



**UNIVERSITY OF KRAGUJEVAC,  
FACULTY OF MEDICAL SCIENCES**



- 1. Radiotherapy of gynecological malignancies**
- 2. Special considerations for radiotherapy – vulnerable population –  
radiotherapy in pediatric population and elderly**

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**Kragujevac, 2024**

# **Radiotherapy of gynecological malignancies**

- EBRT (2D-conventional, 3D-CRT, IMRT, VMAT)
- 2D or 3D brachytherapy (intracavitary and/or interstitial)

# General aspects of the application of radiotherapy in gynecological malignancies

**RADICAL, POSTOPERATIVE, PREOPERATIVE, PALLIATIVE**

<b>EBRT</b> <ul style="list-style-type: none"><li>• Large volume - small pelvis (includes Ln, tumor)</li><li>• Extended – includes the paraortal Ln</li><li>• LINAC</li><li>• 3D-CRT, IMRT, VMAT</li><li>• SBRT (relapse)</li></ul>	<b>Brachytherapy (IC, IS, IC+IS)</b> <ul style="list-style-type: none"><li>• High doses in a small volume</li><li>• Inverse square law</li><li>• Big dose drop</li><li>• Placement of radioactive sources</li></ul>
<b>Combination EBRT+BT+CHT</b>	

# Radiotherapy plan

It depends on prognostic factors:

- Tumor related factors
- Anatomical extension of the disease (stage, parametrial infiltration, tumor volume, lymphatic involvement)
- Histological characteristics
- Patient-related factors (age, PS, anemia)
- Treatment-related factors (tumor size, surgical margin, total radiation time and dose)



STATEMENT

Open Access

# MRI in female pelvis: an ESUR/ESR survey



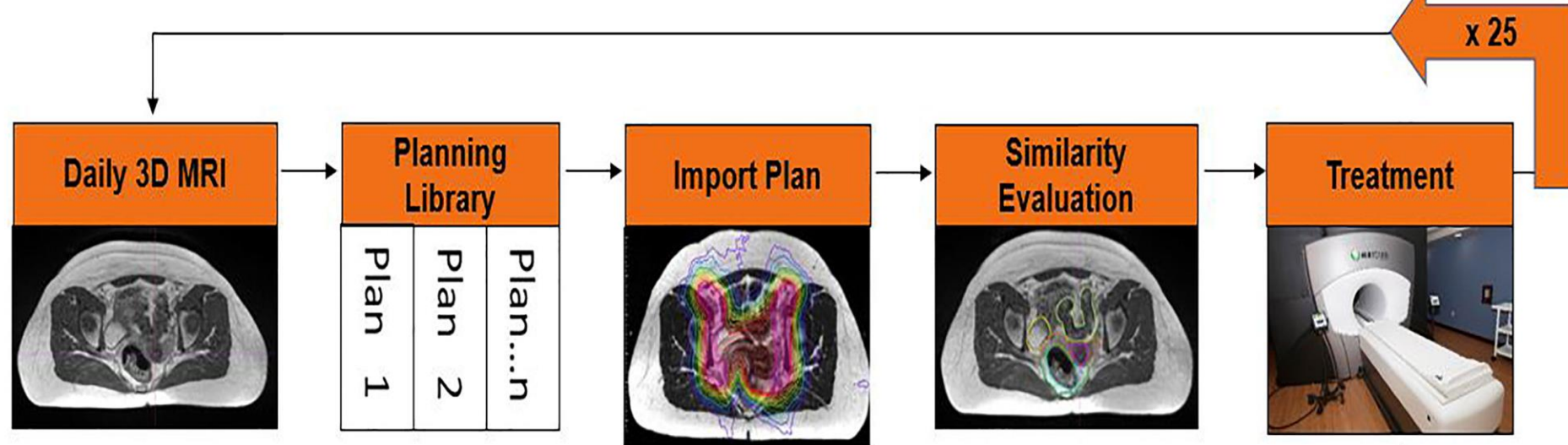
Stephanie Nougaret<sup>1,2\*</sup>, Yulia Lakhman<sup>3</sup>, Sophie Gourgou<sup>4</sup>, Rahel Kubik-Huch<sup>5</sup>, Lorenzo Derchi<sup>6</sup>, Evis Sala<sup>7</sup>, Rosemarie Forstner<sup>8</sup> and the European Society of Radiology (ESR) and the European Society of Urogenital Radiology (ESUR)

## Abstract

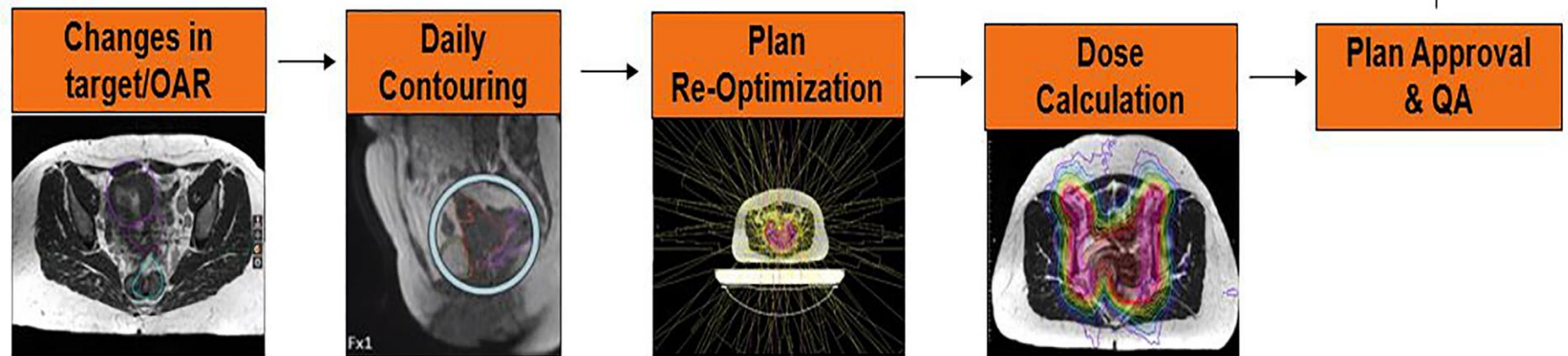
**Objectives:** While magnetic resonance imaging (MRI) is considered the gold standard for the imaging of female pelvis, there is an ongoing debate about the most appropriate indications and optimal imaging protocols. The European Society of Urogenital Radiology (ESUR) launched a survey to evaluate the current utilization of female pelvic MRI in clinical practice.

**Methods:** The ESUR female imaging subgroup developed an online survey that was then approved by the ESR board and circulated among the ESR members. The questions in the survey encompassed training and experience, indications for imaging and MR imaging protocols, reporting styles and preferences. The results of the survey were tabulated, and subgroups were compared using  $\chi^2$  test.

**Results:** A total of 5900 ESR members with an interest in both MRI and female pelvic imaging were invited to participate; 840 (14.23%) members completed the survey. Approximately 50% of respondents were academic radiologists (50.6%) and nearly 60% women (59.69%). One third of the respondents were subspecialized in Gynecological imaging. Nearly half of the survey participants were aware of the presence of ESUR guidelines for imaging of the female pelvis (47.1%). The adoption of the ESUR recommendations was higher among subspecialized and/or academic and/or senior and/or European radiologists compared to all others. The current ESUR recommendations about female pelvic MRI protocols were generally followed. However wide variations in practice were identified with respect to the use of contrast media.



## Online Adaptive Workflow



# Vulvar cancer radiotherapy

## **Radical RT +/- CHT potentiation by cisplatin**

Contraindications for surgery

Inoperable tumors, T3-T4, N3

Standard:

Regime I (technique I) : 45Gy, 2Gy per fraction + Boost (e-) 10-20Gy, 2Gy per fraction

Regime II (technique II): 55-65Gy, 1.8-2 Gy per fraction (max. dose: vulva up to 65Gy, inguinum up to 55Gy possibility of split course)

Non-standard: TD 45Gy (AP- PA fields + electrons on inguinum) + boost(s) (inguinum+ perineum) 10-20Gy, 1.8-2Gy

## **Postoperative RT** (start within 6 weeks of surgery)

High-risk group, positive resection margins or insufficient margins (optimal 1-2cm), positive inguinal nodes

Regimen I: 45-50Gy,(e) direct fields, 1.8-2 Gy per fraction

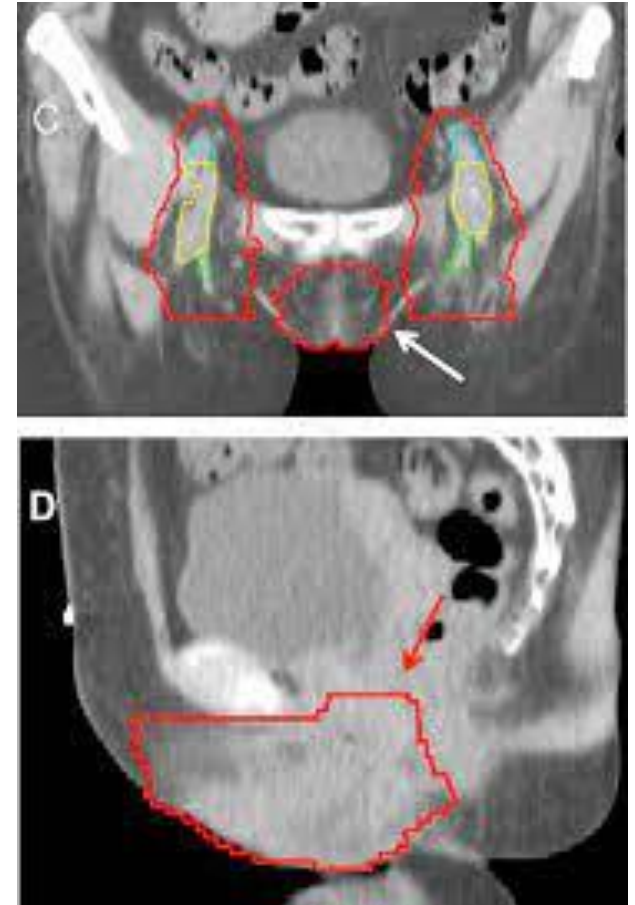
Regime II: 45Gy, (photons), pelvic fields, 2Gy per fraction, all fields + Boost ( e) 10-20Gy, 2Gy per fraction

# **Carcinoma of the vulva FIGO classification (2021)**

# **Lymphatic drainage of the vulva**

# Consider adjuvant radiotherapy

- R1
- Insufficiently wide margins (less than 8mm)
- Metastases in >1 Ln
- Extranodal extension
- Deep stromal infiltration over 5mm
- LVI+



# Preoperative radiotherapy of vulvar cancer

- +/- CHT potentiation
- Locally advanced tumors
- Tumors located right next to the urethra or anus

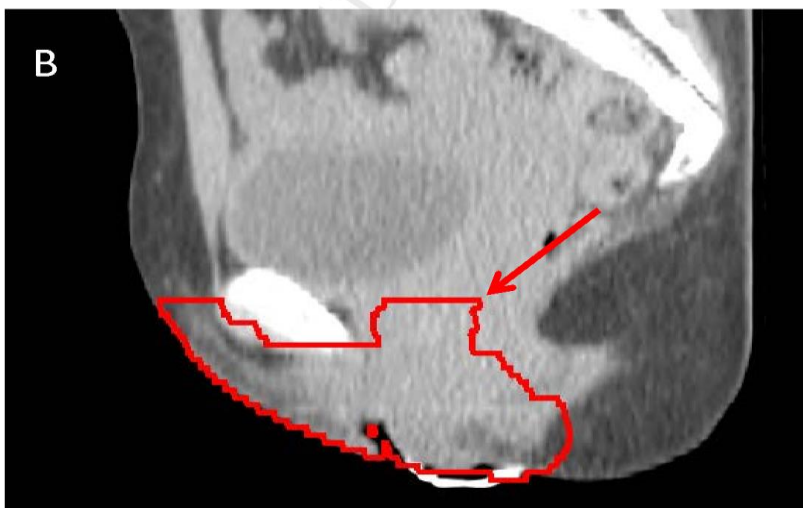
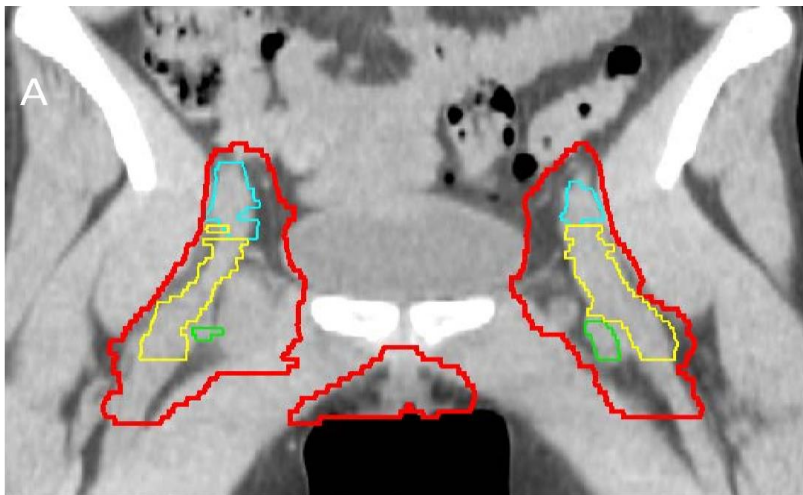


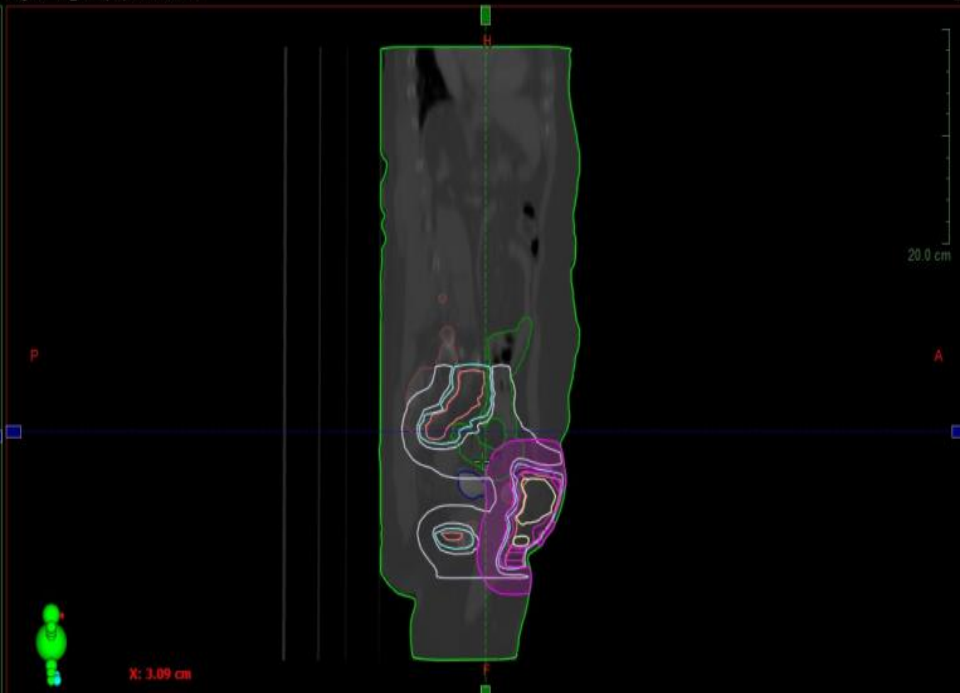
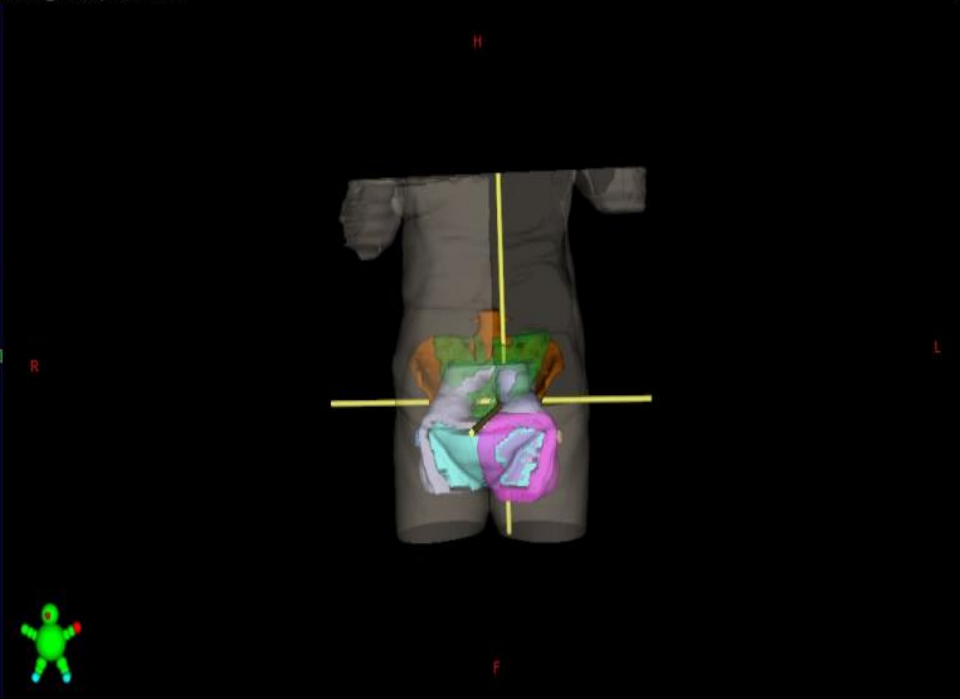
Beriwal S, et al. Preoperative intensity-modulated radiotherapy and chemotherapy for locally advanced vulvar carcinoma. *Gynecol Oncol* 2008;109(2):291-5.

# **Interstitial brachytherapy of the vulva**

- Monotherapy for tumors up to 2 cm in size (T1N0M0)
- EBRT+IS BT (to the tumor bed)
- Palliative or salvage brachytherapy (local recurrence)









vmat - Treatment Approved - Frontal - CT.1

vmat - Treatment Approved - Sagittal - CT.1



Color wash [%]

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3D Dose MAX: 108.2 %

3D MAX for PTV: 108.2 %

3D MIN for PTV: 60.0 %

3D MEAN for PTV: 100.7 %

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PLO

PLO

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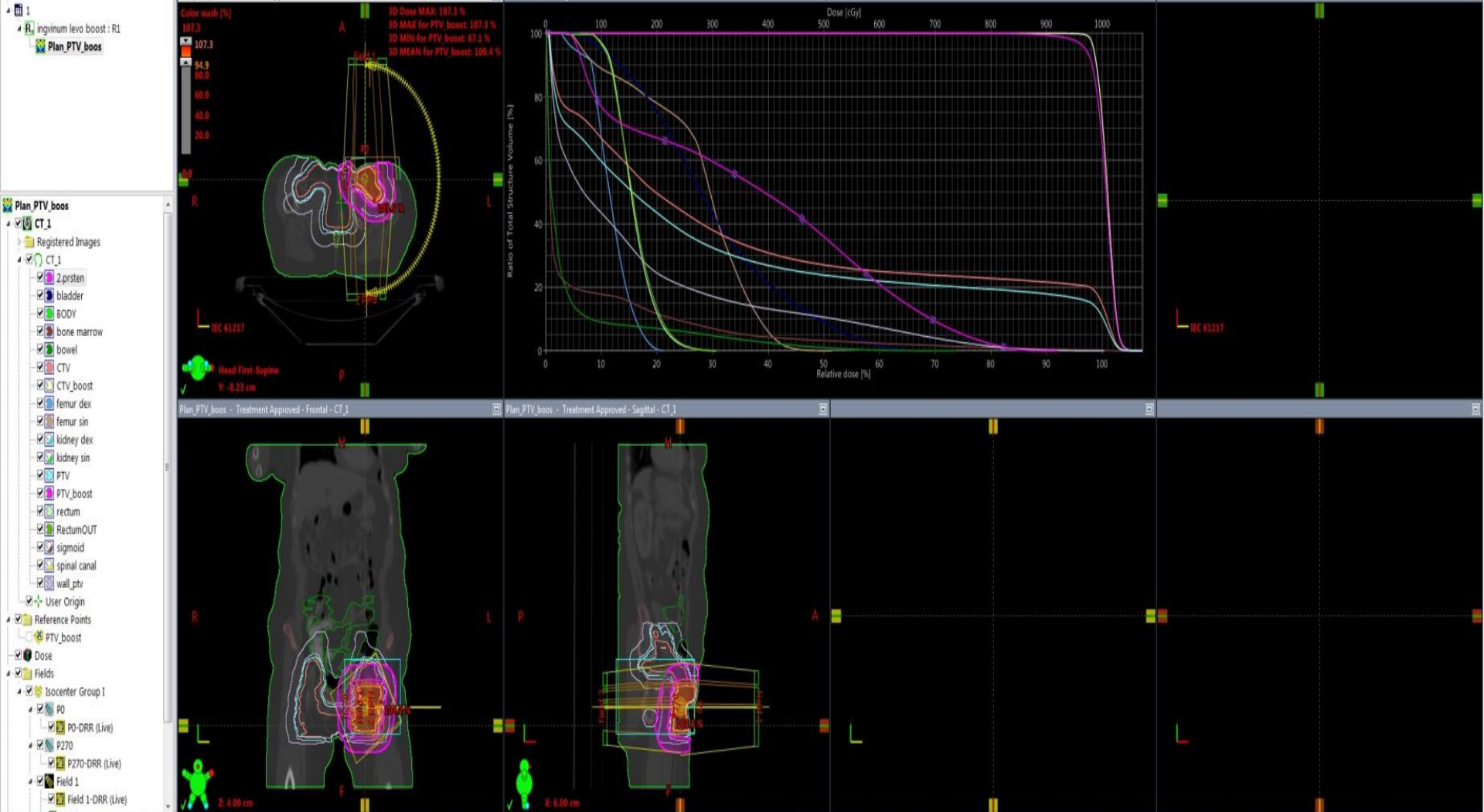
Head First Supine

Y: 0.27 cm



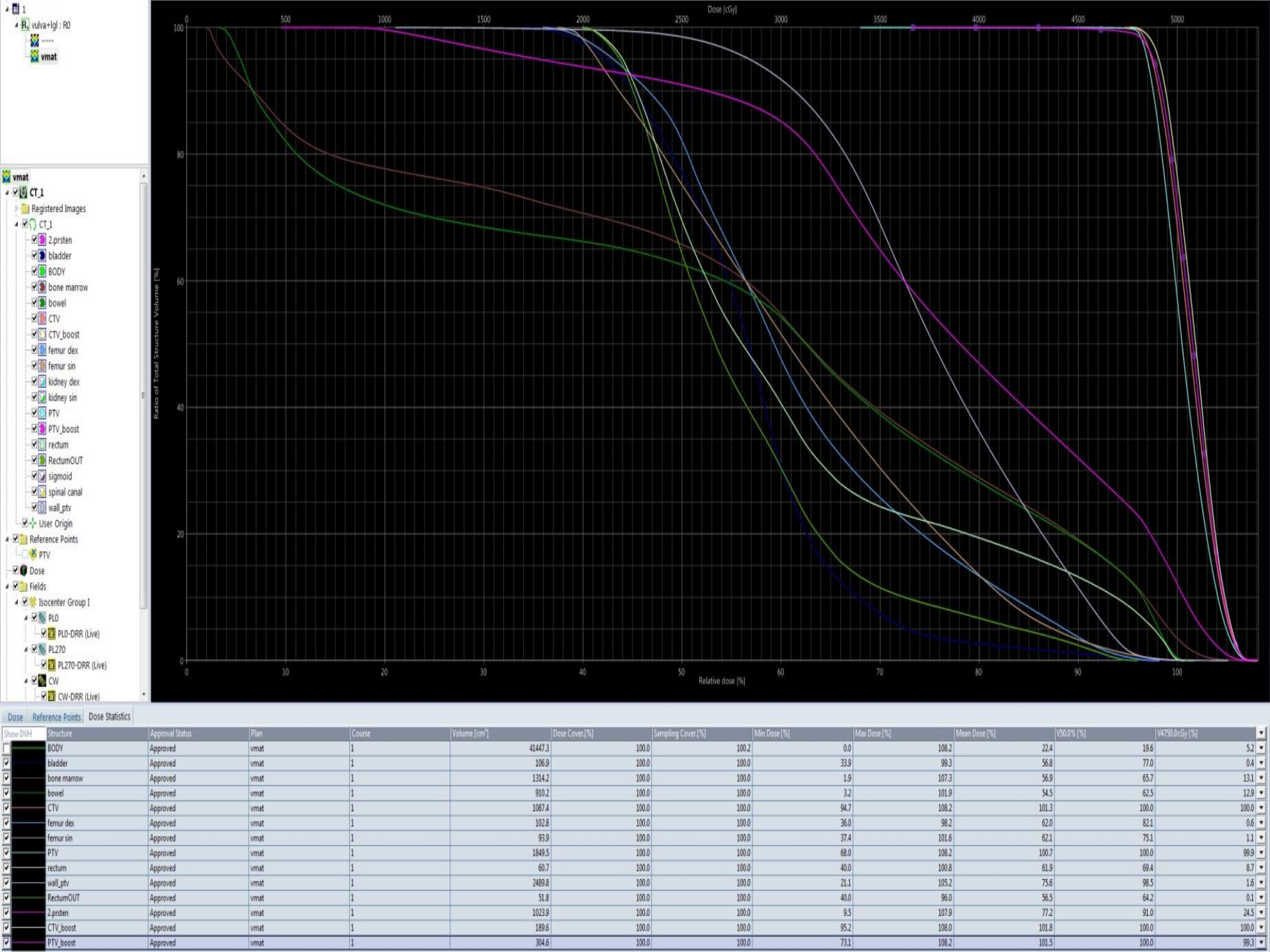






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<input checked="" type="checkbox"/>	femur sin	Approved	Plan_PTV_boos	1	93.9	100.0	100.0	100.0	4.1	51.5	27.3	0.0
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<input checked="" type="checkbox"/>	PTV_boost	Approved	Plan_PTV_boos	1	304.6	100.0	100.0	100.0	67.1	107.3	100.4	100.0







