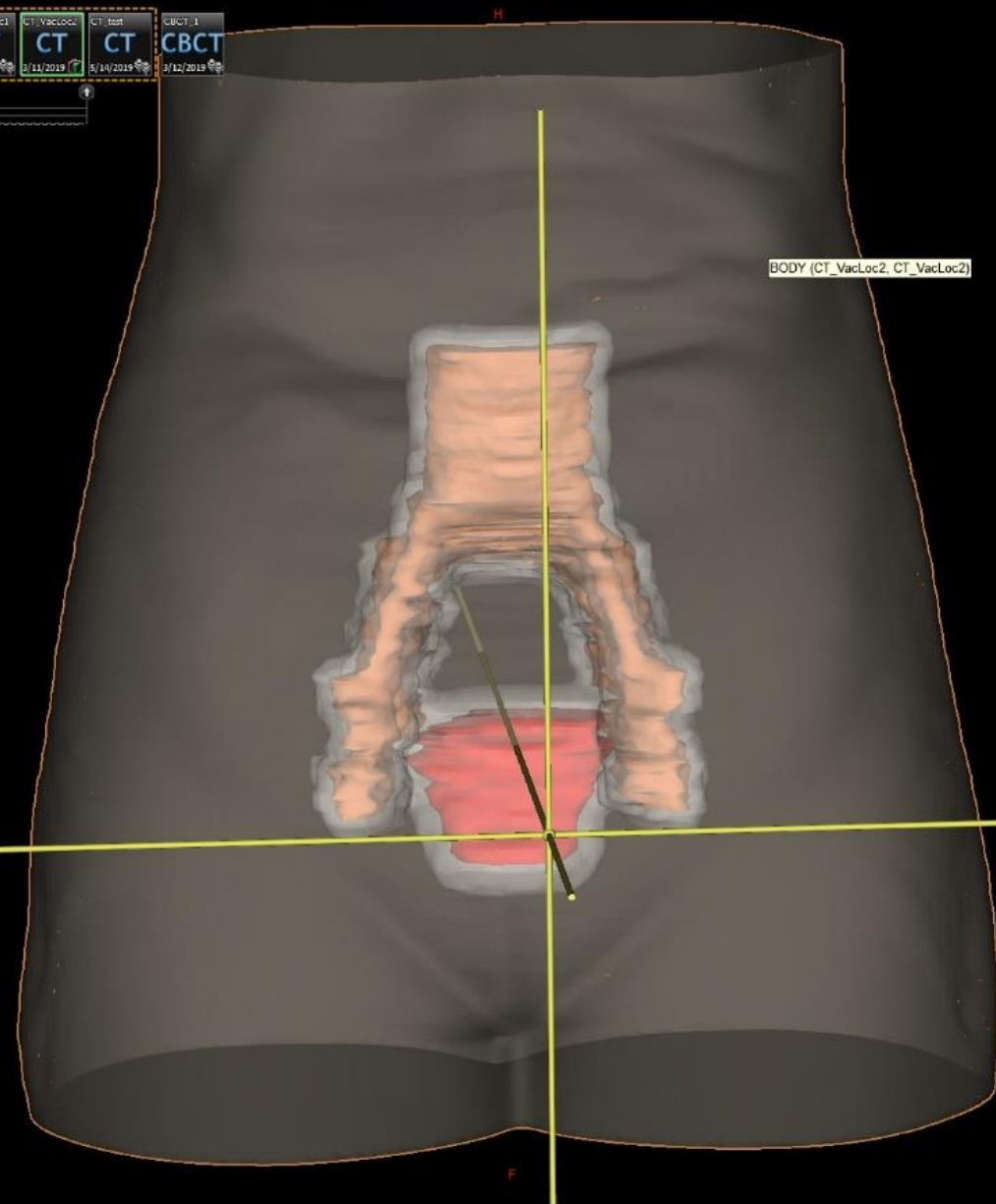
Sagittal - CT\_VadLoc2 - 3/11/2019 9:16 AM