# FIGO classification for tumors of the vagina

TABLE 1 Comparison of staging systems for vaginal cancer

AJCC Stage	Stage grouping (TNM)	FIGO Stage	Stage description
IA	T1a N0 M0	I	The cancer is only in the vagina and is no larger than 2.0 cm (4/5 inch) (T1a) It has not spread to nearby lymph nodes (N0) or to distant sites (M0)
IB	T1b N0 M0	I	The cancer is only in the vagina and is larger than 2.0 cm (4/5 inch) (T1b) It has not spread to nearby lymph nodes (N0) or to distant sites (M0)
IIA	T2a N0 M0	II	The cancer has grown through the vaginal wall, but not as far as the pelvic wall and is no larger than 2.0 cm (4/5 inch) (T2a) It has not spread to nearby lymph nodes (N0) or to distant sites (M0)
IIB	T2b N0 M0	II	The cancer has grown through the vaginal wall, but not as far as the pelvic wall and is larger than 2.0 cm (4/5 inch) (T2b) It has not spread to nearby lymph nodes (N0) or to distant sites (M0)
III	T1 to T3 N1 M0	III	The cancer can be any size and might be growing into the pelvic wall, and/or growing into the lower one-third of the vagina and/or has blocked the flow of urine (hydronephrosis), which is causing kidney problems (T1 to T3). It has also spread to nearby lymph nodes in the pelvis or groin (inguinal) area (N1) but not distant sites (M0)
	OR T3 N0 M0	III	The cancer is growing into the pelvic wall, and/or growing into the lower one-third of the vagina and/or has blocked the flow of urine (hydronephrosis), which is causing kidney problems (T3) It has not spread to nearby lymph nodes (N0) or to distant sites (M0)
IVA	T4 Any N M0	IVA	The cancer is growing into the bladder or rectum or is growing out of the pelvis (T4) It might or might not have spread to lymph nodes in the pelvis or groin (inguinal area) (Any N). It has not spread to distant sites (M0)
IVB	Any T Any N M1	IVB	The cancer has spread to distant organs such as the lungs or bones (M1). It can be any size and might or might not have grown into nearby structures or organs (Any T) It might or might not have spread to nearby lymph nodes (Any N)

# Vaginal cancer radiotherapy

## **Radical radiotherapy or postoperative +/- CHT potentiation**

St. I (infiltration of more than 0.5 cm of mucosa) - IVA

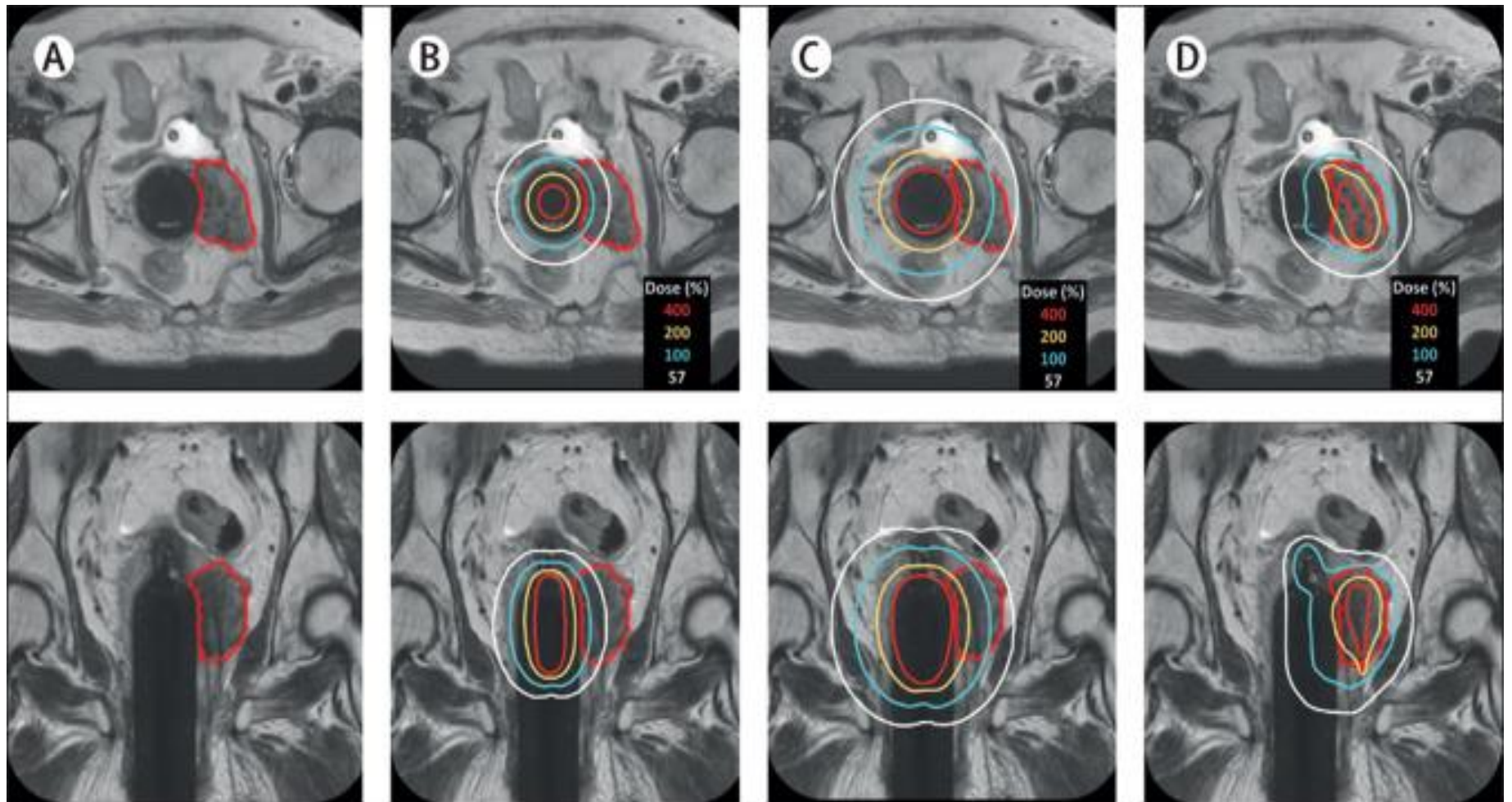
Adjuvant RT after tumor excision (abnormal)

Standard: 46Gy, 1.8-2Gy per day, 5 days/week

- Boost on enlarged inguinal lymphatic(s): up to max 15-20Gy in 7-10 fractions
- Brachytherapy: after 5-10 fractions of EBRT

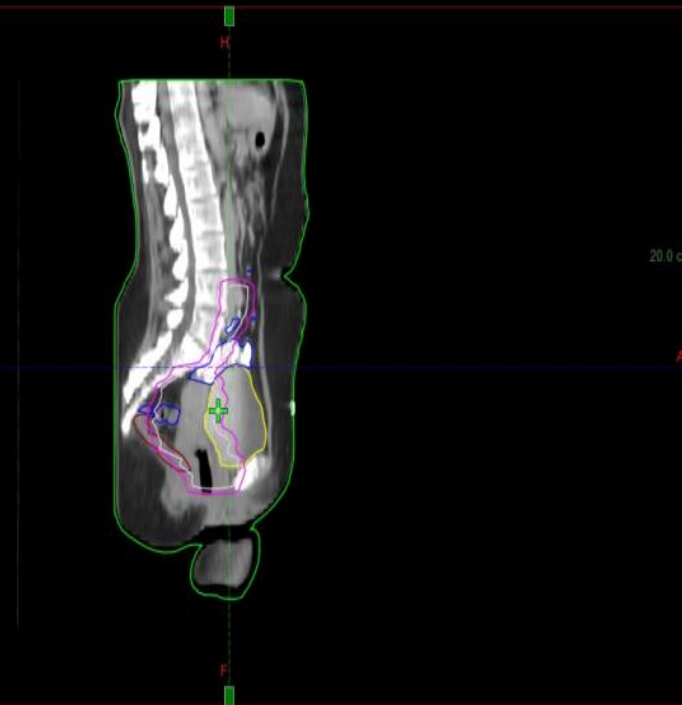
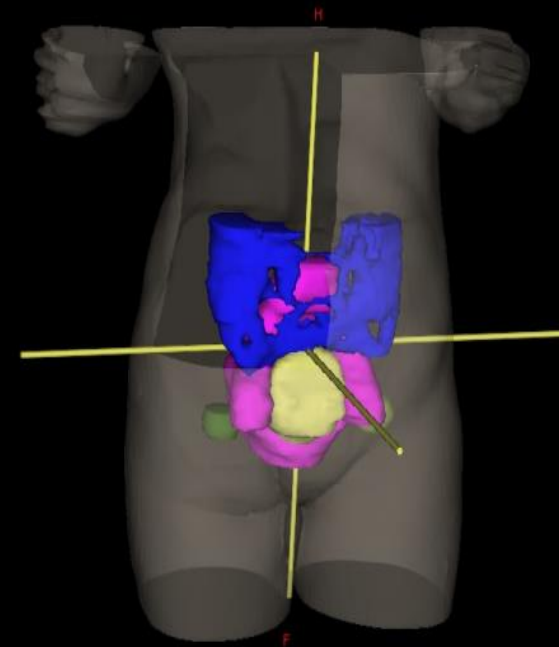
Non-standard:

- hemostatic application (before EBRT)
- in advanced tumors with altered topographic relationships after 30Gy EBRT or after completed EBRT

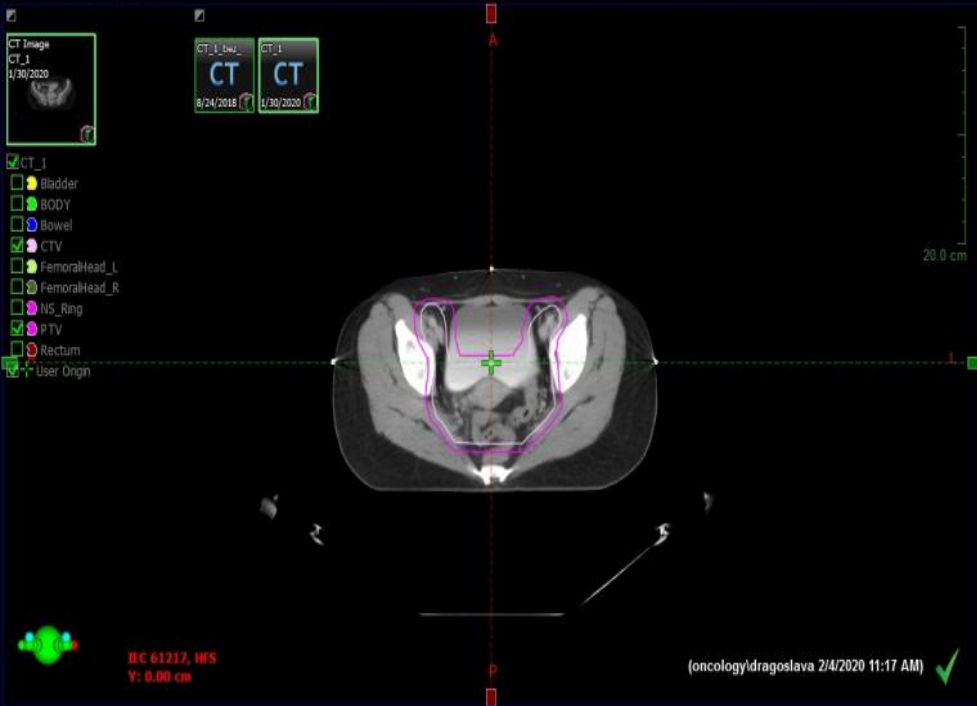


Westerveld H, et al. Definitive radiotherapy with image-guided adaptive brachytherapy for primary vaginal cancer. *Lancet Oncol* 2020;21(3):e157-67.

# Miami Applicators



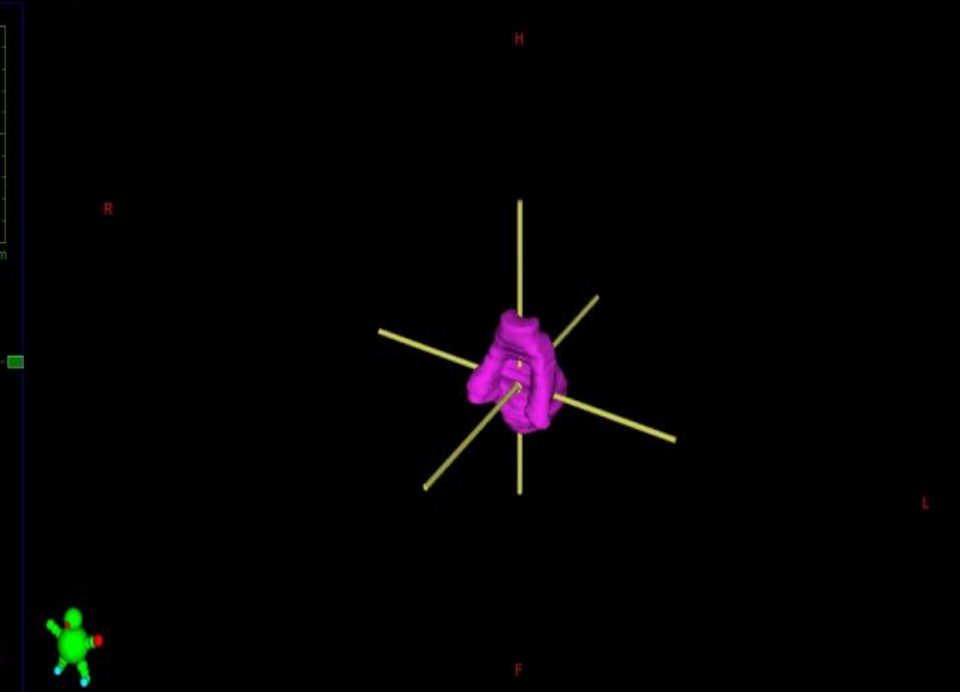
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Frontal - CT\_1 - 1/30/2020 10:07 AM



3D - CT\_1 - 1/30/2020 10:07 AM

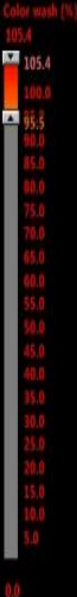


Sagittal - CT\_1 - 1/30/2020 10:07 AM

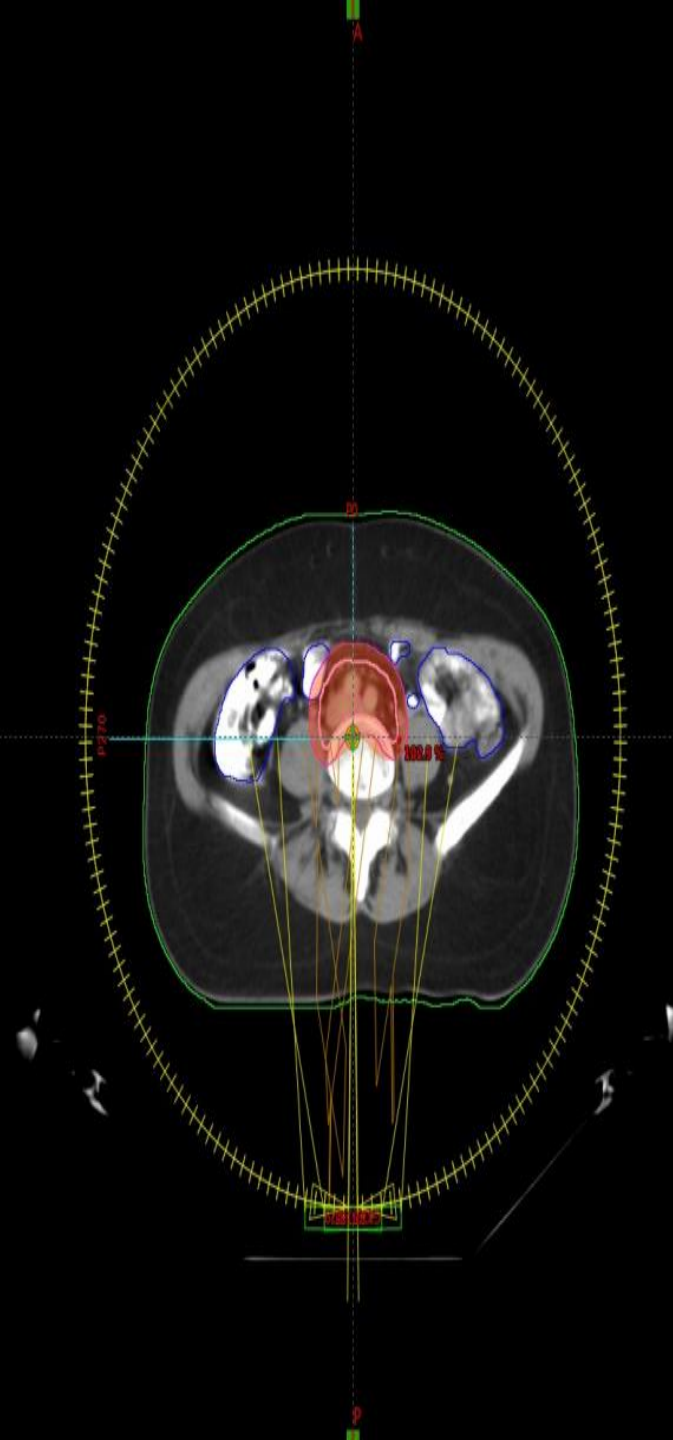








1D Dose MAX: 105.4 %  
1D MAX for PTV: 101.4 %  
1D MIN for PTV: 89.9 %  
1D MEAN for PTV: 99.8 %



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Head First-Supine  
V: 10.50 cm





## Staging of Cervical Cancer

**TABLE I: International Federation of Gynecology and Obstetrics Staging of Cervical Cancer 2018**

Stage	Description
I	Tumor confined to the uterus
IA	Invasive carcinoma (diagnosed microscopically) with maximum depth of invasion < 5 mm
IA1	Measured stromal invasion < 3 mm in depth
IA2	Measured stromal invasion $\geq$ 3 mm and < 5 mm in depth
IB	Invasive carcinoma with depth of invasion $\geq$ 5 mm, limited to cervix uteri
IB1	Invasive carcinoma with $\geq$ 5 mm stromal invasion and < 2 cm in greatest dimension
IB2	Invasive carcinoma $\geq$ 2 cm and < 4 cm in greatest dimension
IB3	Invasive carcinoma $\geq$ 4 cm in greatest dimension
II	Tumor invades outside uterus but not pelvic sidewall
IIA	Without parametrial invasion
IIA1	Invasive carcinoma $\leq$ 4 cm in greatest dimension
IIA2	Invasive carcinoma $\geq$ 4 cm in greatest dimension
IIB	With parametrial invasion
III	Tumor invades pelvic sidewall and lower third of vagina, affecting kidney
IIIA	Tumor invades lower third of vagina without pelvic sidewall involvement
IIIB	Tumor invades pelvic sidewall or causes hydronephrosis
IIIC	Tumor involves pelvic or paraaortic lymph nodes, or both, irrespective of tumor size and extent
IIIC1	Pelvic lymph node metastasis only
IIIC2	Para-aortic lymph node metastasis
IV	Bladder or rectal invasion
IVA	Invades mucosa of bladder or rectum
IVB	Spread to distant organs

# Cervical cancer postoperative radiotherapy

- 4-6 weeks after surgery
- Medium risk group: after adequate surgery, without parametrium infiltration, negative resection margins, negative lymph nodes:

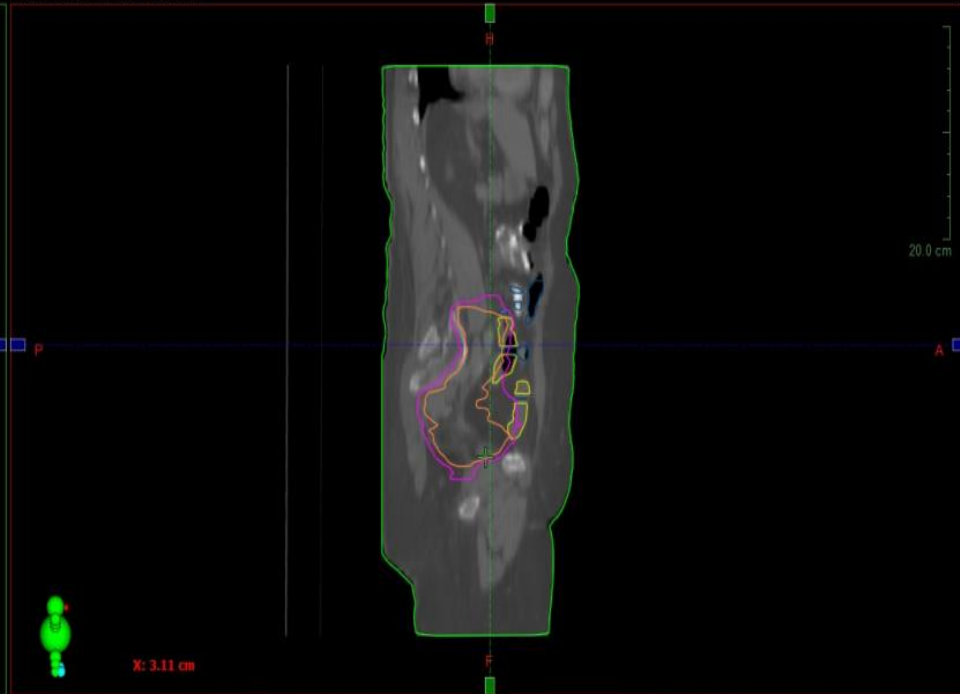
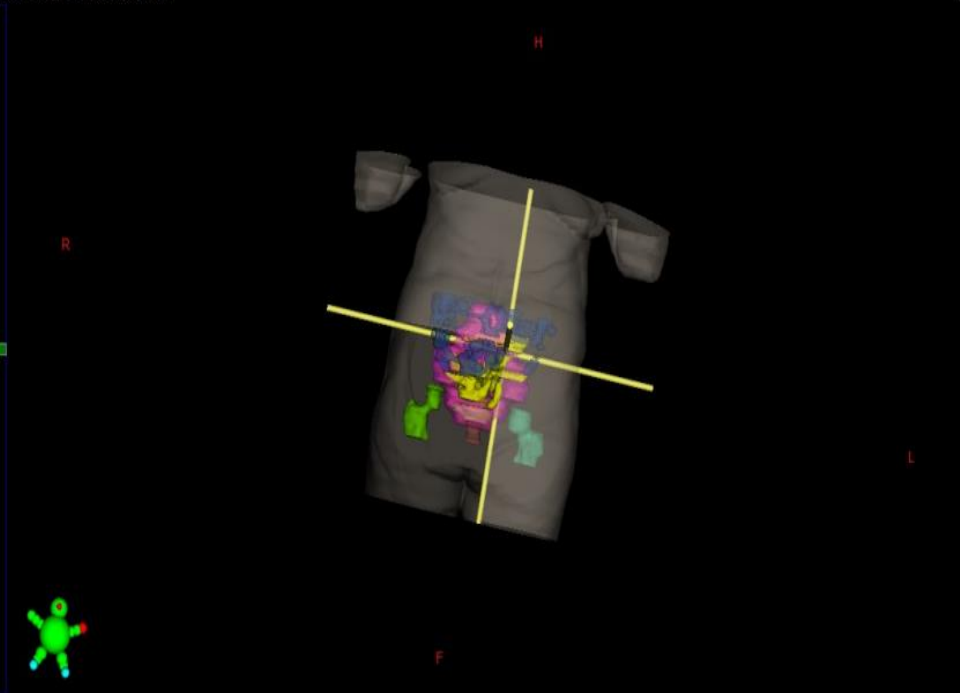
GOG score > 120

- LVI+, deep stromal invasion, regardless of tumor size
  - LVI+, invasion of the middle third of the stroma, tumor > 2cm
  - LVI+, superficial stromal invasion, tumor > 5cm
  - LVI-, medium or deep invasion, tumor > 4cm
- 
- High-risk group +/-CHT potentiation: positive resection margins, positive parameters, positive lymph nodes, inadequate type of surgery