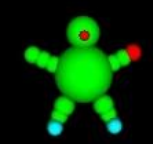
3D - CT\_VacLoc2 - 3/11/2019 9:16 AM



CT 1 2/25/2019	RA1 3/1/2019	CT 1 3/1/2019	CBCT 1 3/6/2019	CT_VacLoc1 3/6/2019	CT_VacLoc2 3/11/2019	CT Test 5/14/2019	CBCT 1 3/12/2019
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- Drawing Tools
- Select Structures
  - Draw Planar Contour
  - Brush
  - Eraser
  - Draw Geometrical Shape
  - Create or Edit Annotation
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  - Edit Reference Points
  - Draw Reference Line
  - Calypso Beacon Detection







TRIIVA190225

C  
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 1

- pi270
- pi270-DRR (Live)
- pi0
- pi0-DRR (Live)
- piCBCT
- piCBCT-DRR (Live)
- Field 2

Fields Dose Reference Points Dose Statistics

Structure	Approval Status	Plan	Course	Volume [cm <sup>3</sup> ]	Dose Cover [%]	Sampling Cover [%]	Min Dose [cGy]	Max Dose [cGy]	Mean Dose [cGy]	
CTV_Intermediate	Approved	PI1RA	C	257.2	100.0	100.0	3499.8	4723.9	4562.7	
CTV_High	Approved	PI1RA	C	57.0	100.0	100.0	4363.2	4731.2	4539.7	
Colon	Approved	PI1RA	C	69.0	100.0	100.0	211.2	4309.5	1195.4	
Bladder	Approved	PI1RA	C	81.7	100.0	100.0	3278.2	4724.5	4334.9	
BODY	Approved	PI1RA	C	17716.9	100.0	100.0	9.6	4808.1	1294.2	
FemoralJoint_L	Approved	PI1RA	C	42.5	100.0	100.0	759.6	4437.9	1966.9	
FemoralJoint_R	Approved	PI1RA	C	43.1	100.0	100.0	782.3	4402.4	2012.0	
Kidney_R	Approved	PI1RA	C	114.4	100.0	100.0	99.8	582.2	99.5	
Rectum	Approved	PI1RA	C	36.1	100.0	100.0	592.7	4641.3	3706.6	
SmallBowel	Approved	PI1RA	C	335.8	100.0	100.0	0.0	4703.3	3616.6	
SpinalCord	Approved	PI1RA	C	34.3	100.0	100.0	102.2	4168.7	2252.3	
sygma	Approved	PI1RA	C	117.9	100.0	100.0	1901.3	4677.4	4082.4	
Kidney_L	Approved	PI1RA	C	84.7	100.0	100.0	99.8	216.8	74.0	
seroma	Approved	PI1RA	C	37.1	100.0	100.0	242.5	707.5	425.2	
PTV def	Approved	PI1RA	C	880.1	100.0	100.0	1332.0	4808.1	4512.3	

Ready







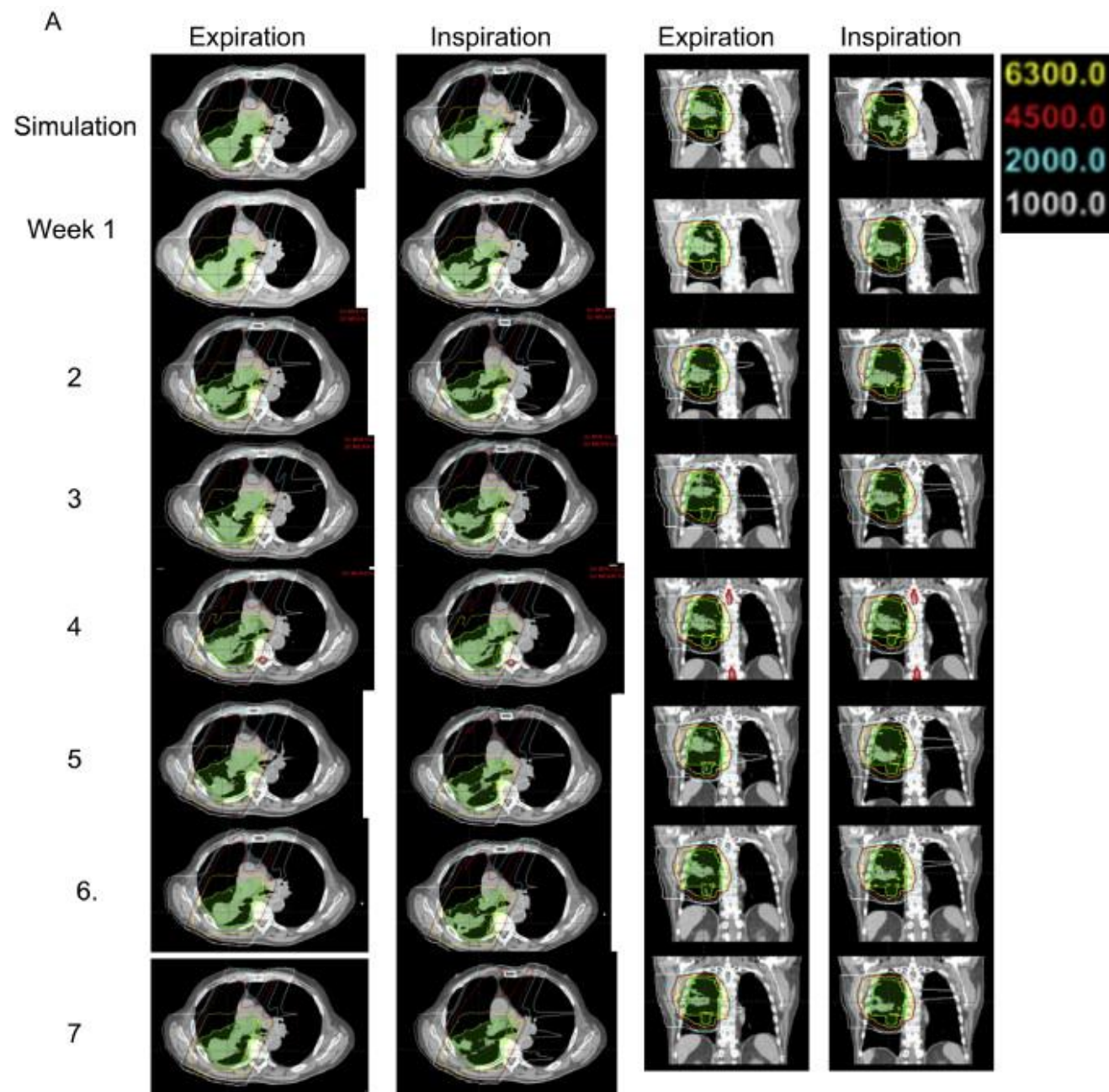
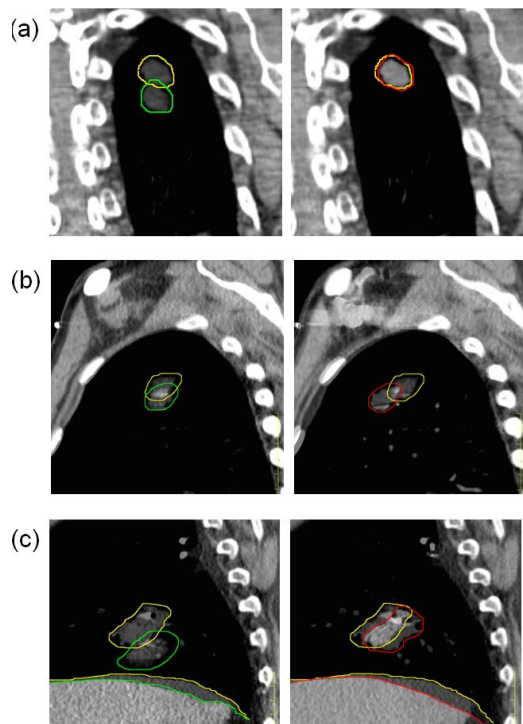
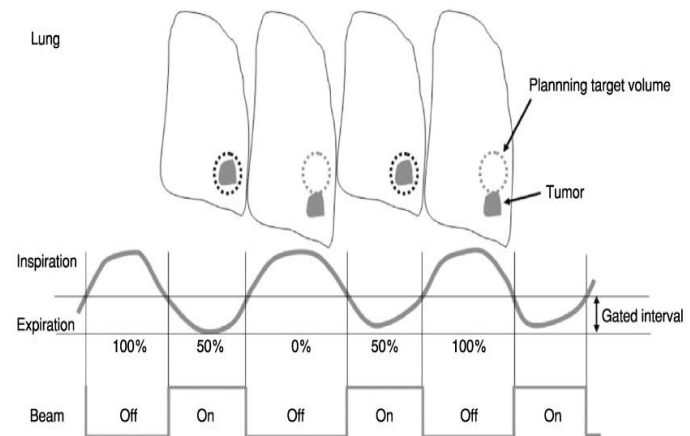