# Cervical cancer postoperative radiotherapy

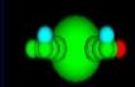
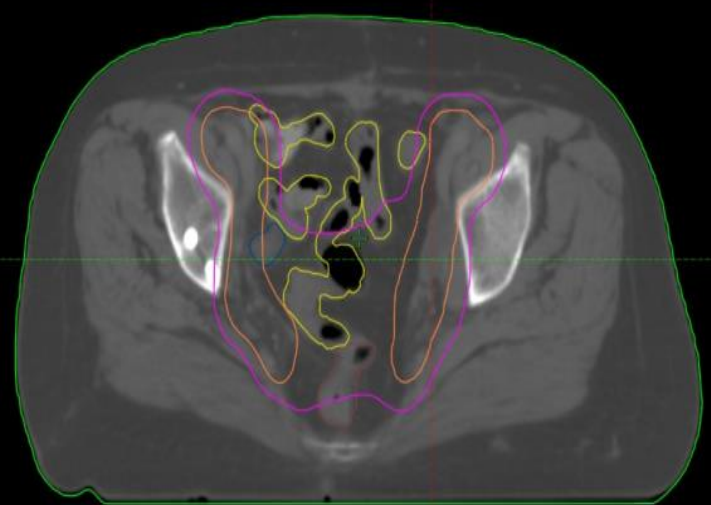
Pelvis:

- medium risk group 40-45Gy, 1.8-2 Gy per fraction
- high-risk group 45-50Gy, 1.8-2 Gy per fraction
- Para-aortic region: 45Gy, 5 days/week, 1.8 Gy per fraction
- Palliative doses: 30 Gy in 10 fractions, 20 Gy in 5 fractions
- Nodal boost:
- 55Gy pelvic lymphatics SIB – within 25 fractions / sequential up to a total dose with a daily dose of 1.8Gy
- 57.5Gy – 60Gy paraaortic lymphatics SIB - within 25 fractions / sequential up to a total dose with a daily dose of 1.8Gy





- ☒ CT\_1
- ☒ Bladder
- ☒ BODY
- ☒ Bowel
- ☒ CTV\_Intermediate
- ☒ Femur\_L
- ☒ Femur\_R
- ☒ HS\_Ring
- ☒ ITV\_Intermediate
- ☒ rectum
- ☒ Sigma
- ☒ User Origin

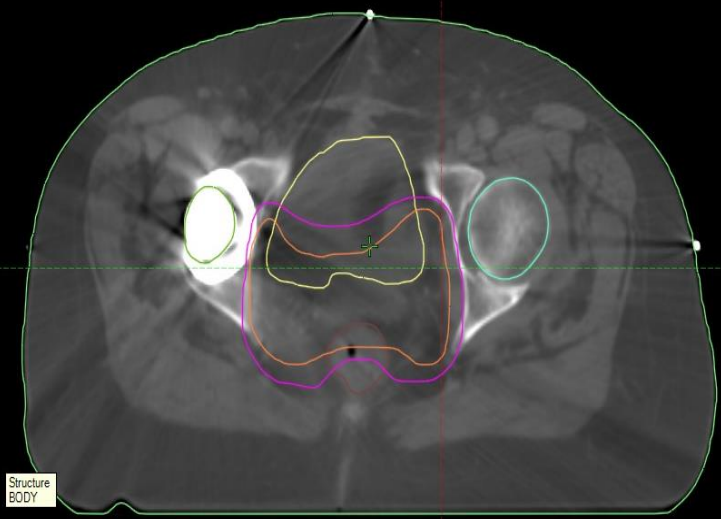


HC 61217, HFS  
Y: 3.50 cm



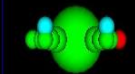


- ☒ CT\_1
- ☒ Bladder
- ☒ BODY
- ☒ Bowel
- ☒ CTV\_Intermediate
- ☒ Femur\_L
- ☒ Femur\_R
- ☐ HFS\_Ring
- ☒ PTV\_Intermediate
- ☒ rectum
- ☒ Sygma
- ☒ User Origin



Structure  
BODY

20.0 cm



REC 61217, HFS  
Y: 0.50 cm

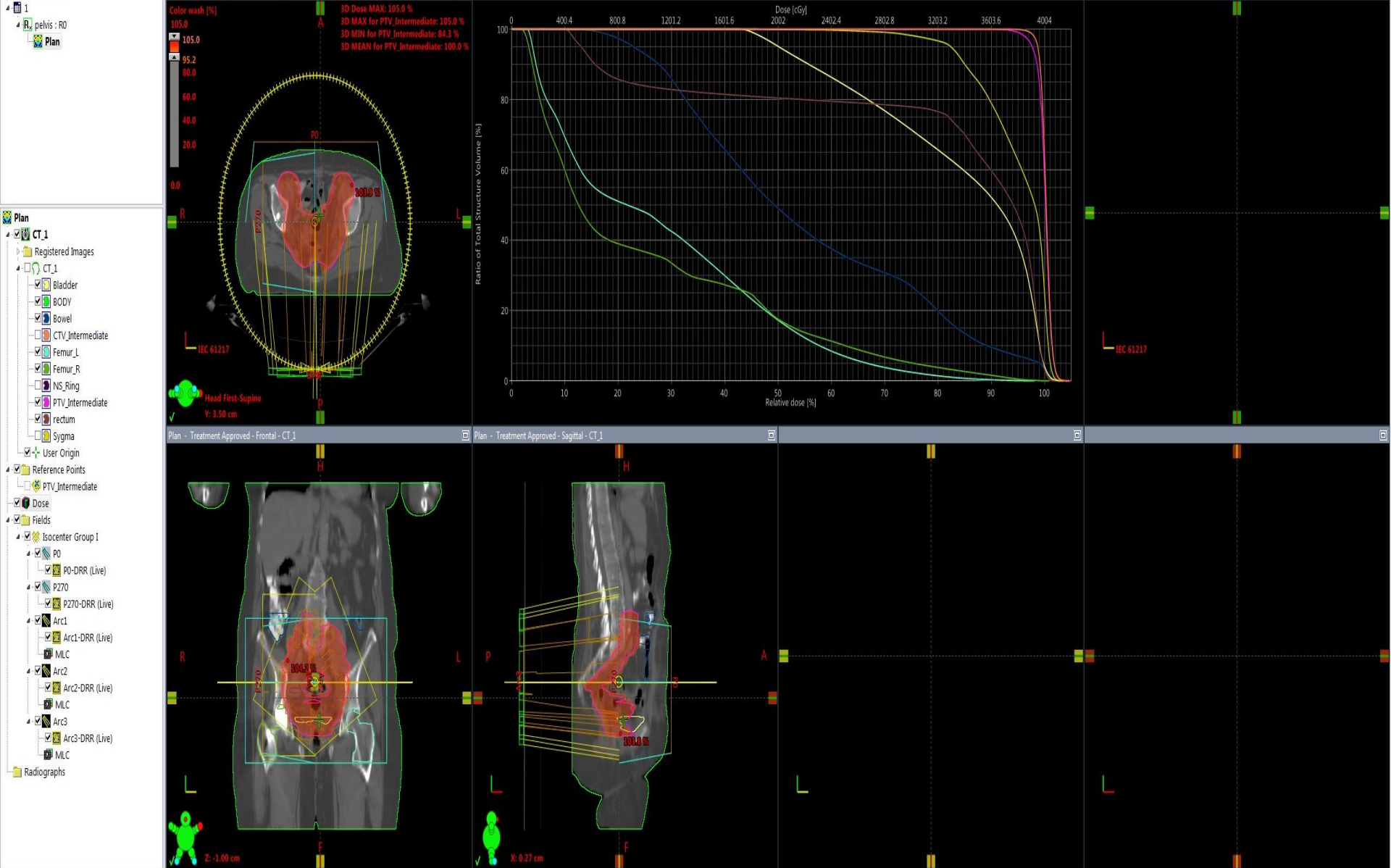
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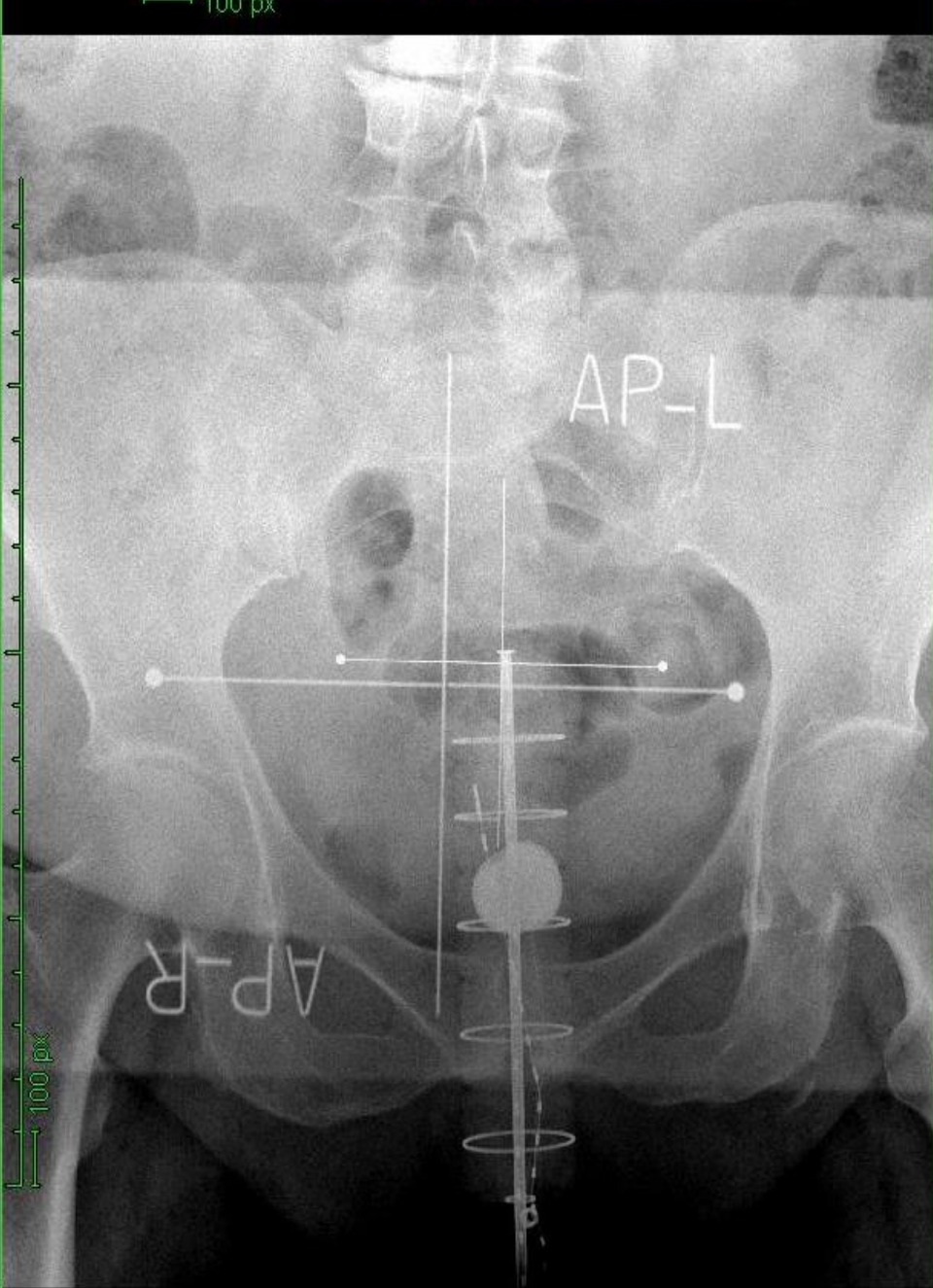
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<input checked="" type="checkbox"/>	CTV_Intermediate	Approved	Plan	1	903.8	100.0	100.0	91.0	104.6	100.3	100.0	0.0

# Postoperative brachytherapy of cervical cancer

EBRT + Brachytherapy: 2-3 applications with a dose of 6 Gy per application, once a week

Brachytherapy 4x6 Gy

- EQD2 dose to the region of the vaginal scar in the range of 65-70Gy
- the dose is prescribed at 0.5 cm from the surface of the vaginal ovoids, i.e. the vaginal cylinder
- the known burdens for the risk organs are determined in the ICRU reference points Bmax for the bladder and Rmax for the rectum according to ICRU-38 recommendations



Patient

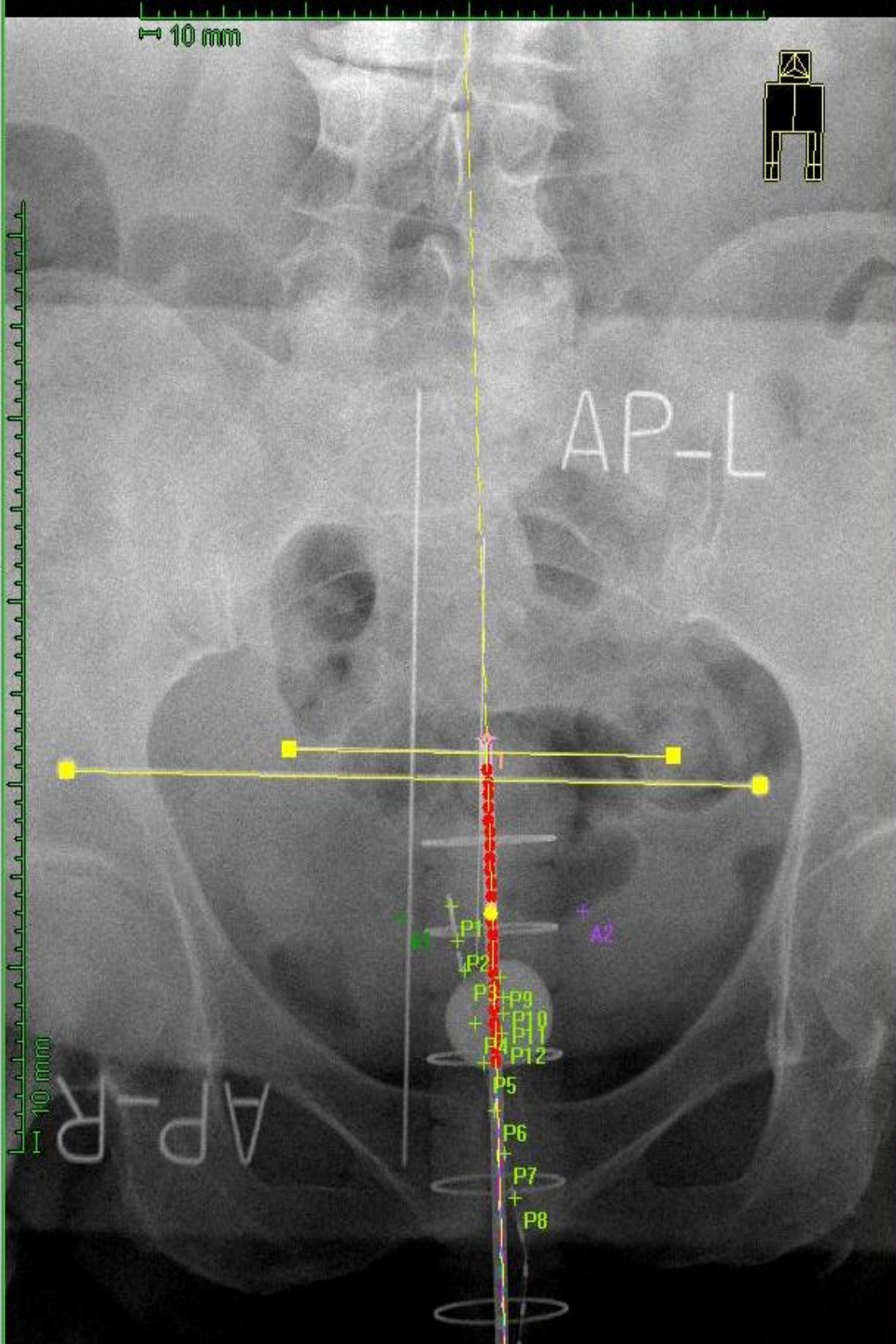
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01/02

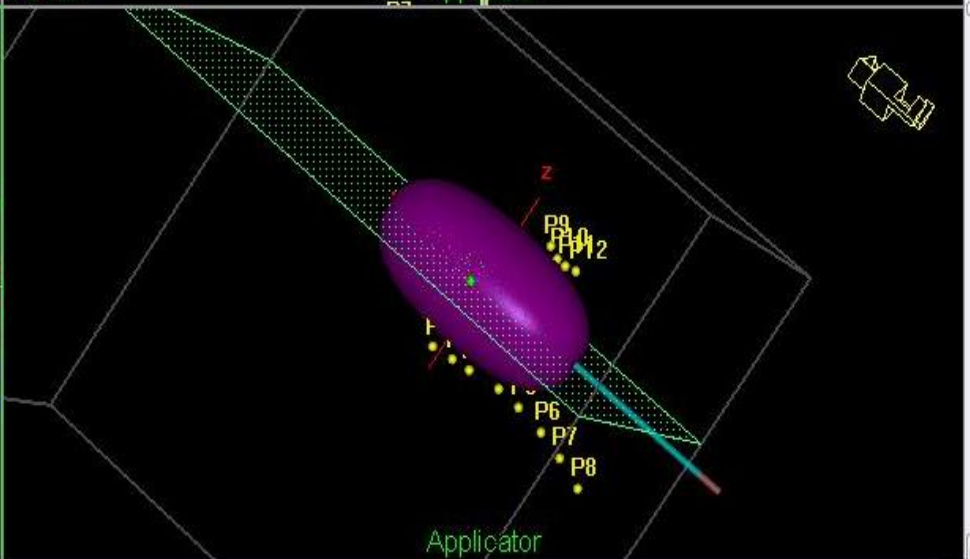
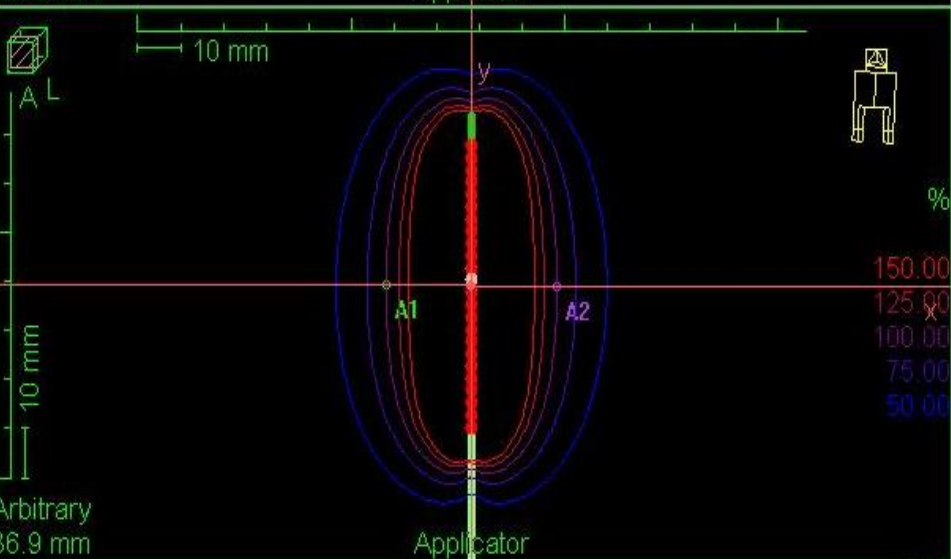
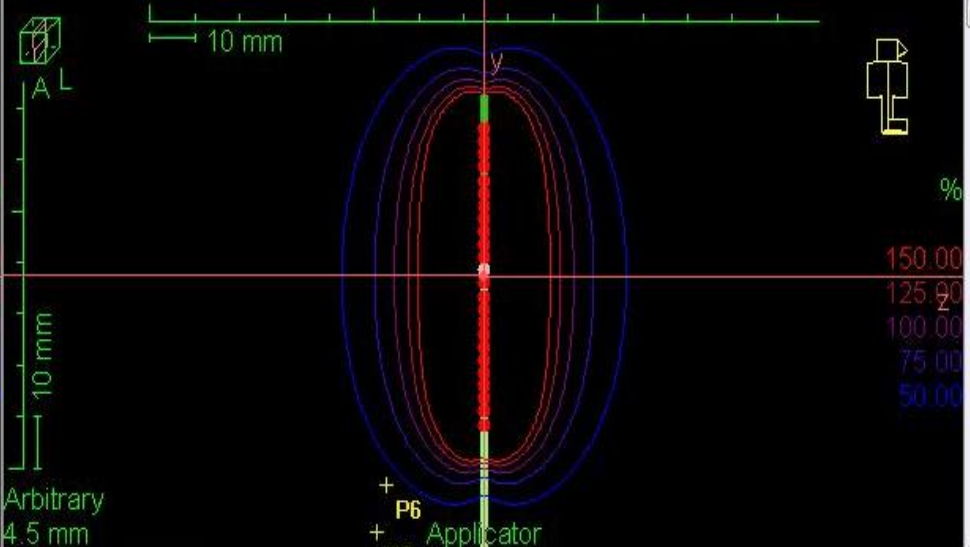
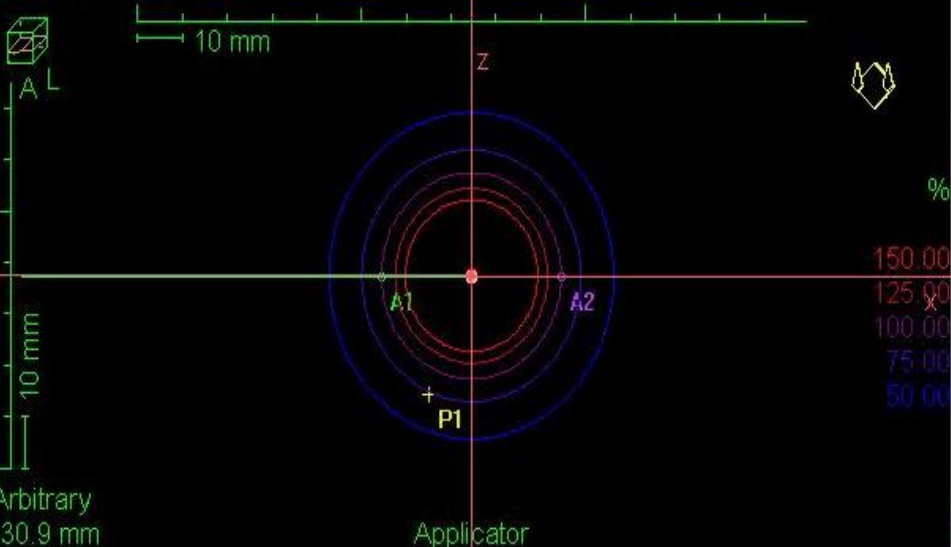


Patient

CR 01  
02/02



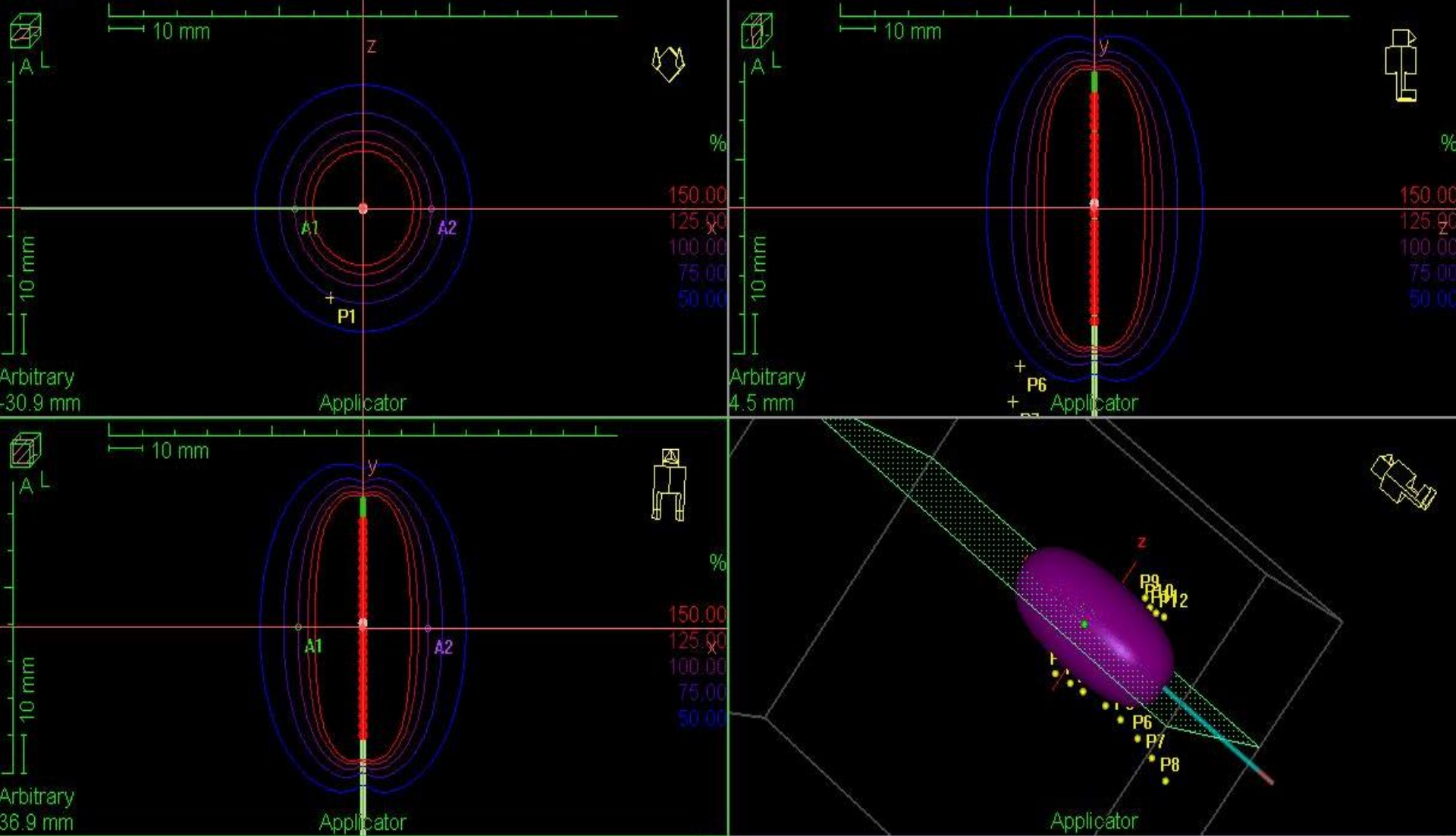




- ROI Set
- Plans
- M2\_Plan1\_F1
- Ap Applicator
- Points
- rektum
- besika
- Applicator