# IMAGE GUIDED RADIOTHERAPY - IGRT

- 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

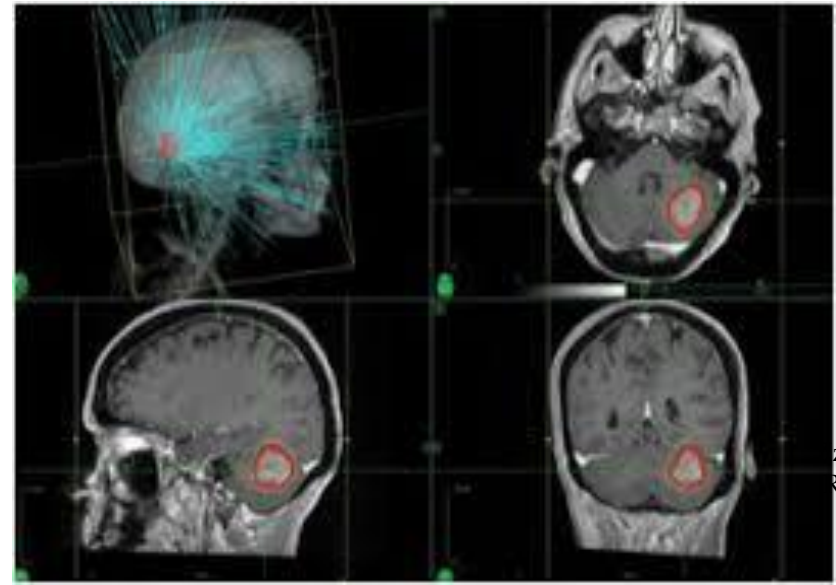
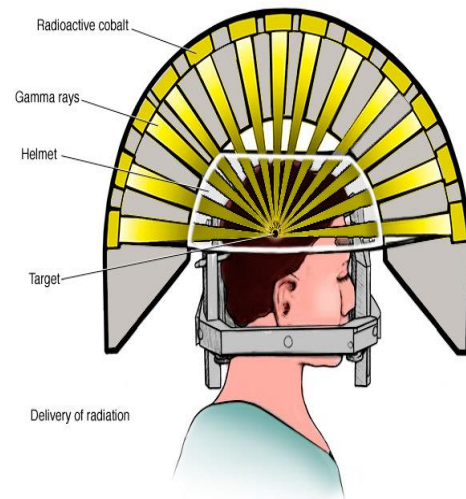
- improvement in the irradiation of tumor sites affected by respiratory motion such as lung, breast, and liver tumors
- decreased radiation related toxicity to organs at risk
  - *integration of respiratory movements into treatment planning,*
  - *forced shallow breathing with abdominal compression,*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