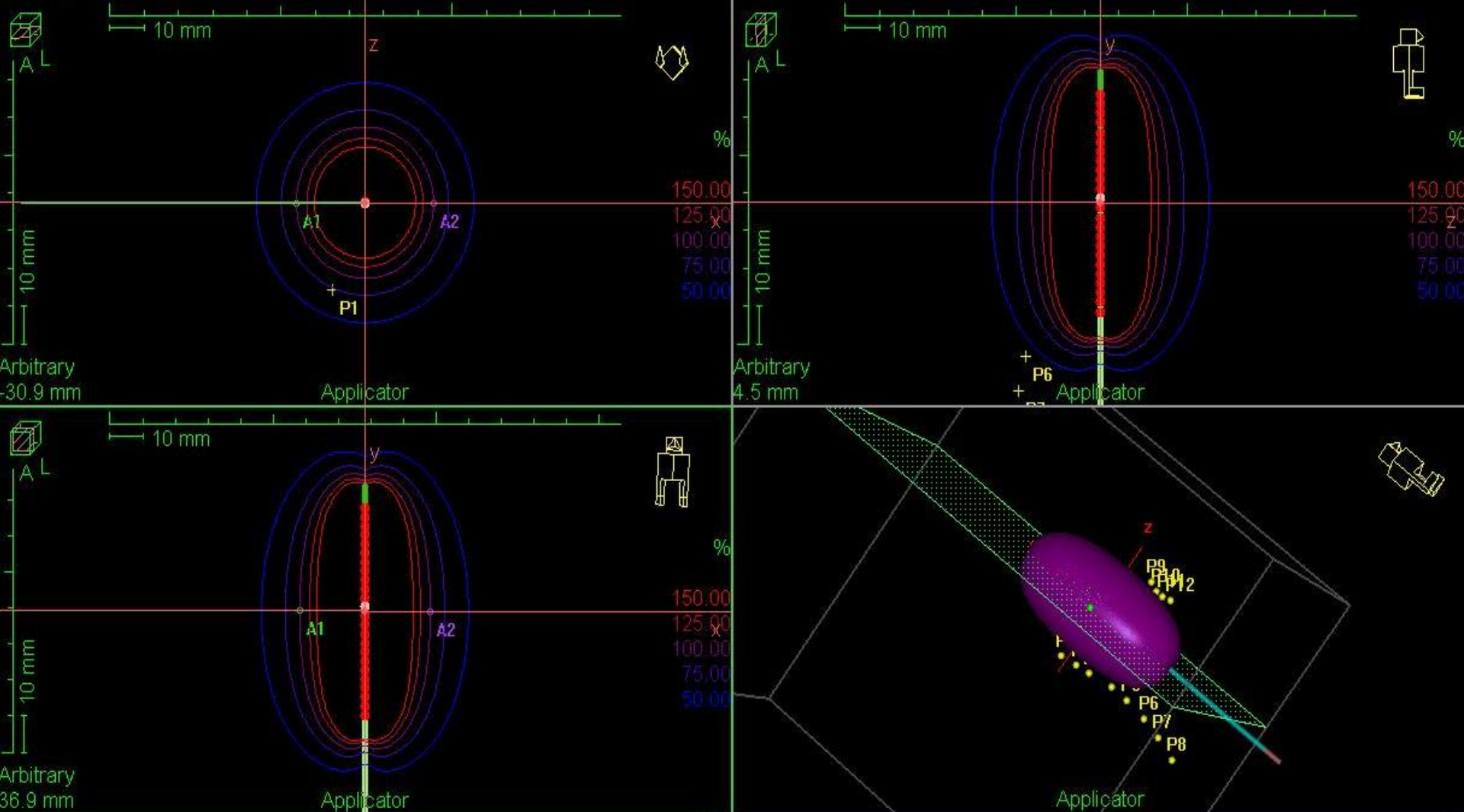
Name	X [mm]	Y [mm]	Z [mm]	Coord...	Act. Dos...	Act. Dose [%]	Normalization	Norm. Dose [%]	Optimization	Opt. Rel. Dose [%]	Opt. Weight
A1	-20.0	0.0	0.0	Applic...	701.28	100.18	yes	100.00	no	100.00	100.00
A2	20.0	0.0	0.0	Applic...	698.72	99.82	yes	100.00	no	100.00	100.00



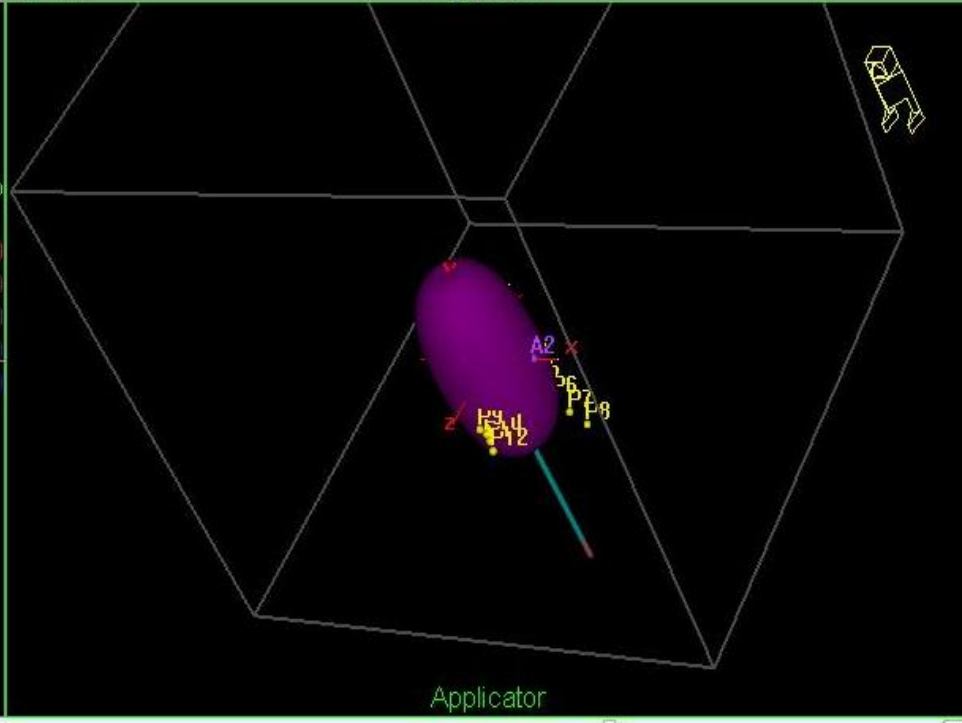
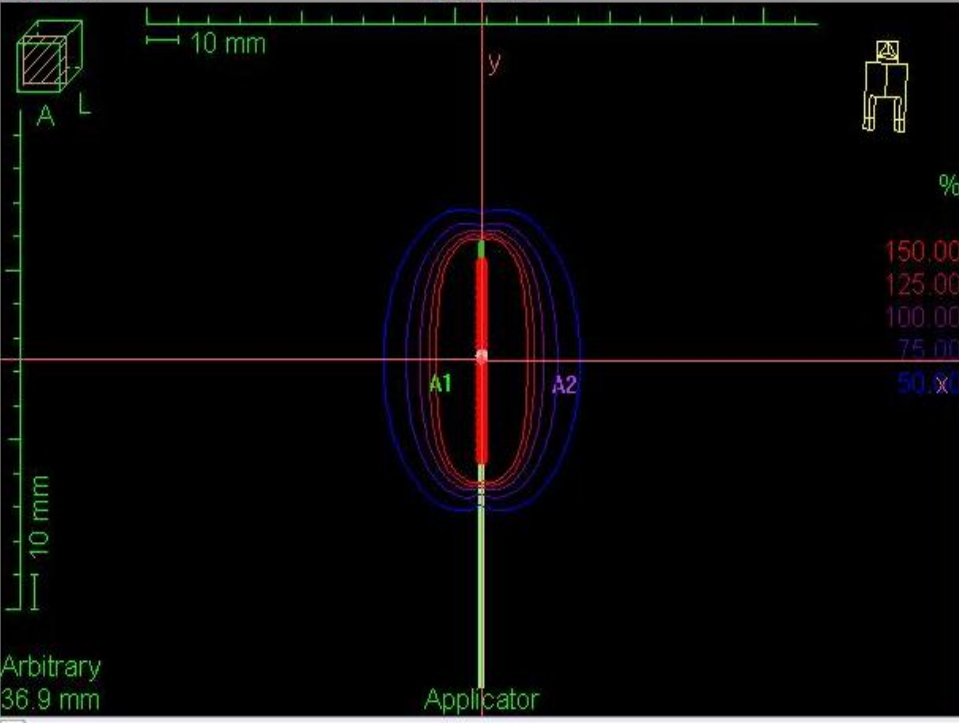
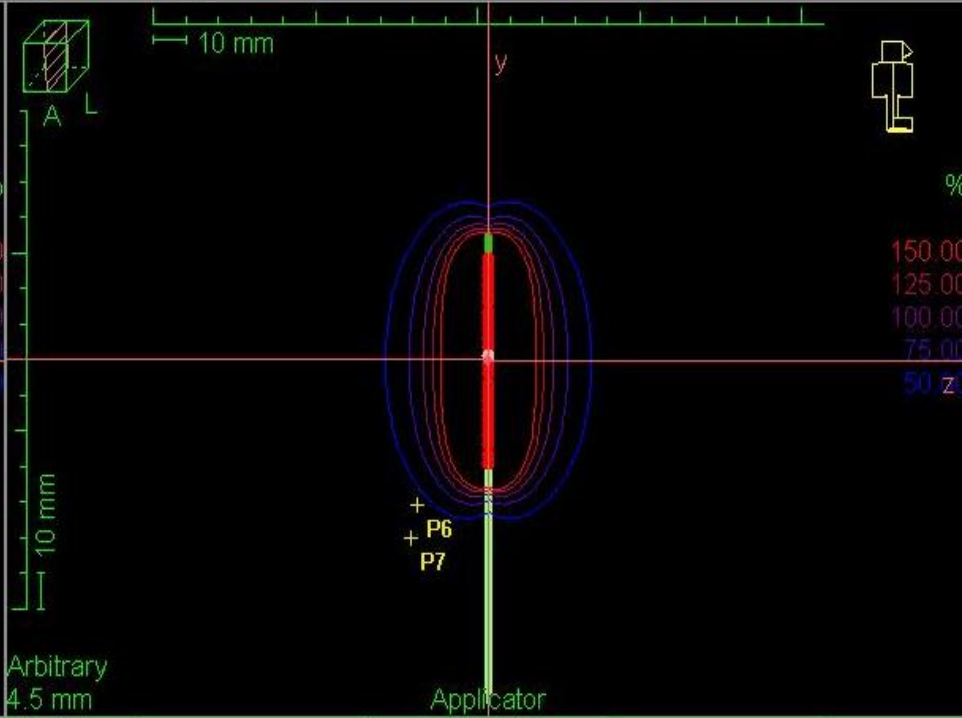
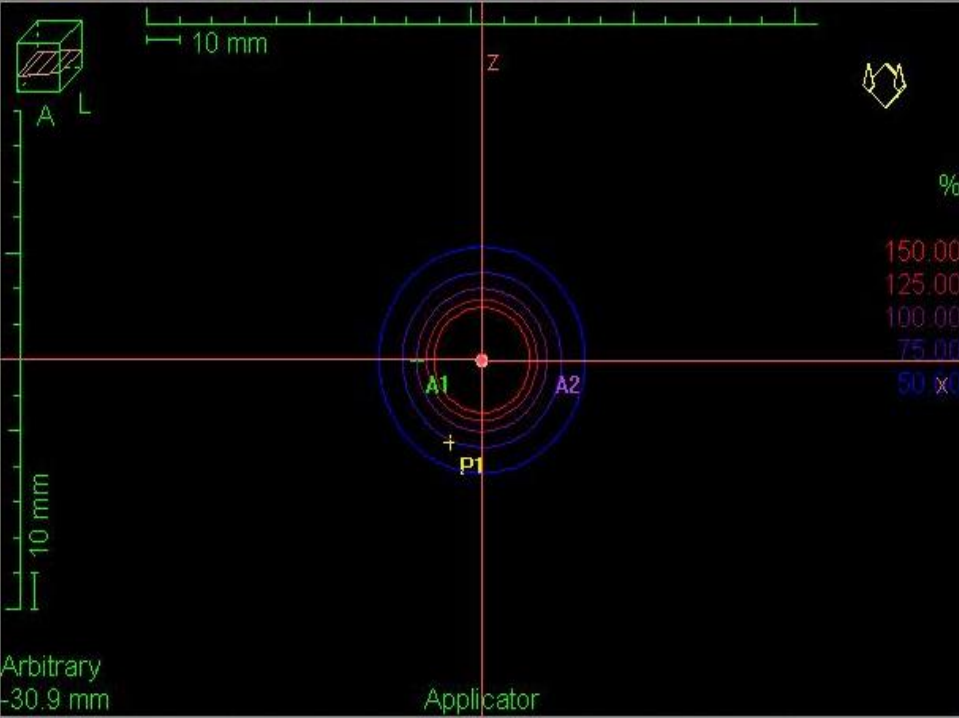


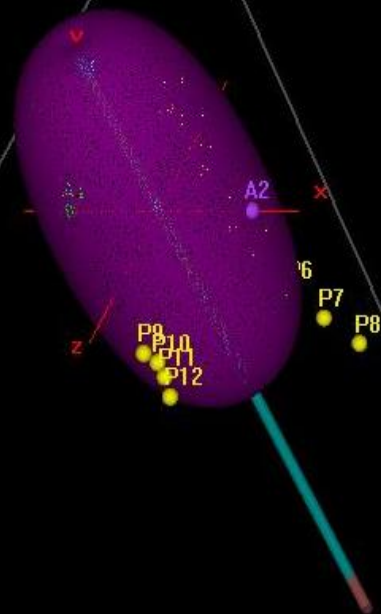
ROI Set												
Plans												
M2_Plan1_F1												
Ap Applicator												
Points												
rektum												
beska												
Applicator												
Name	X [mm]	Y [mm]	Z [mm]	Coord...	Act. Dos...	Act. Dose [%]	Normalization	Norm. Dose [%]	Optimization	Opt. Rel. Dose [%]	Opt. Weight	Shift [mm]
P9	8.7	-41.5	58.6	Patient	597.61	85.37	no	100.00	no	100.00	100.00	0.0
P10	9.2	-45.4	56.9	Patient	647.73	92.53	no	100.00	no	100.00	100.00	0.0
P11	9.2	-48.7	56.9	Patient	622.57	88.94	no	100.00	no	100.00	100.00	0.0
P12	9.2	-52.4	57.9	Patient	549.02	78.43	no	100.00	no	100.00	100.00	0.1



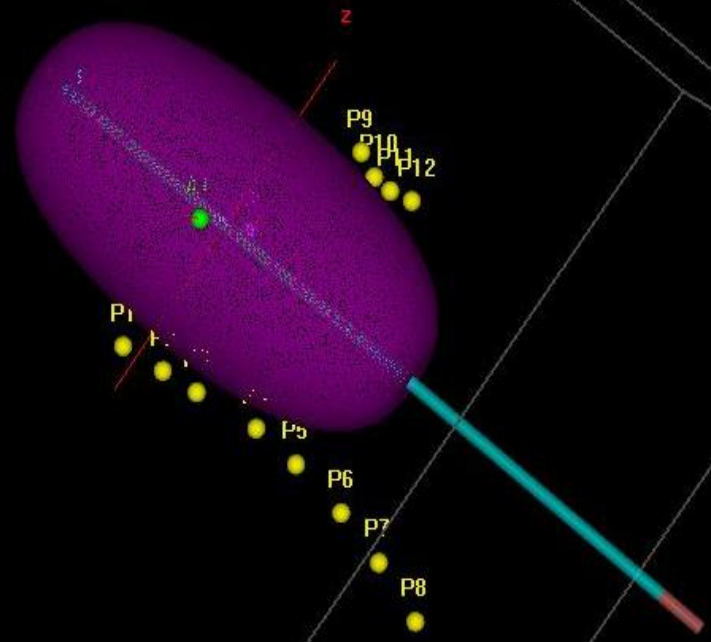


ROI Set	Name	X [mm]	Y [mm]	Z [mm]	Coord...	Act. Dos...	Act. Dose [%]	Normalization	Norm. Dose [%]	Optimization	Opt. Rel. Dose [%]	Opt. Weight	Shift [mm]
Plans	P1	-3.5	-30.3	13.7	Patient	504.70	72.10	no	100.00	no	100.00	100.00	0.0
M2_Plan1_F1	P2	-1.9	-37.4	14.6	Patient	540.70	77.24	no	100.00	no	100.00	100.00	0.0
Appl.	P3	-0.4	-43.4	15.4	Patient	559.71	79.96	no	100.00	no	100.00	100.00	0.0
Points	P4	2.2	-53.9	16.9	Patient	552.11	78.87	no	100.00	no	100.00	100.00	0.0
rektum	P5	4.5	-61.8	16.5	Patient	439.04	62.72	no	100.00	no	100.00	100.00	0.0
besika	P6	7.1	-71.5	15.1	Patient	278.61	39.80	no	100.00	no	100.00	100.00	0.0
Appl.	P7	9.5	-80.3	12.9	Patient	177.88	25.41	no	100.00	no	100.00	100.00	0.0
	P8	11.9	-89.9	9.5	Patient	114.93	16.42	no	100.00	no	100.00	100.00	0.0





Applicator



Applicator

# Radiotherapy of locally advanced cervical cancer

FIGO St. IB bulky, IIA, IIB – IVA

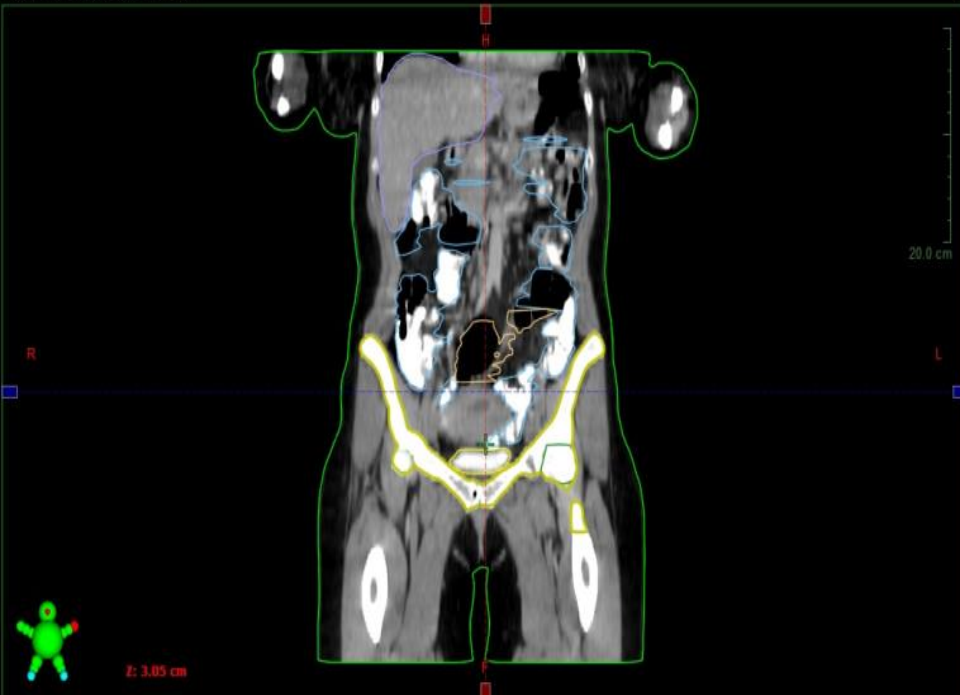
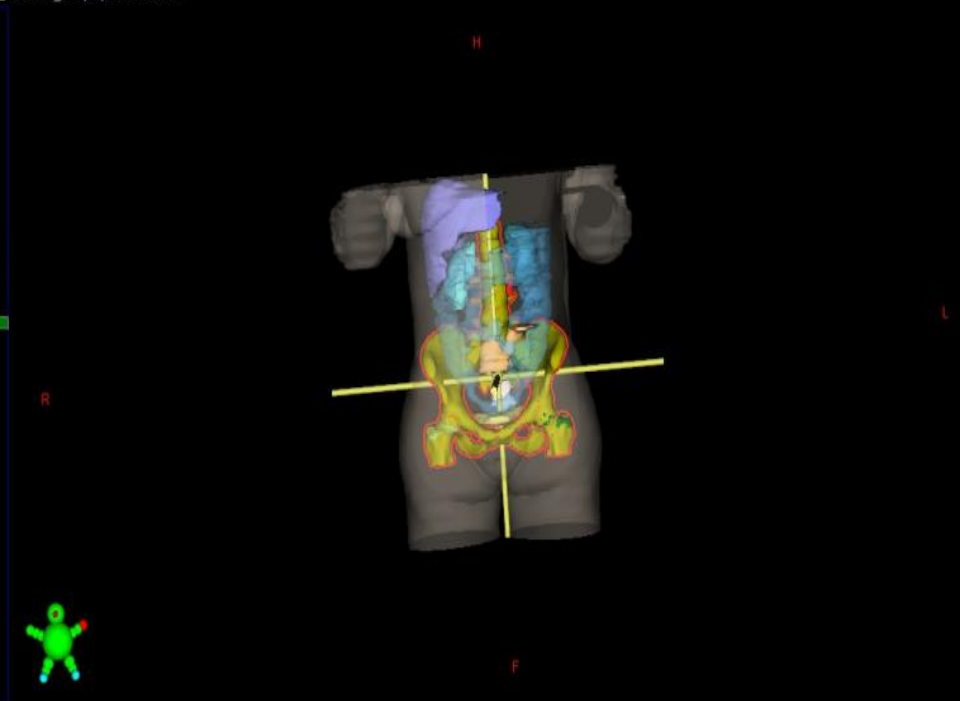
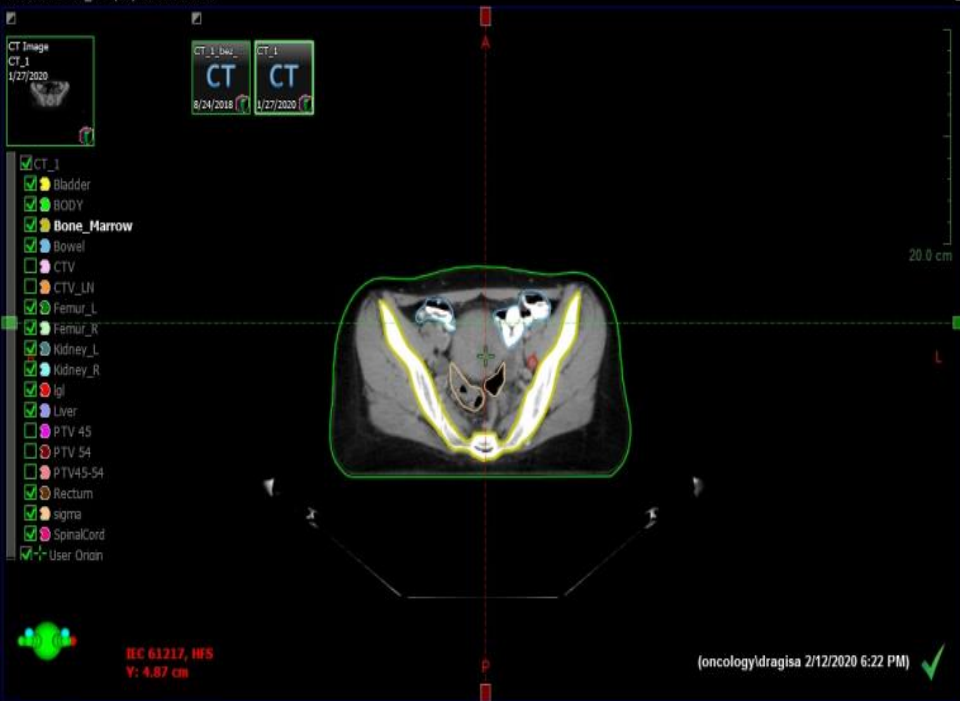
- RT+CHT potentiation (standard) + brachytherapy
- the patient does not agree to operative treatment
- in CT-verified enlarged common iliac lymphatics, prophylactic RT paraortal
- Standard: 46Gy, 1.8-2Gy per fraction, 5 days/week
- Boost to parameters (rest Tu) 5Gy
- Boost on enlarged inguinal lymphatics: up to max 55Gy
- Prophylactic RT of the para-aortic region up to L3: TD 45 Gy, 1.8 Gy per fraction