# Stereotactic radiotherapy

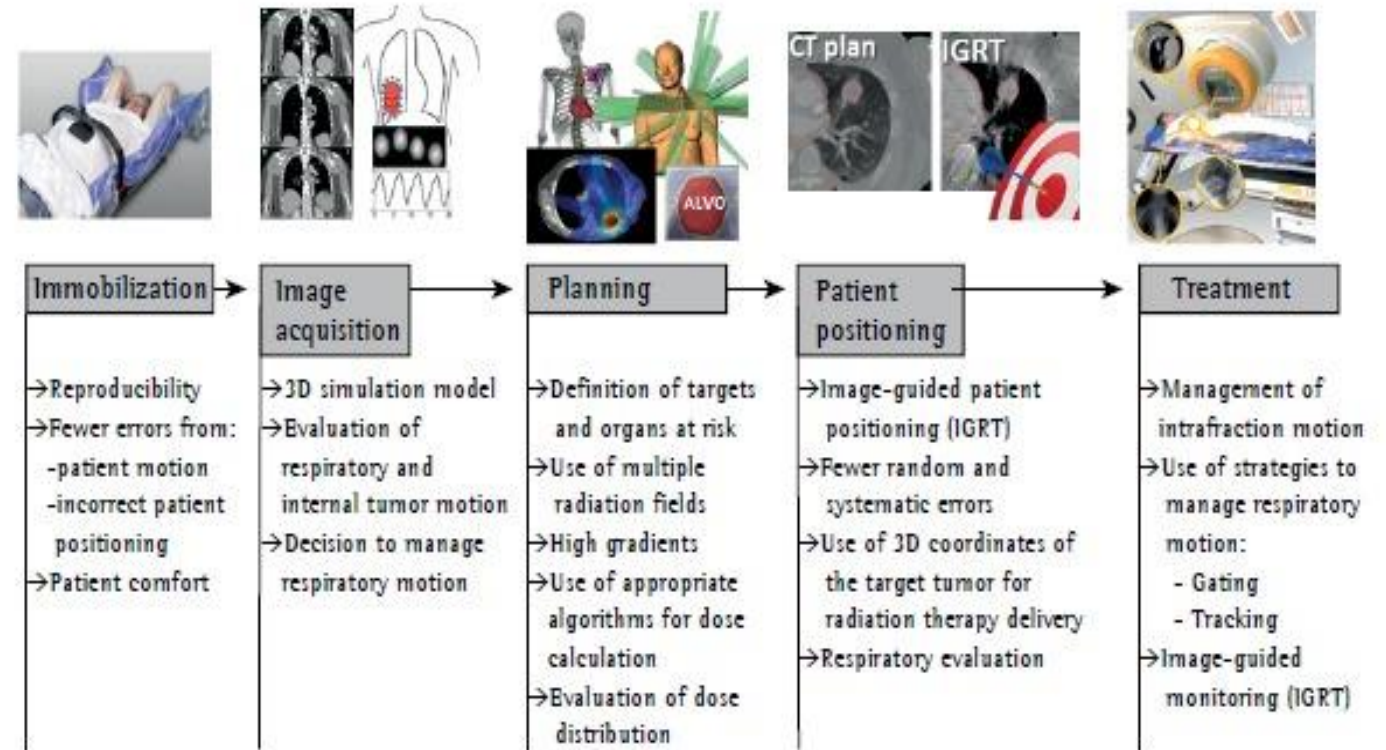
- high-precision radiotherapy technique that utilises high doses of radiation in a few or single fractions
- Stereotactic radiosurgery (SRS); Stereotactic body radiation therapy (SBRT) or stereotactic ablative radiotherapy (SABR)
- Numbers of indications