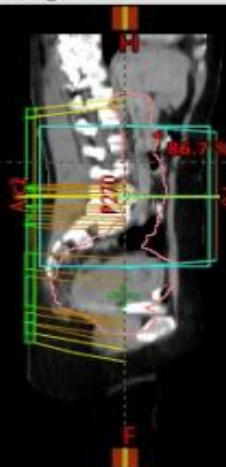
# Delineation of target volumes

- Therapeutic CT with or without co-registration with CT, PET-CT or MRI images.
- International Commission on Radiation Units and Measurements - ICRU 50, ICRU 62 and ICRU 83
- **GTV** - integrates the total tumor volume with involvement of surrounding structures and involved lymph nodes
- **CTV** - includes the entire uterus, parametrium, broad and proximal uterine ligament and the upper half of the vagina. In case of infiltration of the vagina, the CTV extends to the introitus of the vagina. The lower margin should be placed 3 cm below the lower edge of the tumor. The CTV of the affected nodes is defined with the help of a margin set at 1 cm from the affected lymph nodes, or 0.7 cm from the unaffected ones.
- **PTV** - is created by adding isotropic margins of 0.5 to 1 cm

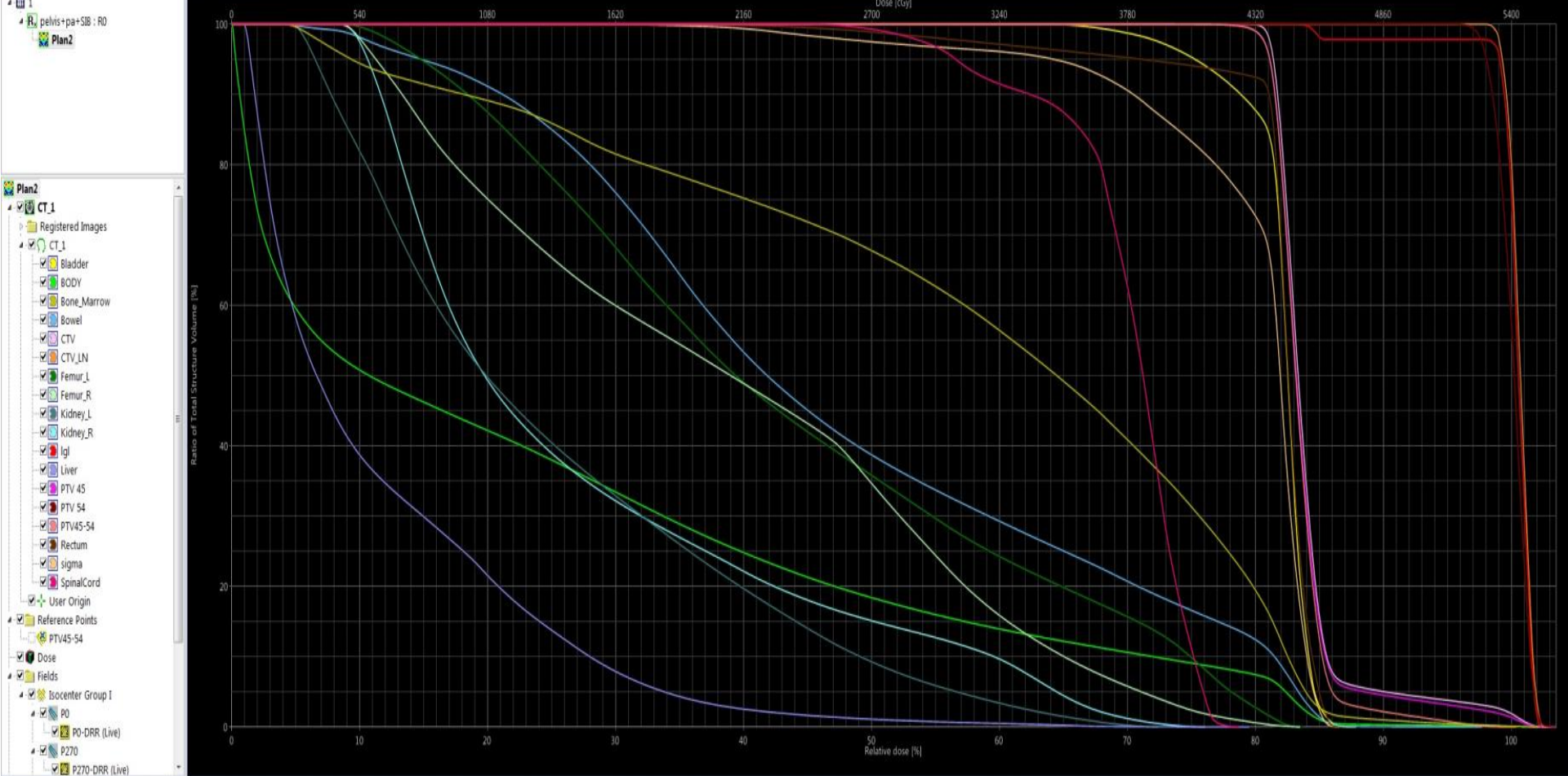








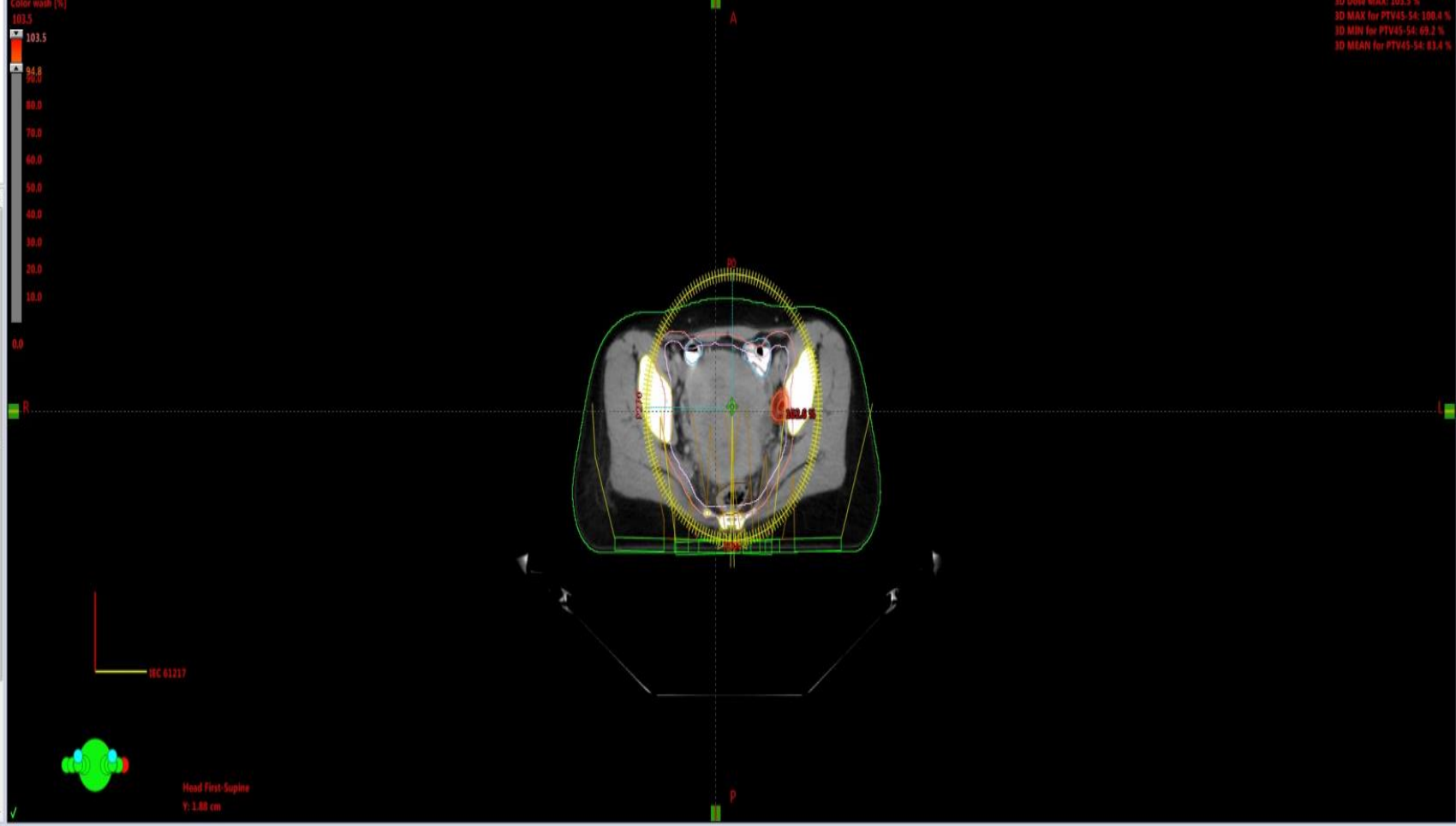




Dose		Reference Points		Dose Statistics									
Show DVH	Structure	Approval Status	Plan	Course	Volume [cm³]	Dose Cover [%]	Sampling Cover [%]	Min Dose [%]	Max Dose [%]	Mean Dose [%]	V50.0 [%]	V4750.0cGy [%]	
<input checked="" type="checkbox"/>	BODY	Approved	Plan2	1	39258.6	100.0	99.9	0.0	103.5	23.9	18.4	0.4	
<input checked="" type="checkbox"/>	Kidney_R	Approved	Plan2	1	199.3	100.0	100.0	8.4	76.1	27.4	15.1	0.0	
<input checked="" type="checkbox"/>	Kidney_L	Approved	Plan2	1	191.3	100.0	100.0	4.7	72.5	24.8	9.3	0.0	
<input checked="" type="checkbox"/>	Bladder	Approved	Plan2	1	75.5	100.0	100.0	63.6	87.9	81.9	100.0	0.0	
<input checked="" type="checkbox"/>	Igl	Approved	Plan2	1	8.9	100.0	100.2	83.0	102.4	100.2	100.0	97.8	
<input checked="" type="checkbox"/>	Bowel	Approved	Plan2	1	1334.6	100.0	100.0	4.2	97.8	46.8	38.7	0.1	
<input checked="" type="checkbox"/>	sigma	Approved	Plan2	1	159.2	100.0	100.0	29.7	86.6	79.1	97.5	0.0	
<input checked="" type="checkbox"/>	Rectum	Approved	Plan2	1	91.2	100.0	100.0	33.7	86.5	81.4	98.9	0.0	
<input checked="" type="checkbox"/>	Femur_L	Approved	Plan2	1	76.0	100.0	100.0	8.6	83.8	43.2	35.8	0.0	
<input checked="" type="checkbox"/>	Femur_R	Approved	Plan2	1	81.9	100.0	100.0	8.3	83.5	38.8	34.6	0.0	
<input checked="" type="checkbox"/>	Liver	Approved	Plan2	1	1519.3	100.0	99.8	0.8	79.5	11.5	1.1	0.0	
<input checked="" type="checkbox"/>	CTV	Approved	Plan2	1	1587.8	100.0	100.0	78.6	103.5	84.1	100.0	5.7	
<input checked="" type="checkbox"/>	PTV 45	Approved	Plan2	1	2467.3	100.0	100.0	69.2	103.5	83.8	100.0	5.2	
<input checked="" type="checkbox"/>	CTV_LN	Approved	Plan2	1	20.2	100.0	100.1	97.9	102.8	100.7	100.0	100.0	
<input checked="" type="checkbox"/>	PTV 54	Approved	Plan2	1	57.7	100.0	100.1	94.8	103.5	100.1	100.0	100.0	
<input checked="" type="checkbox"/>	PTV45-54	Approved	Plan2	1	2407.9	100.0	100.0	69.2	100.4	83.4	100.0	2.9	
<input checked="" type="checkbox"/>	Bone_Marrow	Approved	Plan2	1	1842.3	100.0	100.0	4.0	102.2	57.5	67.8	1.3	
<input checked="" type="checkbox"/>	SpinalCord	Approved	Plan2	1	26.7	100.0	100.0	44.2	78.8	69.9	99.3	0.0	

3D MAX for PTV45-54: 100.4 %

- CT\_1
  - Registered Images
    - CT\_1
      - Bladder
      - BODY
      - Bone\_Marrow
      - Bowel
      - CTV
      - CTV\_LN
      - Femur\_L
      - Femur\_R
      - Kidney\_L
      - Kidney\_R
      - Igi
      - Liver
      - PTV 45
      - PTV 54
      - PTV45-54
      - Rectum
      - Sigma
      - SpinalCord
    - User Origin
  - Reference Points
    - PTV45-54
  - Dose
  - Fields
    - Isocenter Group 1
      - P0
        - P0-DRR (Live)
      - P270
        - P270-DRR (Live)



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 [%]	V50.0 [%]	V4750.0cGy [%]	
<input checked="" type="checkbox"/>	BODY	Approved	Plan2	1		39256.6	100.0	99.9	0.0	103.5	23.9	18.4	0.4
<input checked="" type="checkbox"/>	Kidney_R	Approved	Plan2	1		199.3	100.0	100.0	8.4	76.1	27.4	15.1	0.0
<input checked="" type="checkbox"/>	Kidney_L	Approved	Plan2	1		191.3	100.0	100.0	4.7	72.5	24.8	9.3	0.0
<input checked="" type="checkbox"/>	Bladder	Approved	Plan2	1		75.5	100.0	100.0	63.6	87.9	81.9	100.0	0.0
<input checked="" type="checkbox"/>	IgJ	Approved	Plan2	1		8.9	100.0	100.2	83.0	102.4	100.2	100.0	97.8
<input checked="" type="checkbox"/>	Bowel	Approved	Plan2	1		1334.6	100.0	100.0	4.2	97.8	46.8	38.7	0.1
<input checked="" type="checkbox"/>	sigma	Approved	Plan2	1		159.2	100.0	100.0	29.7	86.6	79.1	97.5	0.0
<input checked="" type="checkbox"/>	Rectum	Approved	Plan2	1		91.2	100.0	100.0	33.7	86.5	81.4	98.9	0.0
<input checked="" type="checkbox"/>	Femur_L	Approved	Plan2	1		76.0	100.0	100.0	8.6	83.8	43.2	35.8	0.0
<input checked="" type="checkbox"/>	Femur_R	Approved	Plan2	1		81.9	100.0	100.0	8.3	83.5	38.8	34.6	0.0
<input checked="" type="checkbox"/>	Liver	Approved	Plan2	1		1519.3	100.0	99.8	0.8	79.5	11.5	1.1	0.0
<input checked="" type="checkbox"/>	CTV	Approved	Plan2	1		1587.8	100.0	100.0	78.6	103.5	84.1	100.0	5.7
<input checked="" type="checkbox"/>	PTV45	Approved	Plan2	1		2467.3	100.0	100.0	69.2	103.5	83.8	100.0	5.2
<input checked="" type="checkbox"/>	CTV_LIN	Approved	Plan2	1		20.2	100.0	100.1	97.9	102.8	100.7	100.0	100.0
<input checked="" type="checkbox"/>	PTV54	Approved	Plan2	1		57.7	100.0	100.1	94.8	103.5	100.1	100.0	100.0
<input checked="" type="checkbox"/>	PTV45-54	Approved	Plan2	1		2407.9	100.0	100.0	69.2	100.4	83.4	100.0	2.9
<input checked="" type="checkbox"/>	Bone_Marrow	Approved	Plan2	1		1842.3	100.0	100.0	4.0	102.2	57.5	67.8	1.3
<input checked="" type="checkbox"/>	SpinalCord	Approved	Plan2	1		26.7	100.0	100.0	44.2	78.8	69.9	99.3	0.0

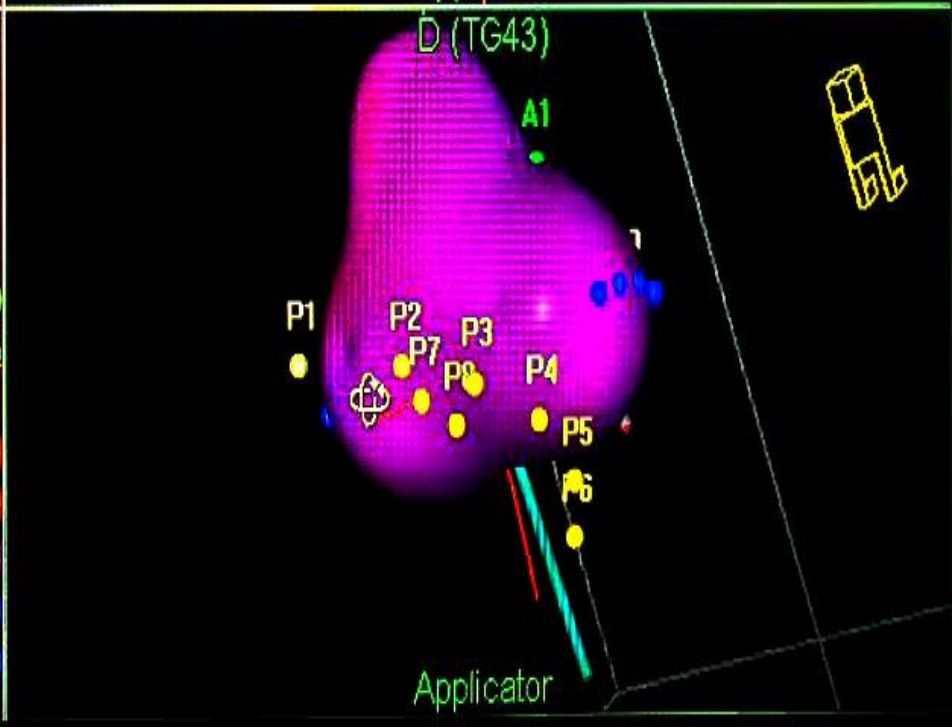
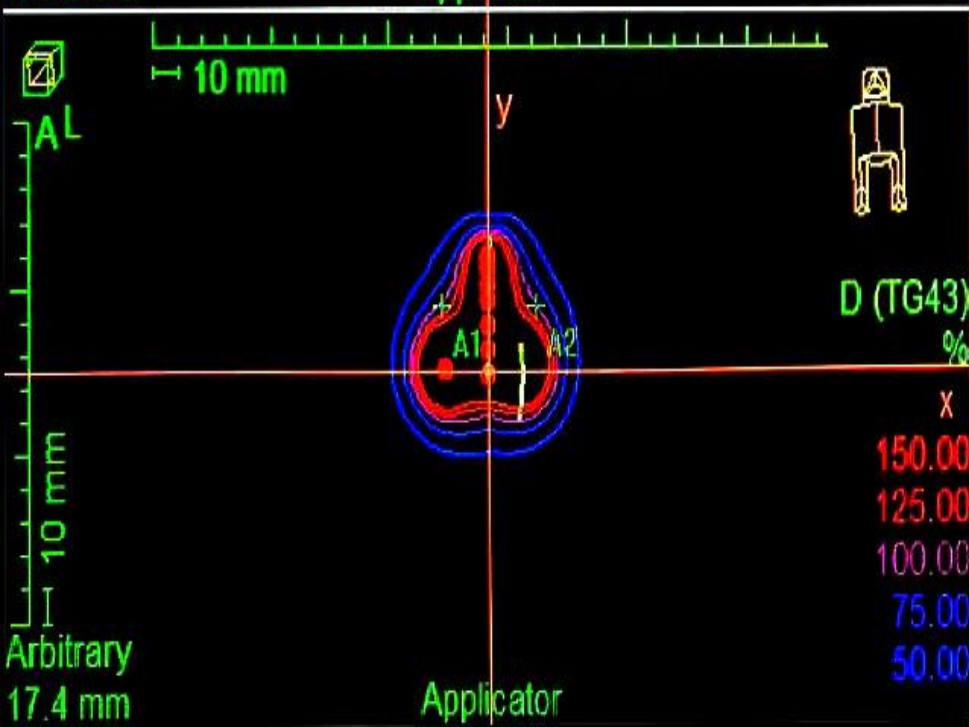
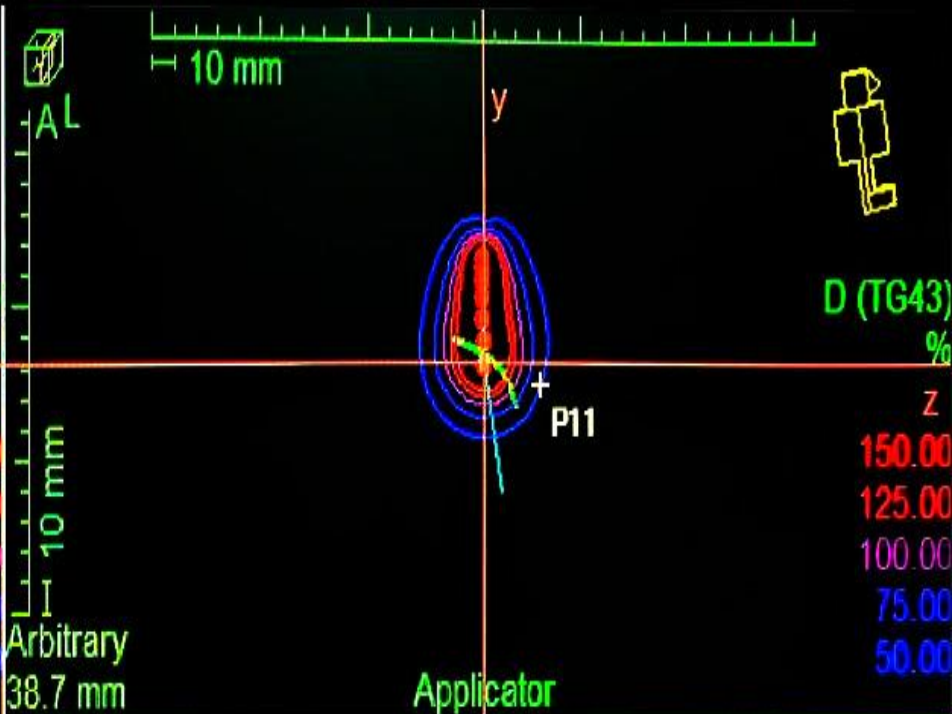
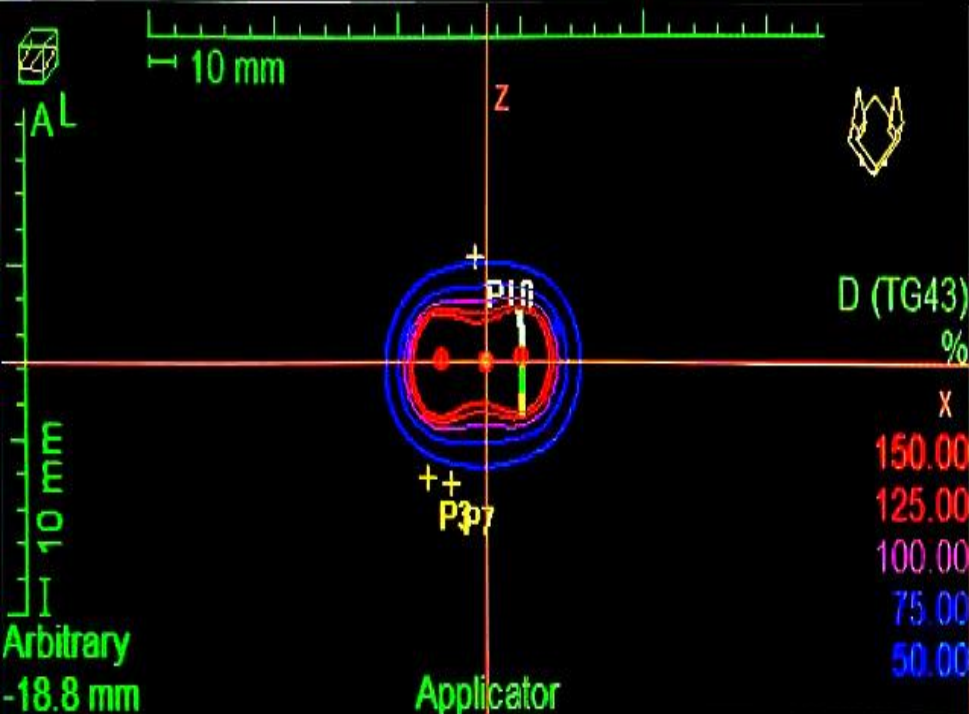




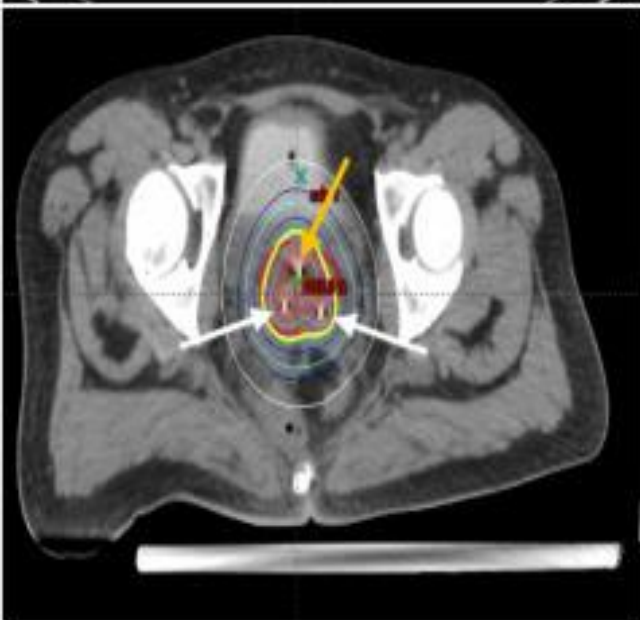
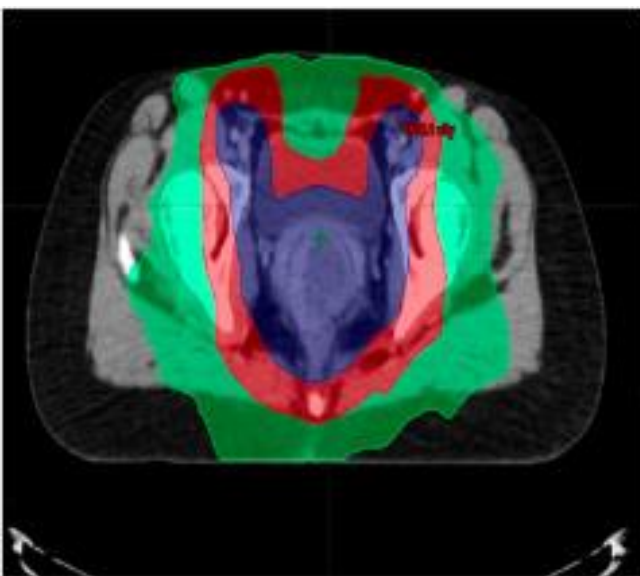


# Brachytherapy

- The procedure is performed in the brachytherapy operating room
- In analgesia, general or spinal anesthesia
- American Association of Physicists in Medicine, ICRU Report No 38 and the Manchester System of Calculation of Dose Delivery at Point A
- EQD2 calculation
- LQ model -  $\alpha/\beta$  ratio for cervical cancer is 10 Gy, while for late radiation toxicity of organs at risk it is 3 Gy



The half-time of recovery of normal cells is 1.5 hours, according to which, based on the radiobiological characteristics of this tumor and organs at risk, it is ideal to achieve a maximum duration of treatment of 50 days.