zvor: Mayo Clinic. SRS.  
Radiosurgery.gr

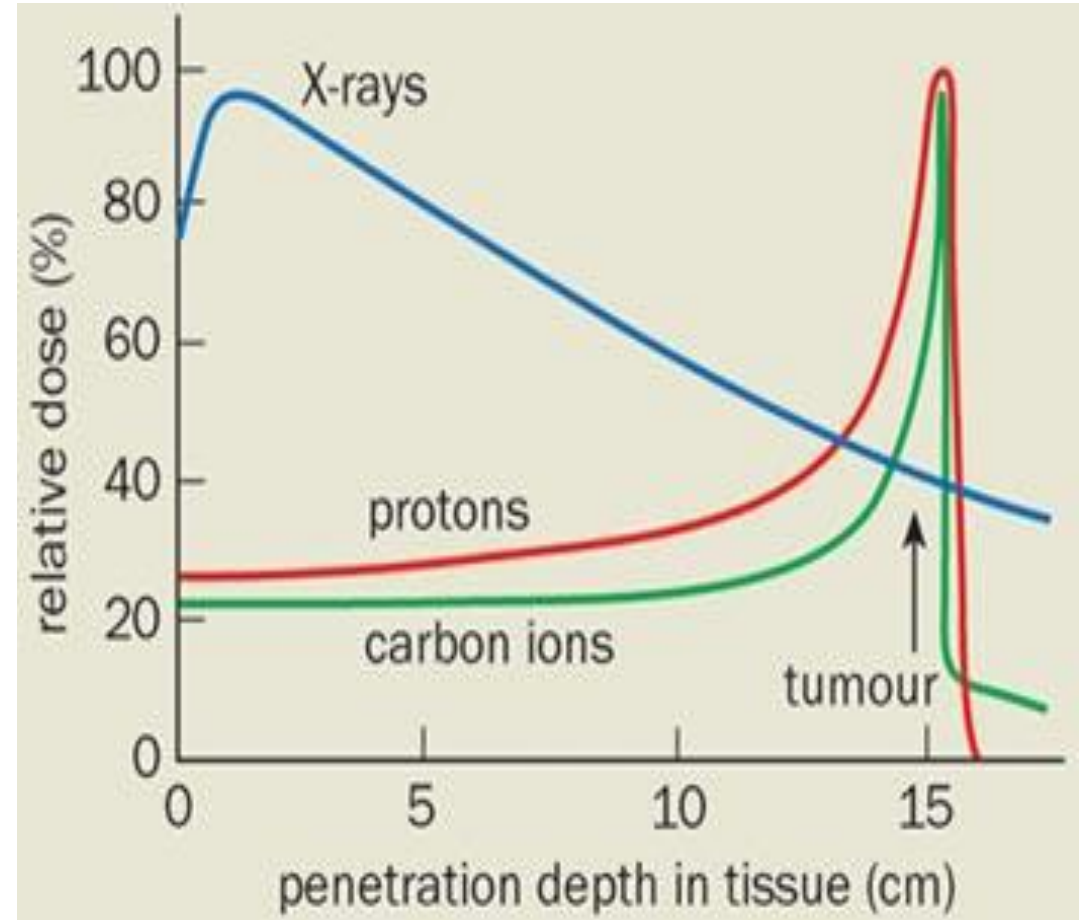
# *Stereotactic Body Radiotherapy, SBRT*

- 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.