# GEC-ESTRO BT committi recommendations

- **HR-CTV** - represents a region of high risk for local relapse due to the presence of microscopic disease
- **IR-CTV** - with a high risk for local relapse, in the regions of the initial macroscopic disease, which contains most of the microscopic disease at the time of brachytherapy
- **GTV** - changes during the treatment, according to which it is necessary that GTV and CTV are described and delineated during each brachytherapy application
- In order to save the organs from risk, delineation is performed, as well as the calculation of the dose to be delivered to the 2 cm<sup>2</sup> that are most exposed during the application of brachytherapy. The dose delivered during the brachytherapy application is added to the dose delivered by the EBRT technique according to the EQD2 model



# Combination of the IS+IC brachytherapy

- It is performed after the completion of EBRT with the aim of delivering a biologically equivalent dose of 90-95 Gy to the HR-CTV.
- Co-registration of the initial MRI or ST scan with the scans taken during the last week of EBRT.
- After placing the intrauterine probe and the ovoid, the dose contribution to the target volume and organs at risk is calculated. Tumor coverage with the prescribed dose is analyzed.
- For regions that do not have adequate dose coverage, interstitial brachytherapy needles are used in which the radiation source is located.
- Needles for interstitial brachytherapy are placed in the under treatment regions of the tumor

## Dosage prescriptions

- They are based on dose values that are the product of institutional experience and - or from recommendations (point A)
- Dose and fractionation schemes are based on the application of a linear quadratic model
- Overall dose:
- Small (locally advanced) Tu (2-3cm, Ib1,IIa,IIb):75-80Gy
- Advanced Tu (>3-4cm Ib2,IIb,IIIb,IVa):85Gy>

# FIGO classification for endometrial cancer (2023)

Stage	Description
Stage I	Confined to the uterine corpus and ovary <sup>c</sup>
IA	Disease limited to the endometrium OR non-aggressive histological type, i.e. low-grade endometrioid, with invasion of less than half of myometrium with no or focal lymphovascular space involvement (LVSI) OR good prognosis disease IA1 Non-aggressive histological type limited to an endometrial polyp OR confined to the endometrium IA2 Non-aggressive histological types involving less than half of the myometrium with no or focal LVSI IA3 Low-grade endometrioid carcinomas limited to the uterus and ovary <sup>c</sup>
IB	Non-aggressive histological types with invasion of half or more of the myometrium, and with no or focal LVSI <sup>d</sup>
IC	Aggressive histological types <sup>e</sup> limited to a polyp or confined to the endometrium
Stage II	Invasion of cervical stroma without extrauterine extension OR with substantial LVSI OR aggressive histological types with myometrial invasion
IIA	Invasion of the cervical stroma of non-aggressive histological types
IIB	Substantial LVSI <sup>d</sup> of non-aggressive histological types
IIC	Aggressive histological types <sup>e</sup> with any myometrial involvement
Stage III	Local and/or regional spread of the tumor of any histological subtype
IIIA	Invasion of uterine serosa, adnexa, or both by direct extension or metastasis IIIA1 Spread to ovary or fallopian tube (except when meeting stage IA3 criteria) <sup>c</sup> IIIA2 Involvement of uterine subserosa or spread through the uterine serosa
IIIB	Metastasis or direct spread to the vagina and/or to the parametria or pelvic peritoneum IIIB1 Metastasis or direct spread to the vagina and/or the parametria IIIB2 Metastasis to the pelvic peritoneum
IIIC	Metastasis to the pelvic or para-aortic lymph nodes or both <sup>f</sup> IIIC1 Metastasis to the pelvic lymph nodes IIIC1i Micrometastasis IIIC1ii Macrometastasis IIIC2 Metastasis to para-aortic lymph nodes up to the renal vessels, with or without metastasis to the pelvic lymph nodes IIIC2i Micrometastasis IIIC2ii Macrometastasis
Stage IV	Spread to the bladder mucosa and/or intestinal mucosa and/or distance metastasis
IVA	Invasion of the bladder mucosa and/or the intestinal/bowel mucosa
IVB	Abdominal peritoneal metastasis beyond the pelvis
IVC	Distant metastasis, including metastasis to any extra- or intra-abdominal lymph nodes above the renal vessels, lungs, liver, brain, or bone

# Radical radiotherapy of endometrial cancer

- Inoperable disease
- Contraindications for operative treatment
- The patient does not agree to operative treatment
  
- EBRT+Brachytherapy+/- CHT
- Pelvis: 45-50Gy, 5 days/week, 1.8-2 Gy per fraction
- Para-aortic region: 45Gy, 5 days/week, 1.8 Gy per fraction
- Palliative doses: 30 Gy in 10 fractions, 20 Gy in 5 fractions
- Nodal boost:
- 55Gy pelvic lymphatics SIB – within 25 fractions / sequential to total dose
- 57.5 Gy para-aortic lymphatics SIB - within 25 fractions / sequential to total dose

# Brachytherapy as part of radical radiation therapy for endometrial cancer

- 2D or 3D technique
- Intrauterine probe and ovoids
- TD 6-7 Gy in 4-6 fractions once a week
- Organ dose burden from risk



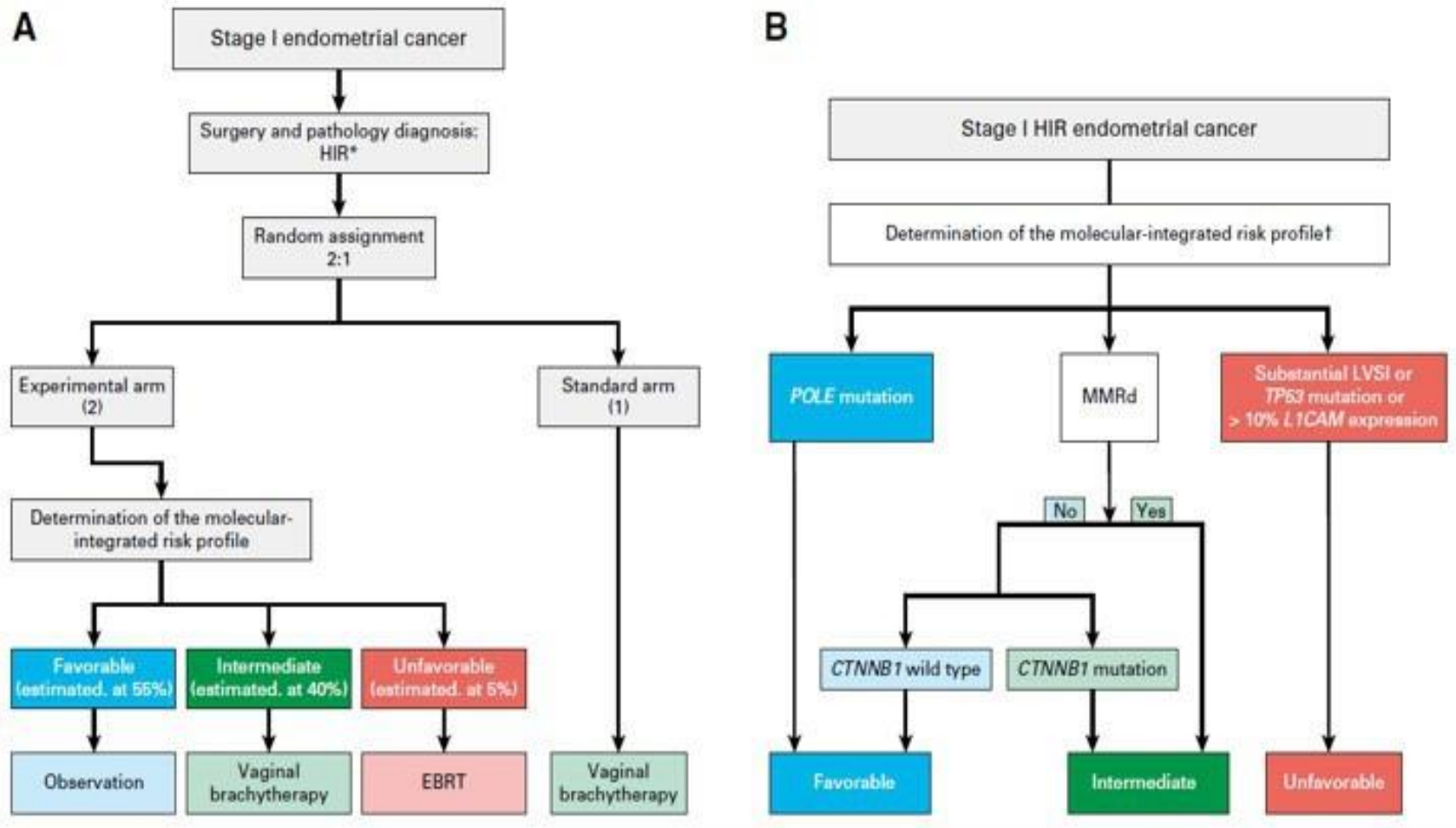


# Postoperative radiotherapy of endometrial cancer

- **Low-risk group:** endometrioid histology, G1/2, depth of infiltration  $\leq 50\%$ , LVI - **follow-up**
- **Intermediate risk group:** endometrioid histology, G1/2, infiltration depth  $\geq 50\%$ , LVI- **adjuvant brachytherapy (optional) or follow-up for patients over 60 years???**
- **Medium-high risk group:** endometrioid histology, G3, depth of infiltration  $\geq 50\%$ , regardless of LVI status, endometrioid histology, G1/2, LVI+, regardless of depth of infiltration - adjuvant RT (EBRT + BT) for unknown nodal status
- Adjuvant RT in G1/2 tumors, LVI+, node negative patients (G3??) - ESMO-ESTRO-ESGO recommendation for the whole group is adj BT if nodes are negative (at least 10 lgl, paraaortic??)
- **High-risk group:** endometrioid histology, G3, depth of infiltration  $\geq 50\%$ , regardless of LVI status - **adjuvant radiotherapy**
- FIGO stage II, endometrioid histology - adjuvant radiotherapy, adjuvant brachytherapy for G1/2, LVI- tumors, node negative
- FIGO stage III endometrioid histology, tumors of non-endometrioid histology (serous, clear-cell, undifferentiated, carcinosarcoma) - consider starting treatment with **adjuvant HT IV-VI cycles** (mandatory for FIGO IIIC1/2, FIGO III serous and clear-cell histologies, as well as for undifferentiated cancer and carcinosarcoma regardless of stage) + **sequential adjuvant radiotherapy**

# Postoperative radiotherapy of endometrial cancer

- Pelvis: 40-50 Gy, 5 days/week, 1.8-2 Gy per fraction
- Para-aortic region: 45 Gy, 1.8 Gy per fraction
- Palliative doses: 30 Gy in 10 fractions, 20 Gy in 5 fractions
- Nodal boost:
- 55Gy pelvic lymphatics SIB – within 25 fractions / sequential to total dose
- 57.5Gy para-aortic lymphatics SIB - within 25 fractions / sequential to total dose
- Brachytherapy (2D or 3D)
- Vaginal cylinder
- TD 6-7 Gy in 3-4 fractions



van den Heerik ASVM, Horeweg N, Nout RA, et al. PORTEC-4a: international randomized trial of molecular profile-based adjuvant treatment for women with high-intermediate risk endometrial cancer. *Int J Gynecol Cancer*. 2020 Dec;30(12):2002-2007.

Oaknin A, Bosse TJ, Creutzberg CL, et al; ESMO Guidelines Committee. Electronic address: [clinicalguidelines@esmo.org](mailto:clinicalguidelines@esmo.org). **Endometrial cancer: ESMO Clinical Practice Guideline for diagnosis, treatment and follow-up.** Ann Oncol. 2022 Sep;33(9):860-877.

Table 1. Molecular and clinicopathological features of endometrial cancer molecular subgroups				
	<i>POLE</i> mut (i.e. <i>POLE</i> EDM)	dMMR (i.e. MSI)	NSMP (i.e. p53-wt)	p53aberrant (i.e. p53-abn, p53-mut)
Prevalence in TCGA cohort, %	5-15	25-30	30-40	5-15
Associated molecular features	>100 mut/Mb, SCNA-very low, MSS	10-100 mut/Mb, SCNA-low, MSI	<10 mut/Mb, SCNA-low, MSS	<10 mut/Mb, SCNA-high, MSS
Most frequently associated histological features	Endometrioid Often high grade Ambiguous morphology Prominent TILs and TLSs	Endometrioid Often high grade LVSI substantial Prominent TILs MELF-type invasion	Mostly low grade Notable absence of TILs Squamous differentiation ER/PgR diffuse	All histological subtypes Mostly high grade High cytonuclear atypia Low level of TILs
Associated clinical features	Lower BMI Early stage (IA-IB) Early onset	Higher BMI Lynch syndrome	Higher BMI	Lower BMI Advanced stage Late onset
Diagnostic test	NGS/Sanger/Hotspot: P286R, V411L, S297F, A456P, S459F	MMR-IHC: MLH1, MSH2, MSH6, PMS2 MSI assay		p53-IHC Mutant-like/abnormal staining
Prognosis	Excellent	Intermediate	Intermediate Stage-dependent	Poor

Adapted from McAlpine et al.,<sup>119</sup> with permission from John Wiley and Sons.

BMI, body mass index; dMMR, mismatch repair deficient; EDM, exonuclease domain mutation; ER, estrogen receptor; IHC, immunohistochemistry; LVSI, lymphovascular space invasion; MELF, microcystic elongated and fragmented type of invasion; MMR-IHC, mismatch repair immunohistochemistry; MSI, microsatellite instability; MSS, microsatellite stable; mut/Mb, mutations/megabase; NGS, next-generation sequencing; NSMP, no specific molecular profile; p53-abn, p53-abnormal; p53-mut, p53-mutant; p53-wt, p53-wild type; PgR, progesterone receptor; *POLE*, polymerase epsilon; *POLE*mut, polymerase epsilon-ultramutated; SCNA, somatic copy number alteration; TCGA, The Cancer Genome Atlas; TIL, tumour infiltrating lymphocyte; TLS, tertiary lymphoid structure.

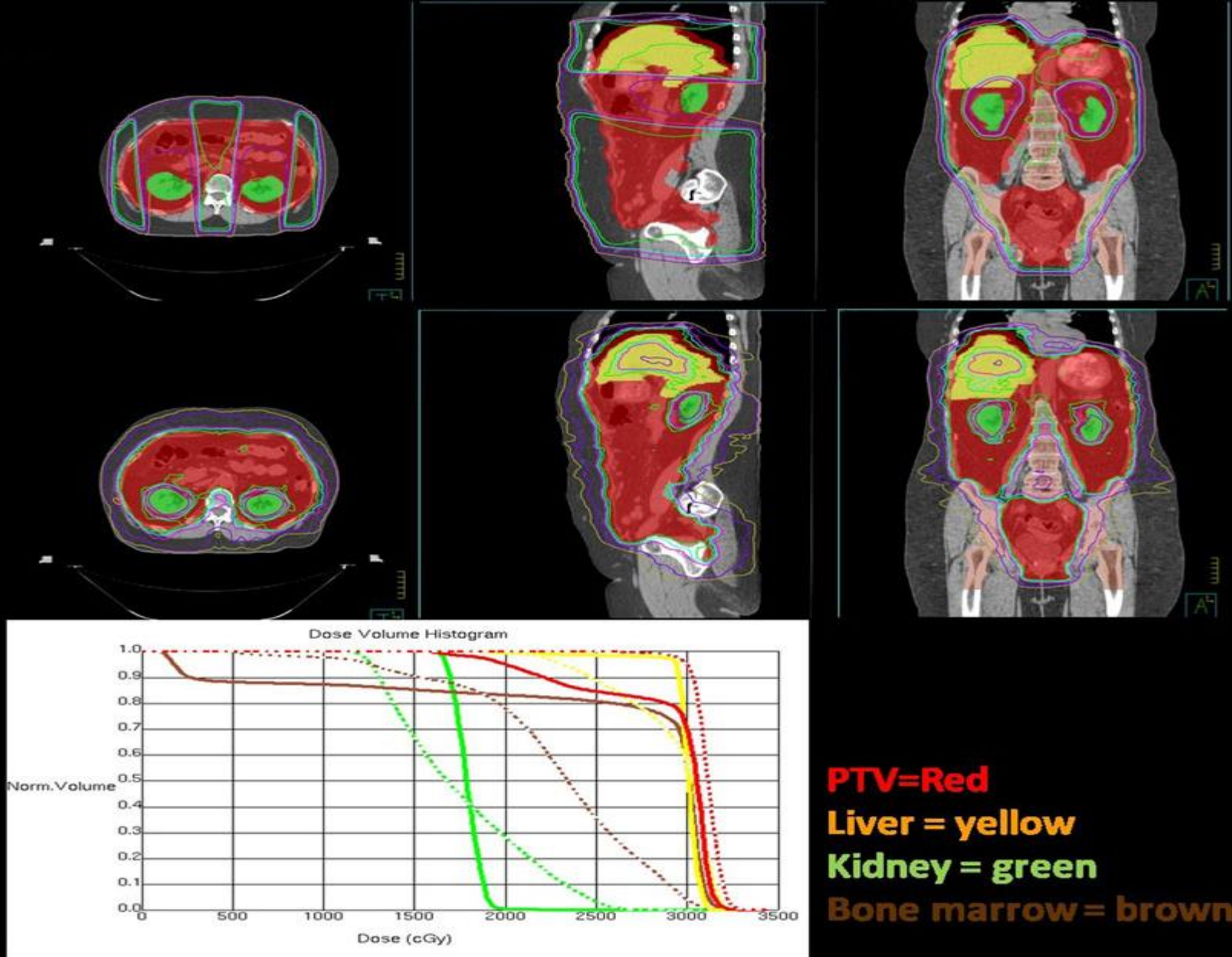
# Ovarial cancer radiotherapy

- Not applicable by default
- Indicated in the adjuvant approach in locally advanced tumors (FIGO st. III) and/or the presence of residual disease

It is carried out in two phases:

- I Whole abdomen irradiation - TD 30 Gy/ 20 frakcija
- II Whole pelvis irradiation - total dose TD 45-50,4 Gy





# **RADIOTHERAPY OF THE GERIATRIC POPULATION**

# Challenges in radiotherapy treatment in the elderly

- General condition of the patient
- Characteristics of locoregional tumor growth
- Risk assessment due to comorbidities
- Assessment of functional reserves of organic systems

# Radiotherapy specifics in the geriatric population

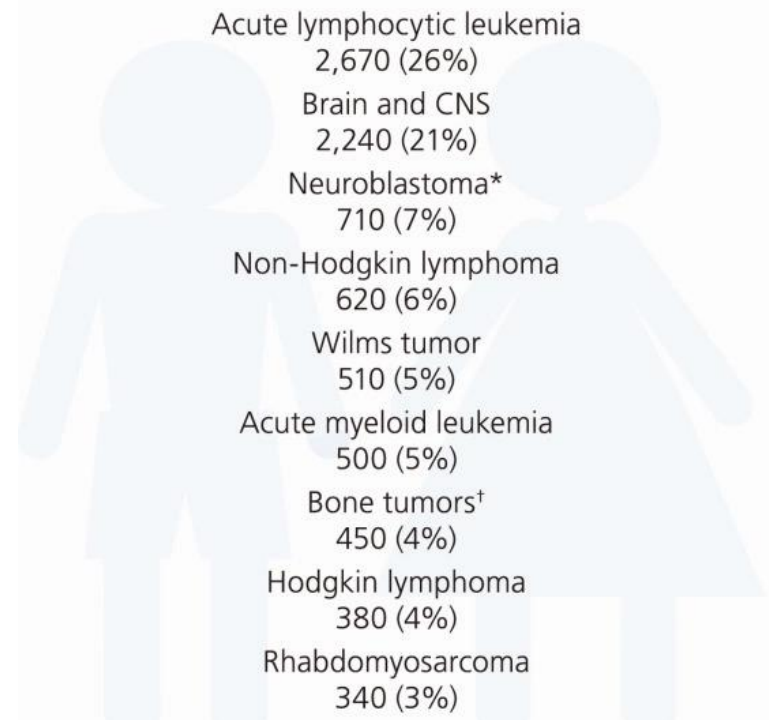
- Dose reduction
- Choosing the right radiotherapy technique
- The right choice of fractionation mode
- Decision on patient eligibility for RT
- Consider expected survival
- Implementation of RT in ambulatory or hospital settings

# **RADIOTHERAPY OF TUMORS IN PEDIATRIC POPULATION**



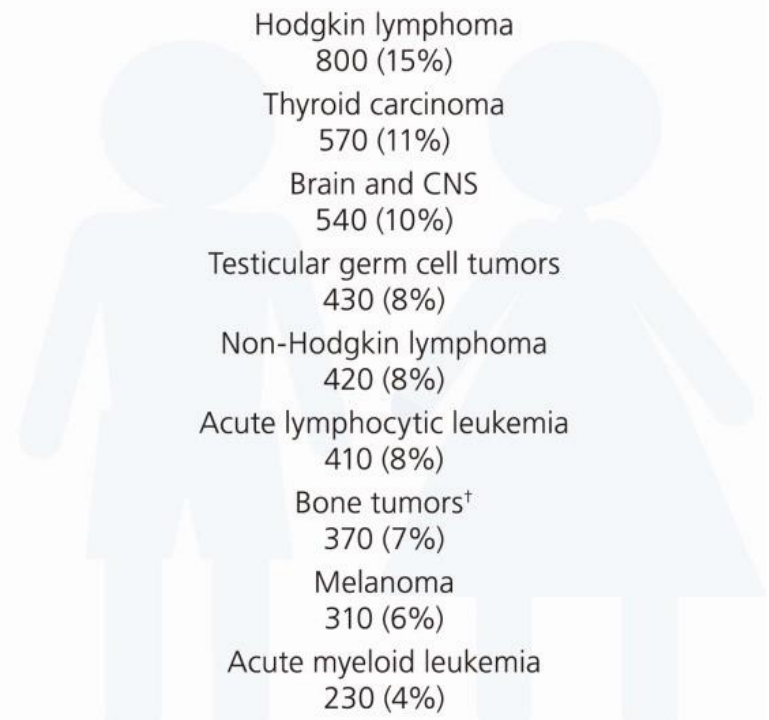
# The most common tumors in children

## Children (Ages 0-14)



Acute lymphocytic leukemia	2,670 (26%)
Brain and CNS	2,240 (21%)
Neuroblastoma*	710 (7%)
Non-Hodgkin lymphoma	620 (6%)
Wilms tumor	510 (5%)
Acute myeloid leukemia	500 (5%)
Bone tumors <sup>†</sup>	450 (4%)
Hodgkin lymphoma	380 (4%)
Rhabdomyosarcoma	340 (3%)
Retinoblastoma	280 (3%)
All sites	10,450

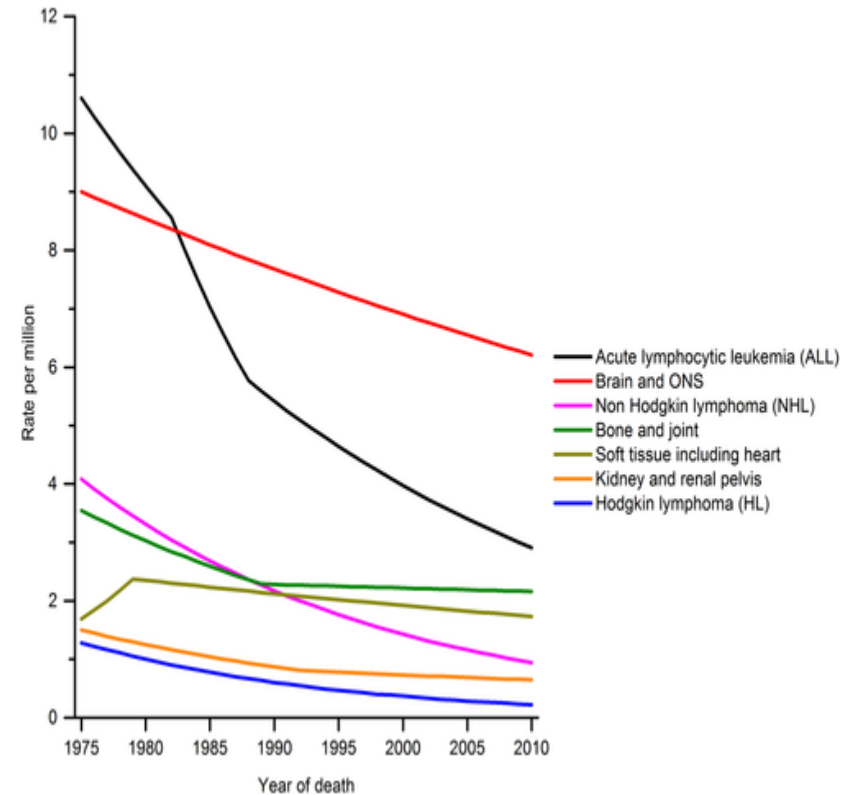
## Adolescents (Ages 15-19)



Hodgkin lymphoma	800 (15%)
Thyroid carcinoma	570 (11%)
Brain and CNS	540 (10%)
Testicular germ cell tumors	430 (8%)
Non-Hodgkin lymphoma	420 (8%)
Acute lymphocytic leukemia	410 (8%)
Bone tumors <sup>†</sup>	370 (7%)
Melanoma	310 (6%)
Acute myeloid leukemia	230 (4%)
Ovarian germ cell tumors	110 (2%)
All sites	5,330

# Epidemiology

- National Cancer Institute, the Centers for Disease Control and Prevention, and the North American Association of Central Cancer Registries- 15,780 new cases diagnosed annually
- Approximately 1 child in 500 will develop cancer before the age of 15



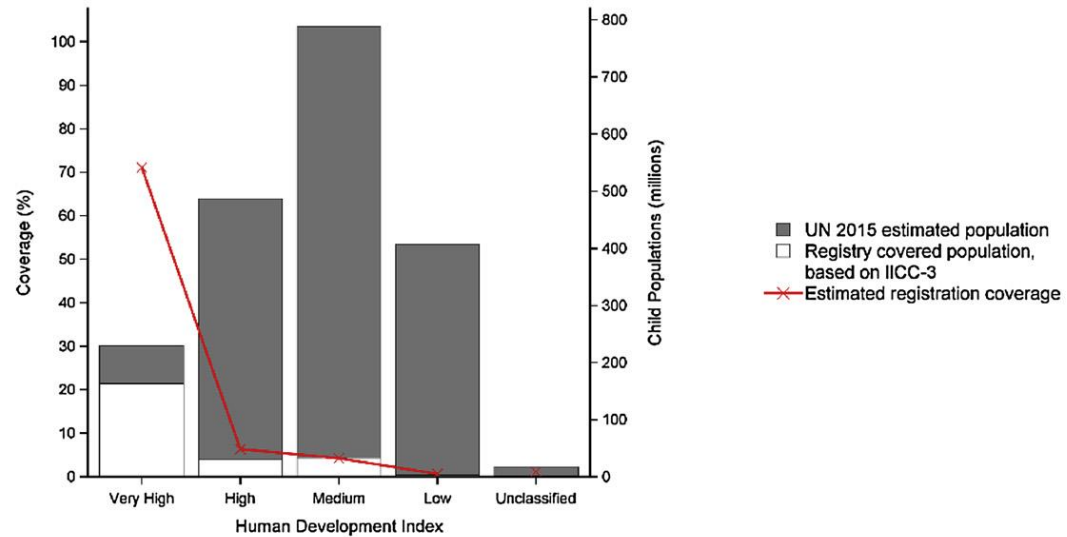
**Trend stope mortaliteta**

In 2015, a total of 360,114 childhood cancers were diagnosed in the world, of which 54% were diagnosed in Asia and 28% in Africa.

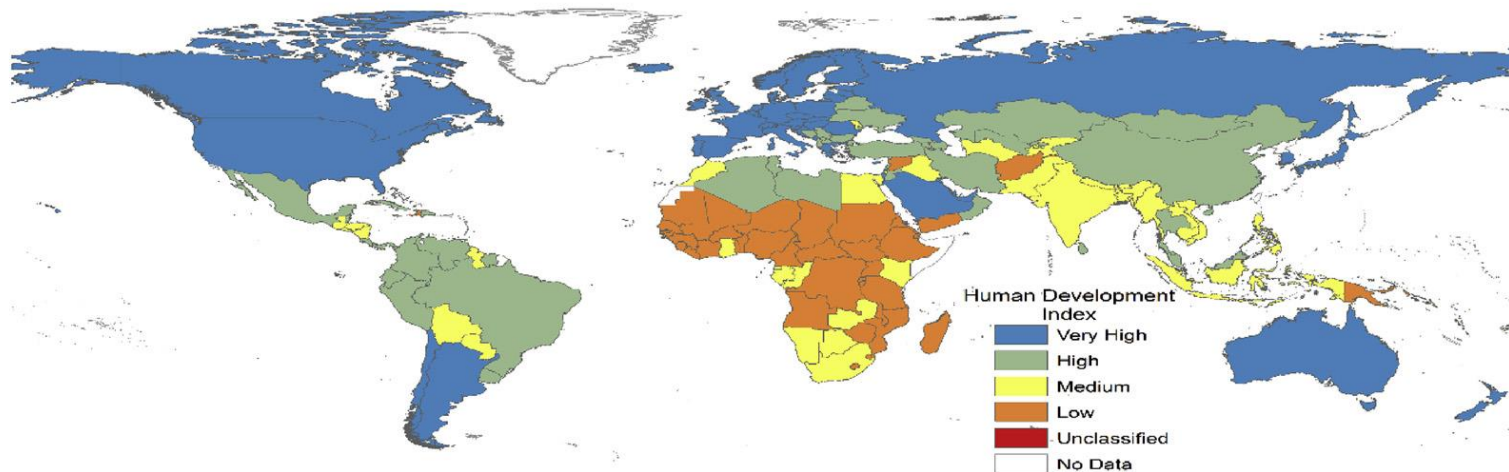
The estimated standardized rates ranged from  
~178 cases per million in Europe and North America, to  
~218 cases per million in West and Central Africa.

# Distribution of newly diagnosed tumors in children

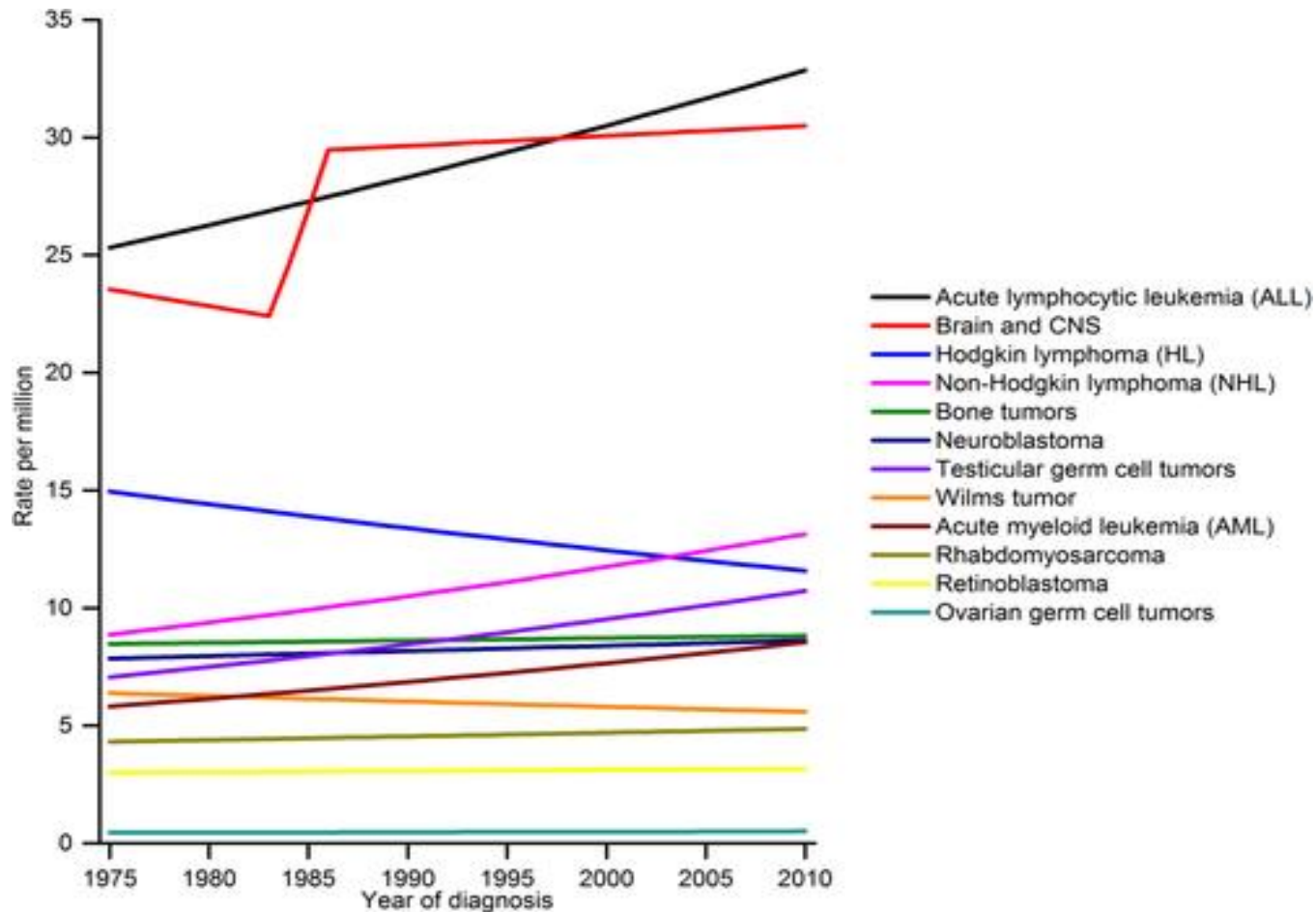
A



B



# Incidence trends of pediatric tumors



- The prognosis of tumors in children is different from tumors in adults
- Most tumors in childhood are determined by high radiosensitivity
- Modern treatment regimens ensure longer survival and now more than 2/3 have long-term survival
- RT is used in 40-50% of children with tumors, in addition to CHT and surgery
- In addition to success in treatment, it is particularly important to apply all procedures to reduce late sequelae to the smallest possible extent
- **Late effects of RT**: soft tissue hypoplasia, bone growth retardation, CNS neuropsychological effects, and radiation-induced secondary tumors
- Use of **CHT associated with late effects** of therapy (late myocardial damage due to anthracycline administration, nephrotoxicity due to cisplatin and ifosfamide and secondary leukemia due to alkylating agents)



# Radiotherapy of tumors in children - general aspects

- It is carried out in highly specialized centers
- The radiotherapy team consists of: a pediatric radiation oncologist, a medical physicist, a radiation technician and a nurse
- Smaller daily doses per fraction (1.2-1.8 Gy)

The patient and family are involved in the treatment process.

- RT in children up to 3-4 years of age requires the use of short-term general anesthesia
- Mandatory rigorous quality control
- Avoid using large fields whenever possible



# HHS Public Access

Author manuscript

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*Clin Oncol (R Coll Radiol)*. 2019 March ; 31(3): 199–207. doi:10.1016/j.clon.2019.01.002.

## **Pediatric Normal Tissue Effects in the Clinic (PENTEC): an international collaboration to analyze normal tissue radiation dose-volume-response relationships for pediatric cancer patients**

Louis S. Constine<sup>a</sup>, Cécile M. Ronckers<sup>b,c</sup>, Chia-Ho Hua<sup>d</sup>, Arthur Olch<sup>e</sup>, Leontien C. M. Kremer<sup>b,c</sup>, Andrew Jackson<sup>f</sup>, Soren M. Bentzen<sup>g</sup>

### Highlights

- RT for pediatric cancer can cause long-term adverse normal tissue effects
- Radiation damage depends on the radiation dose and volume, and developmental status
- For some organs, chemotherapy can exacerbate the effects of radiation
- PENTEC seeks to increase knowledge about pediatric RT dose constraints for organs
- Radiation dosimetric data should be precisely reported in pediatric RT studies

# Leukemias in childhood

- The most common malignant disease in children (30% of childhood malignancies)
- 4000 new cases in the world annually
- ALL (80%), AML (15-20%), CML (5%)

# Treatment of leukemia

- **Surgery** is not used
- **Systemic CHT**
- **Radiotherapy**
- Prophylactic WBRT of the CNS in 10-15% of patients with ALL (Intrathecal administration of CHT is preferred to avoid toxicity)
- Cranial and craniospinal RT in disease relapse



# Cranial and craniospinal radiotherapy in leukemia patients

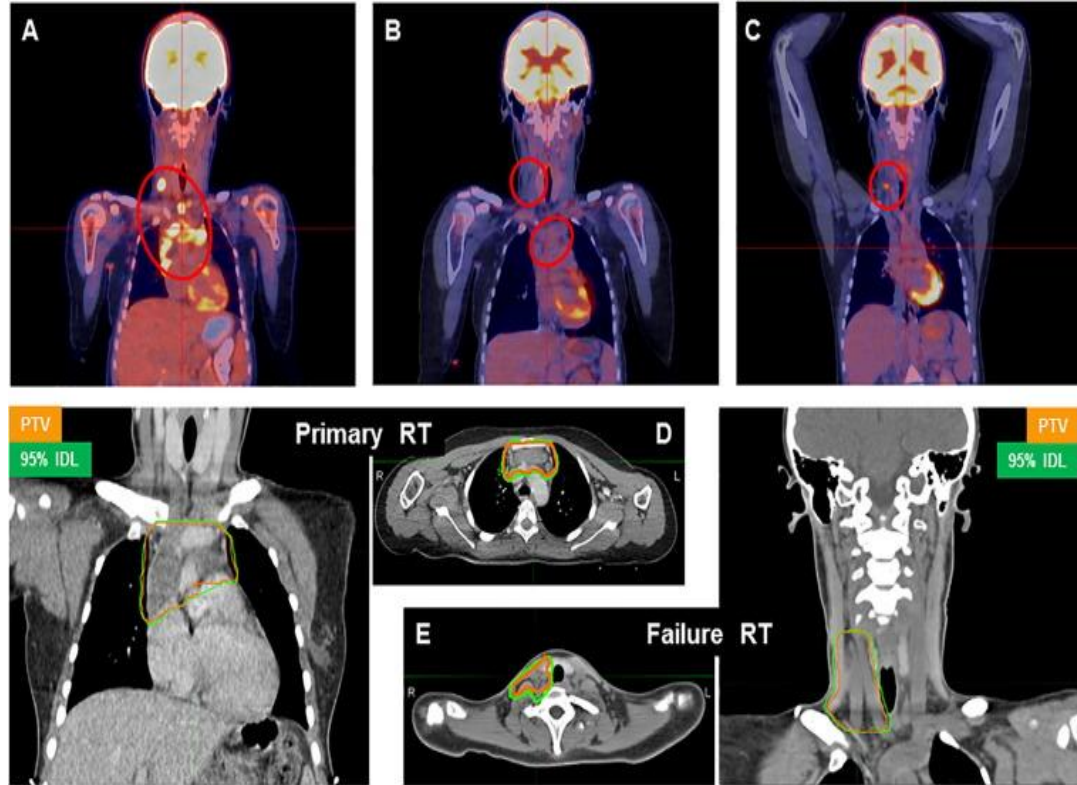
- Delineation of target volume structures for prophylactic and therapeutic RT
- CTV (entire endocranium, both retrobulbar spaces, skull base, C1-C2)
- CTVsp (dural sac with intervertebral openings, cranial border of the lower edge of CTVcr, caudal 2cm below the end of the dural space)
- PTV = CTV + 5mm
- OAR (eye lens, spinal vertebrae, spinal cord)
- Prophylactic dose 12 Gy (1.2 Gy per fraction)
- Therapeutic cranial dose 18 - 24 Gy (1.5 Gy per fraction)
- Spinal dose 6-18 Gy (1.8-2 Gy per fraction)

# Testicular radiotherapy in leukemia patients

- Indications:
- Residual testicular disease persists after CHT
- Relapse of the testicles
- TD 24 Gy (2Gy per fraction)

# Hodgkin's lymphoma in childhood

- Over 80% older than 10 years
- Enlargement of neck LN, mediastinum, supraclavicular LN
- 25-30% B symptomatology
- 10% diagnosed in the IV stage



## Treatment

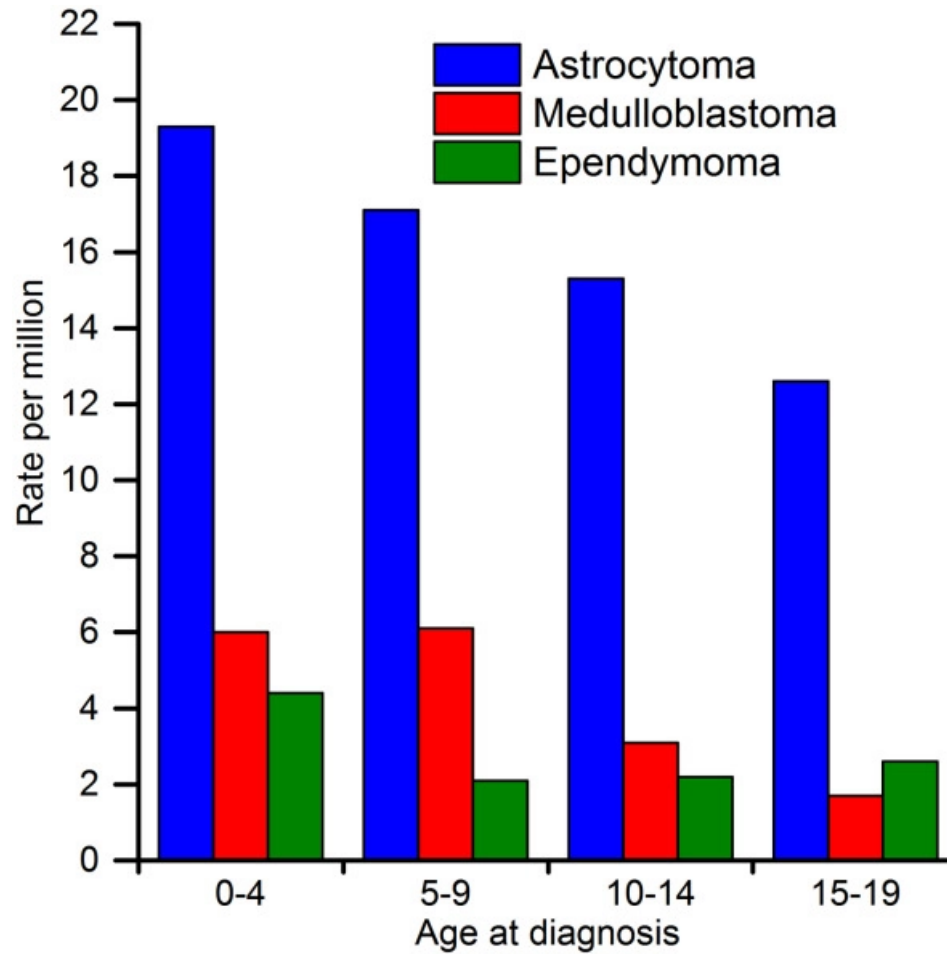
- HT (MOPP, ABVD, ABVD/MOPP, GPOH-HD95, BEACOPP)
- PR or CR – RT applied

- **RT contraindications:** low risk patients, complete remission after HT
- **Indications for RT:**
- PR after HT = RT with TD 15-25 Gy (1.8 Gy per fraction)
- Intermediate and High risk patients = RT regardless of the achieved effect of CHT with TD 15-25 Gy
- Residual disease after HT= IF technique with TD 20-36 Gy
- Disease relapse after HT= IF technique with TD 20-36 Gy

# **Tumors of the central nervous system in childhood**

- Brain tumors in children account for 20% of tumors in pediatric population
- The 5-year survival is about 50%, which is lower than for other pediatric tumors
- Cured children have sequelae either from the tumor or oncological treatment or both
- CHT has not yet contributed to a significant improvement in survival for most pediatric CNS tumors
- Neuro-oncology multidisciplinary team

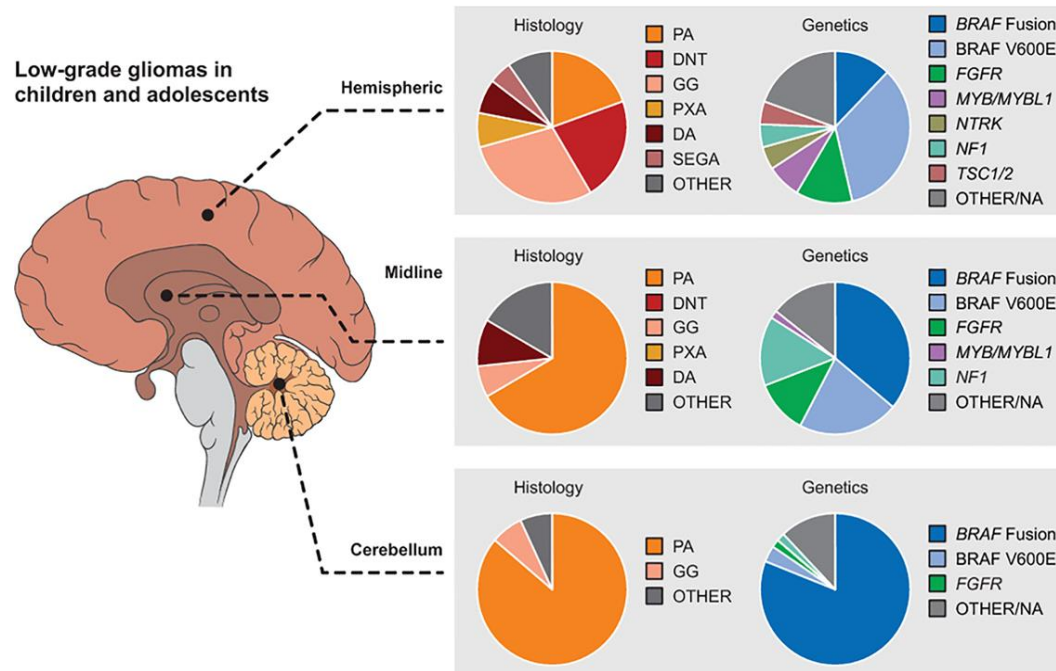
# Frequency of certain tumors of the CNS in children





# Low-grade gliomas

Low-grade gliomas radiotherapy is based on precise imaging to define target volumes



# Radiotherapy techniques for low-grade gliomas

## Position and immobilization

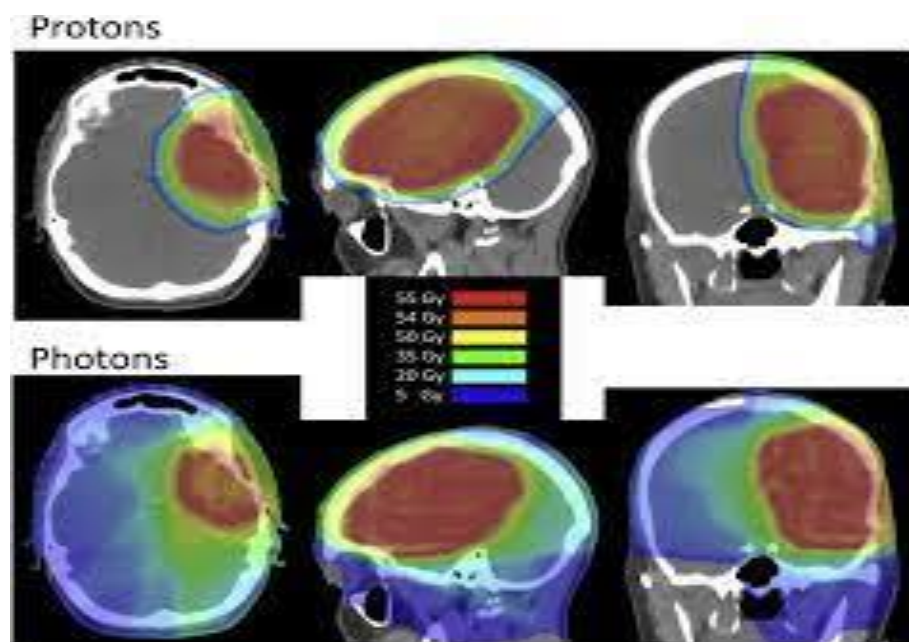
Supination or pronation depending on the anatomy, immobilization - head mask

## Target volumes

GTV - visible tumor on imaging (T2 or "Flair" MRI, fusion with CT)

CTV – in case of surgical resection, the brain tissue that surrounded the tumor with a margin of 0.5 cm for potential spread

54Gy in 30 fractions with 1.8Gy per day



## The 2021 WHO Classification of Tumors of the Central Nervous System: a summary

David N. Louis, Arie Perry, Pieter Wesseling<sup>\*</sup>, Daniel J. Brat<sup>\*</sup>, Ian A. Cree, Dominique Figarella-Branger, Cynthia Hawkins, H. K. Ng, Stefan M. Pfister, Guido Reifenberger, Riccardo Soffietti, Andreas von Deimling, and David W. Ellison

Download

Medulloblastoma, WNT-activated	<i>CTNNB1, APC</i>
Medulloblastoma, SHH-activated	<i>TP53, PTCH1, SUFU, SMO, MYCN, GLI2</i> (methylome)
Medulloblastoma, non-WNT/non-SHH	<i>MYC, MYCN, PRDM6, KDM6A</i> (methylome)

# Medulloblastoma

WNT-activated  
SHH-activated  
*non SHH non*  
WNT

- Tendency to spread via cerebrospinal fluid
- 5-year survival for medulloblastoma 60-70% and similar supratentorial localized tumors 40-50%

# Medulloblastoma

- Surgical resection followed by craniospinal RT with a boost dose applied to the primary tumor site
- Standard application of adjuvant chemotherapy (Vincristine, CCNU, Cisplatin)

# More recent studies also consider prognostic groups: standard and high risk

Standard risk group (age >3 years, postoperative residual tumor <1.5 cm<sup>2</sup>, no signs of dissemination). The percentage of five-year disease free survival is 80%.