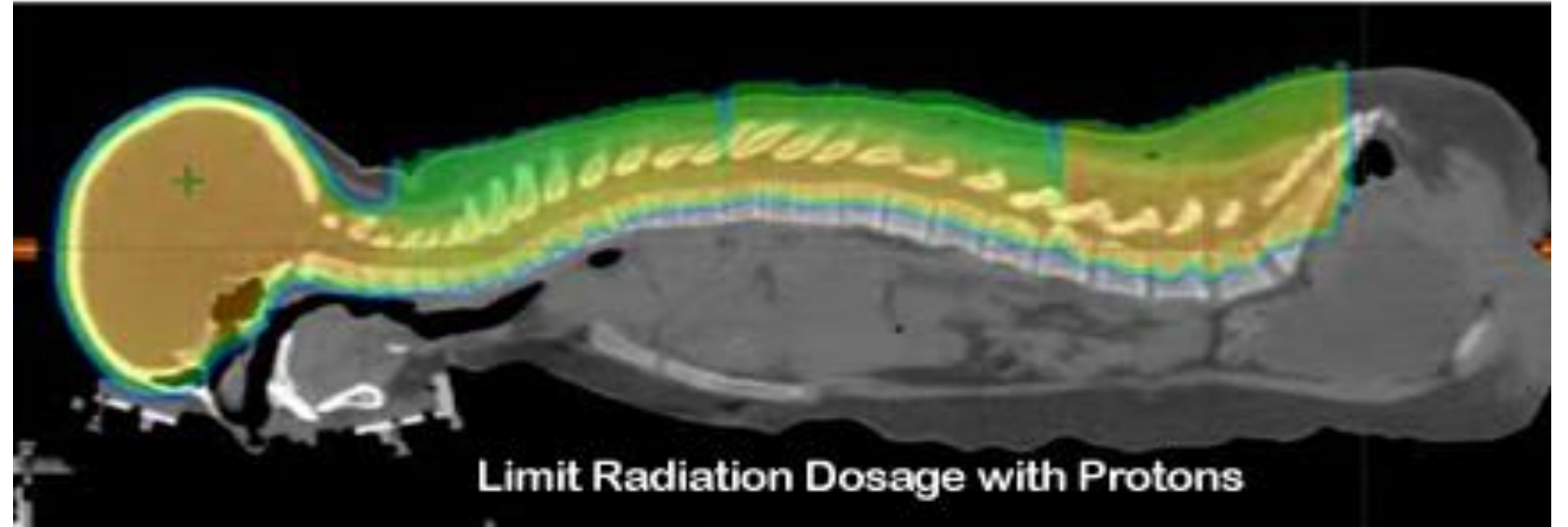
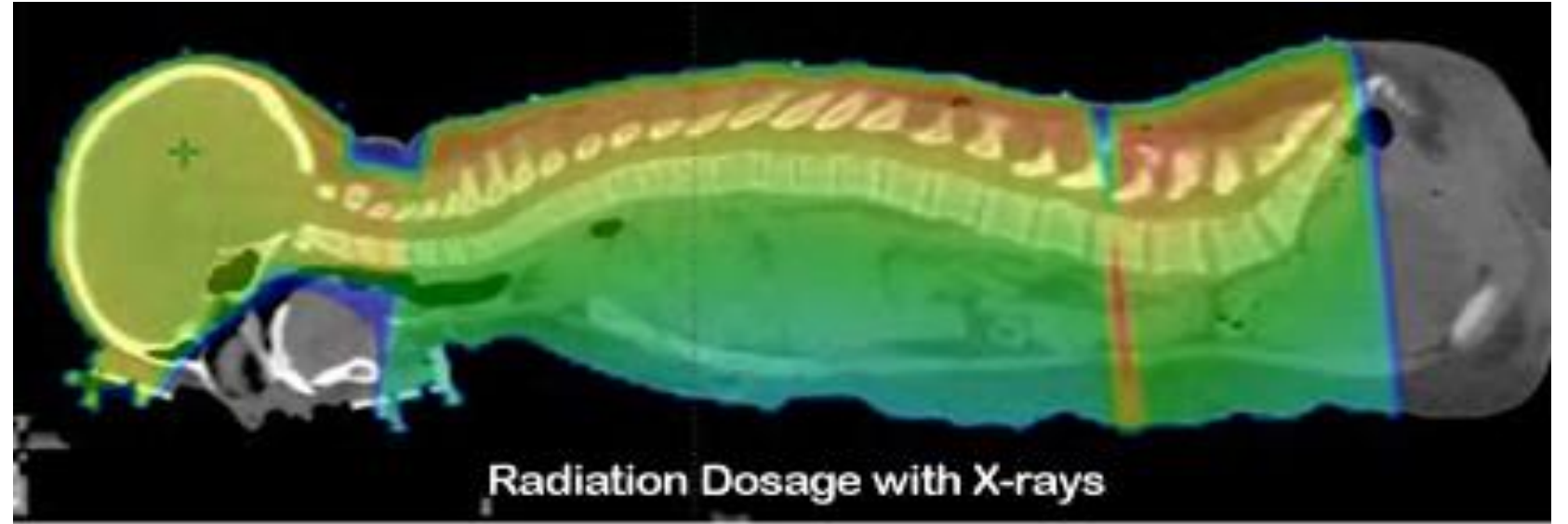


# Proton Therapy

- 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.