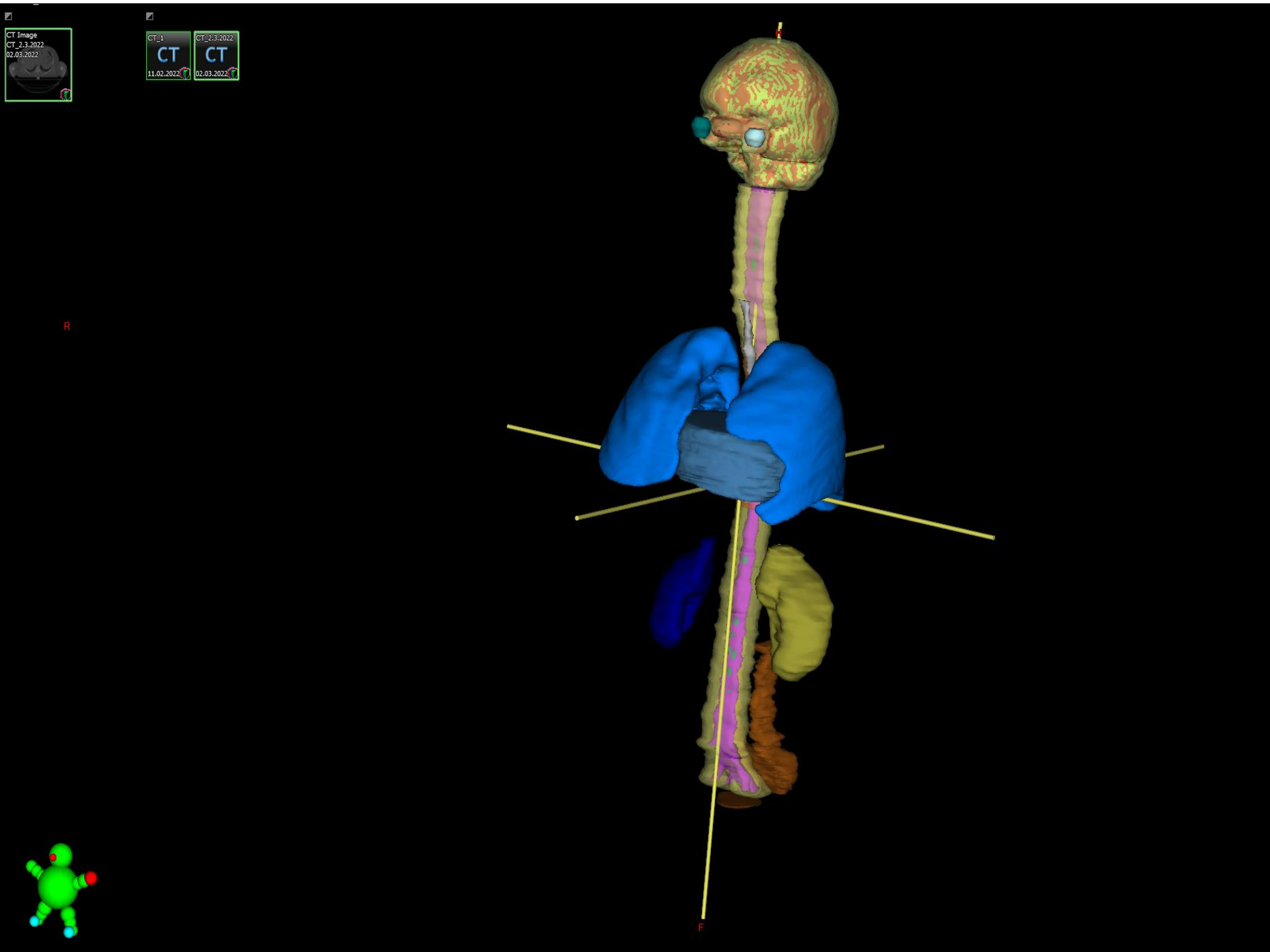
High-risk group (age < 3 years, postoperative residual tumor >1.5 cm<sup>2</sup>, metastatic disease, subtotal resection or biopsy only, male sex). Local relapse often occurs.

Risk	Craniospinal dose	Boost to the posterior cranial fossa
Standard	23,4 Gy in 13 fractions	54-55,8 Gy
High	36-39,6 Gy in 20-22 fractions	54-55,8 Gy



# **Craniospinal radiotherapy (CSRT) of medulloblastoma**

- CSRT is one of the most complex radiotherapy technique
- Patient position and immobilization
- Most often, pronation with a head mask, although supination with immobilization of the body is also possible



R

F





CT Image  
CT 2.3.2022  
02.03.2022

CT\_1  
CT  
11.02.2022

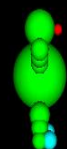
CT\_2.3.2022  
CT  
02.03.2022

H

50.0 cm

A

P



X: 0.38 cm

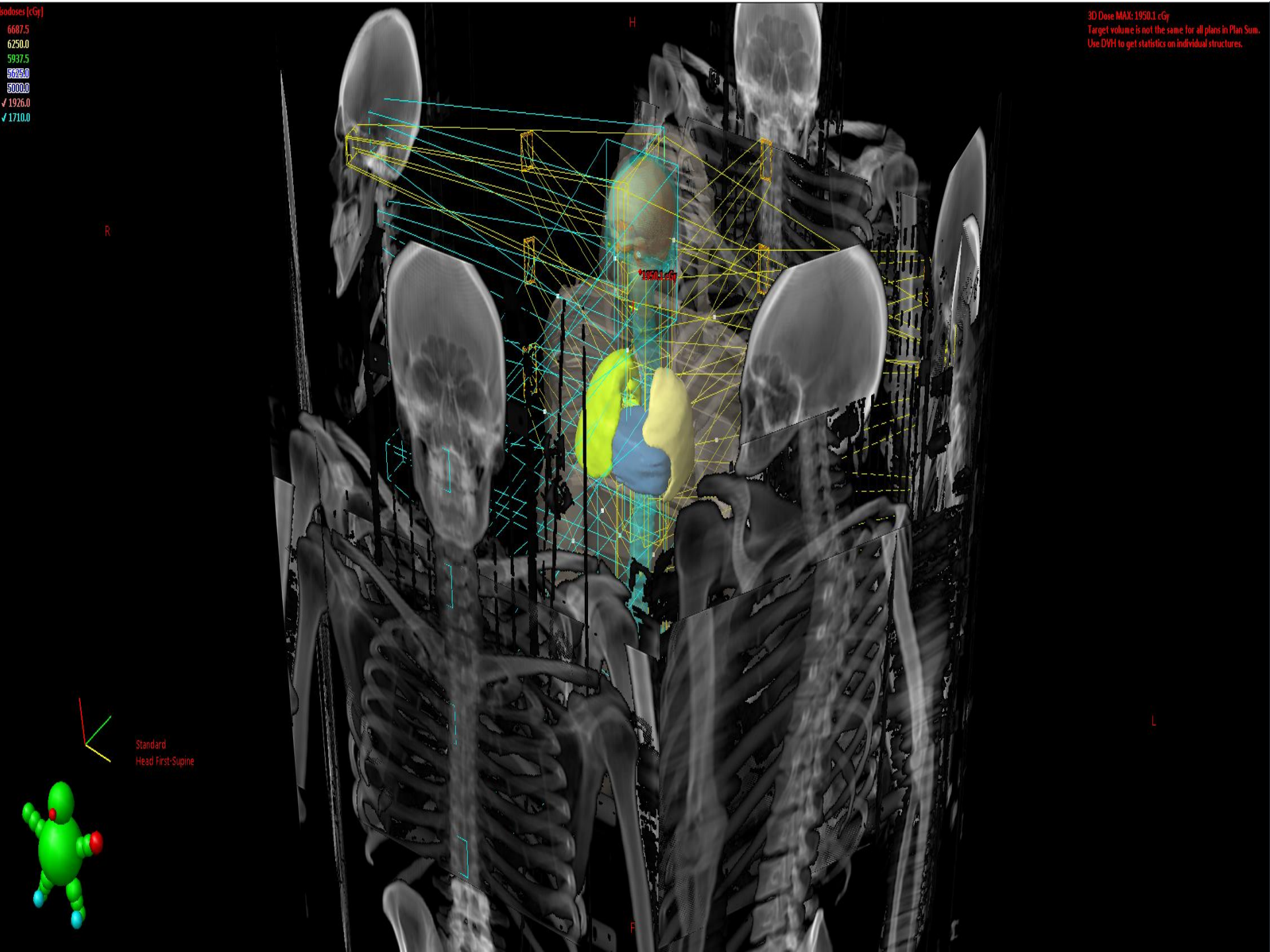
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(oncologylaca 08.03.2022 08:30)



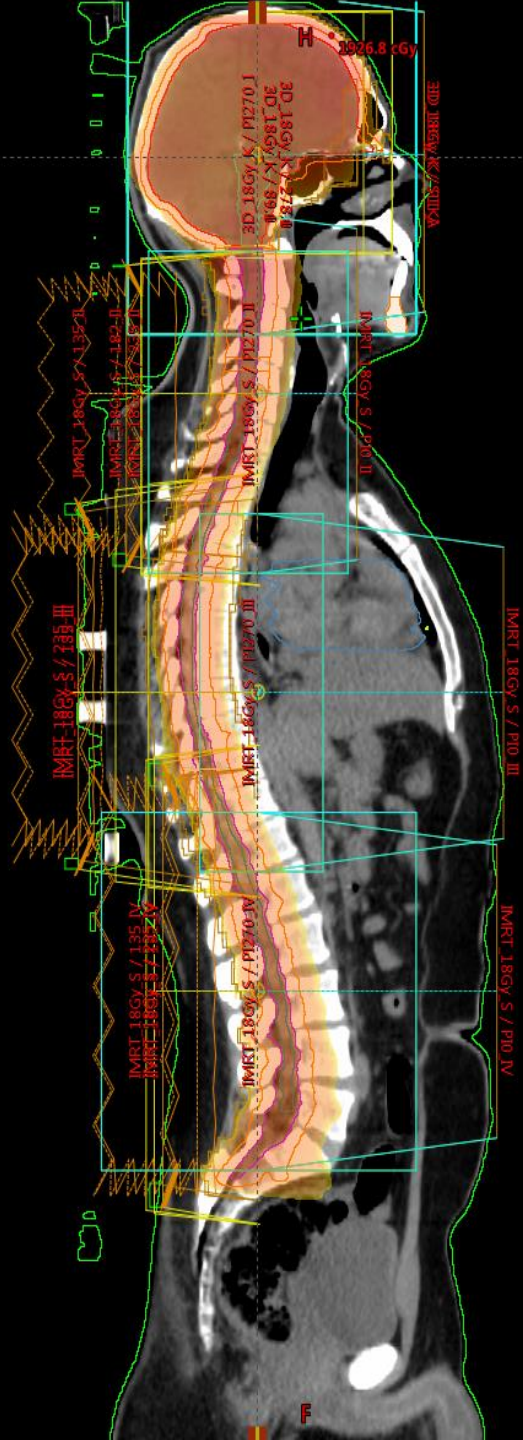
boluses [cGy]  
6687.5  
6250.0  
5937.5  
5625.0  
5000.0  
✓ 1926.0  
✓ 1710.0

3D Dose MAX: 1950.1 cGy  
Target volume is not the same for all plans in Plan Sum.  
Use DVH to get statistics on individual structures.

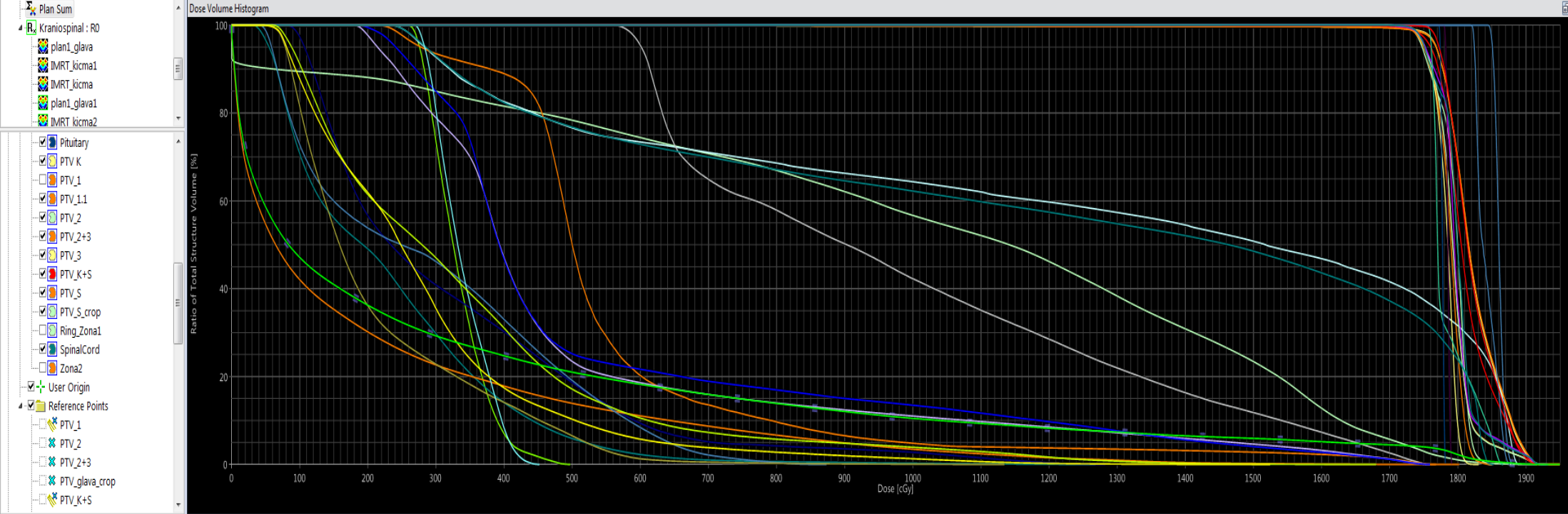


Standard  
Head First-Supine







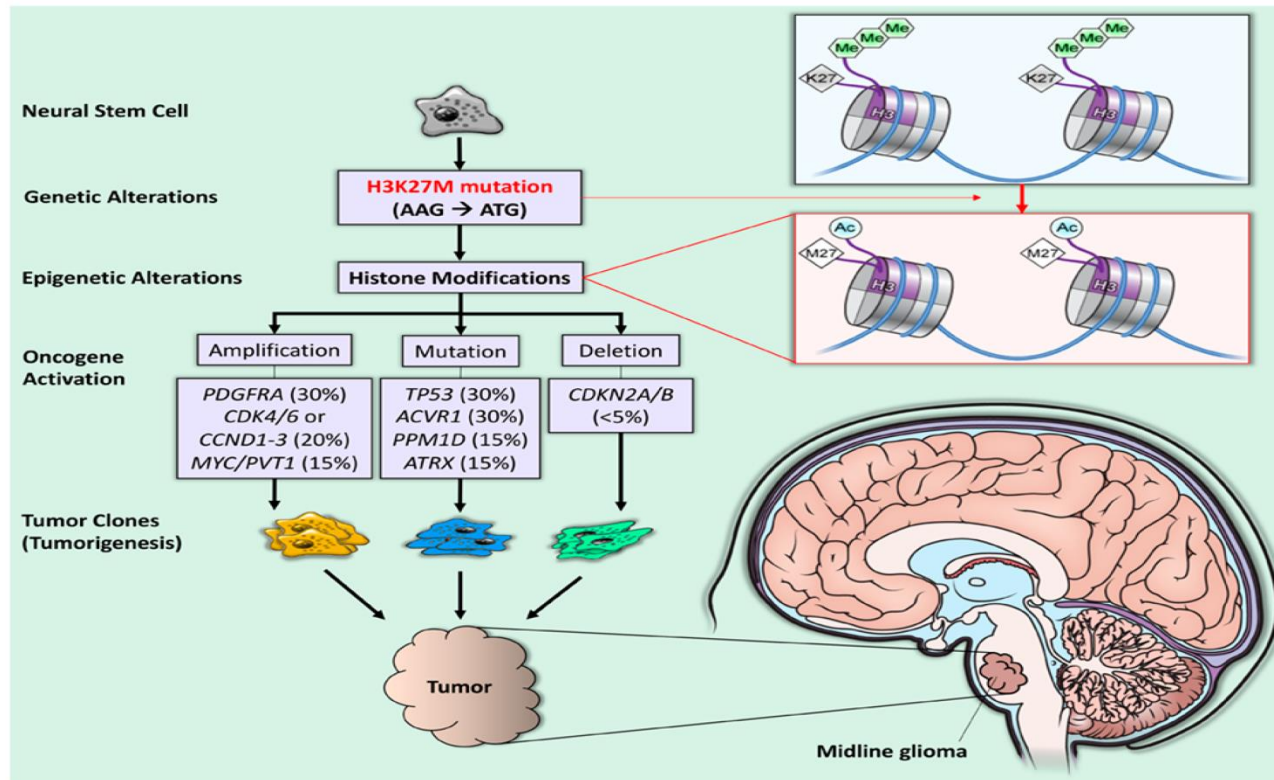


Show DVH	Structure	Approval Status	Plan	Course	Volume [cm³]	Dose Cover [%]	Sampling Cover [%]	Min Dose [cGy]	Max Dose [cGy]	Mean Dose [cGy]	
<input checked="" type="checkbox"/>	Liver	Approved	Plan Sum	1	2498.9	100.0	100.0	30.9	1268.6	226.9	
<input checked="" type="checkbox"/>	BODY	Approved	Plan Sum	1	85528.6	100.0	100.0	0.0	1950.1	315.5	
<input checked="" type="checkbox"/>	Lung_L	Approved	Plan Sum	1	1014.2	100.0	100.0	47.7	1525.2	280.1	
<input checked="" type="checkbox"/>	Lung_R	Approved	Plan Sum	1	1376.1	100.0	100.0	58.4	1681.2	335.4	
<input checked="" type="checkbox"/>	SpinalCord	Approved	Plan Sum	1	52.4	100.0	99.9	1673.4	1933.3	1800.6	
<input checked="" type="checkbox"/>	CTVc	Approved	Plan Sum	1	1515.6	100.0	100.0	403.4	1920.0	1819.9	
<input checked="" type="checkbox"/>	Lens_R	Approved	Plan Sum	1	0.2	100.0	98.8	258.3	497.7	332.2	
<input checked="" type="checkbox"/>	Lens_L	Approved	Plan Sum	1	0.2	100.0	99.9	268.2	451.8	338.5	
<input checked="" type="checkbox"/>	Eye_L	Approved	Plan Sum	1	8.8	100.0	100.1	229.9	1853.2	1213.1	
<input checked="" type="checkbox"/>	Eye_R	Approved	Plan Sum	1	9.0	100.0	100.0	234.8	1890.0	1253.7	
<input checked="" type="checkbox"/>	OpticNerve_L	Approved	Plan Sum	1	0.3	100.0	100.4	1819.4	1876.7	1841.4	
<input checked="" type="checkbox"/>	OpticNerve_R	Approved	Plan Sum	1	0.4	100.0	100.5	1845.3	1880.2	1860.7	
<input checked="" type="checkbox"/>	Pituitary	Approved	Plan Sum	1	0.0	100.0	101.9	1772.2	1782.1	1777.4	
<input checked="" type="checkbox"/>	Chiasm	Approved	Plan Sum	1	0.4	100.0	100.1	1779.5	1791.6	1785.5	
<input checked="" type="checkbox"/>	BrainStem	Approved	Plan Sum	1	24.0	100.0	100.0	1753.3	1866.9	1785.6	
<input checked="" type="checkbox"/>	Parotid_L	Approved	Plan Sum	1	27.4	100.0	100.1	182.5	1759.6	537.0	
<input checked="" type="checkbox"/>	Parotid_R	Approved	Plan Sum	1	25.3	100.0	100.0	178.2	1759.2	510.9	
<input checked="" type="checkbox"/>	Mandible	Approved	Plan Sum	1	68.0	100.0	99.9	193.2	1767.8	560.9	
<input checked="" type="checkbox"/>	Esophagus	Approved	Plan Sum	1	28.6	100.0	100.2	560.7	1754.7	980.9	
<input checked="" type="checkbox"/>	CTVs	Approved	Plan Sum	1	154.6	100.0	100.0	1622.4	1933.3	1798.3	
<input checked="" type="checkbox"/>	Heart	Approved	Plan Sum	1	894.7	100.0	100.0	40.0	873.4	289.1	
<input checked="" type="checkbox"/>	Kidney_L	Approved	Plan Sum	1	278.4	100.0	100.0	51.8	1134.8	214.4	
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<input checked="" type="checkbox"/>	PTV_S_crop	Approved	Plan Sum	1	954.0	100.0	100.0	1637.0	1930.5	1794.0	
<input checked="" type="checkbox"/>	PTV_K	Approved	Plan Sum	1	1926.8	100.0	100.0	291.8	1928.5	1818.4	
<input checked="" type="checkbox"/>	PTV_1	Approved	Plan Sum	1	2058.0	100.0	100.0	291.8	1950.1	1819.3	
<input checked="" type="checkbox"/>	PTV_2	Approved	Plan Sum	1	354.9	100.0	100.0	1684.0	1851.4	1794.2	
<input checked="" type="checkbox"/>	PTV_3	Approved	Plan Sum	1	479.6	100.0	100.0	1637.0	1831.4	1782.4	
<input checked="" type="checkbox"/>	PTV_K+S	Approved	Plan Sum	1	2899.6	100.0	100.0	291.8	1950.1	1810.0	
<input checked="" type="checkbox"/>	Ring_Zona1	Approved	Plan Sum	1	3886.7	100.0	99.7	0.0	1917.0	1009.3	
<input checked="" type="checkbox"/>	Zona2	Approved	Plan Sum	1	7804.4	100.0	100.0	0.0	1802.8	202.9	
<input checked="" type="checkbox"/>	PTV_2+3	Approved	Plan Sum	1	836.3	100.0	100.0	1637.0	1851.4	1787.4	
<input checked="" type="checkbox"/>	PTV_1.1	Approved	Plan Sum	1	2050.9	100.0	100.0	291.8	1950.1	1819.3	
<input checked="" type="checkbox"/>	PTV_S	Approved	Plan Sum	1	970.0	100.0	100.0	1463.0	1950.1	1793.5	



# Tumors of the brainstem

- Chemotherapy did not show benefit
- Conventional radiotherapy provides useful palliation in 75% of children
- PFS usually less than 6 months
- Hyperfractionated or accelerated RT does not improve treatment outcome



# Brainstem tumors

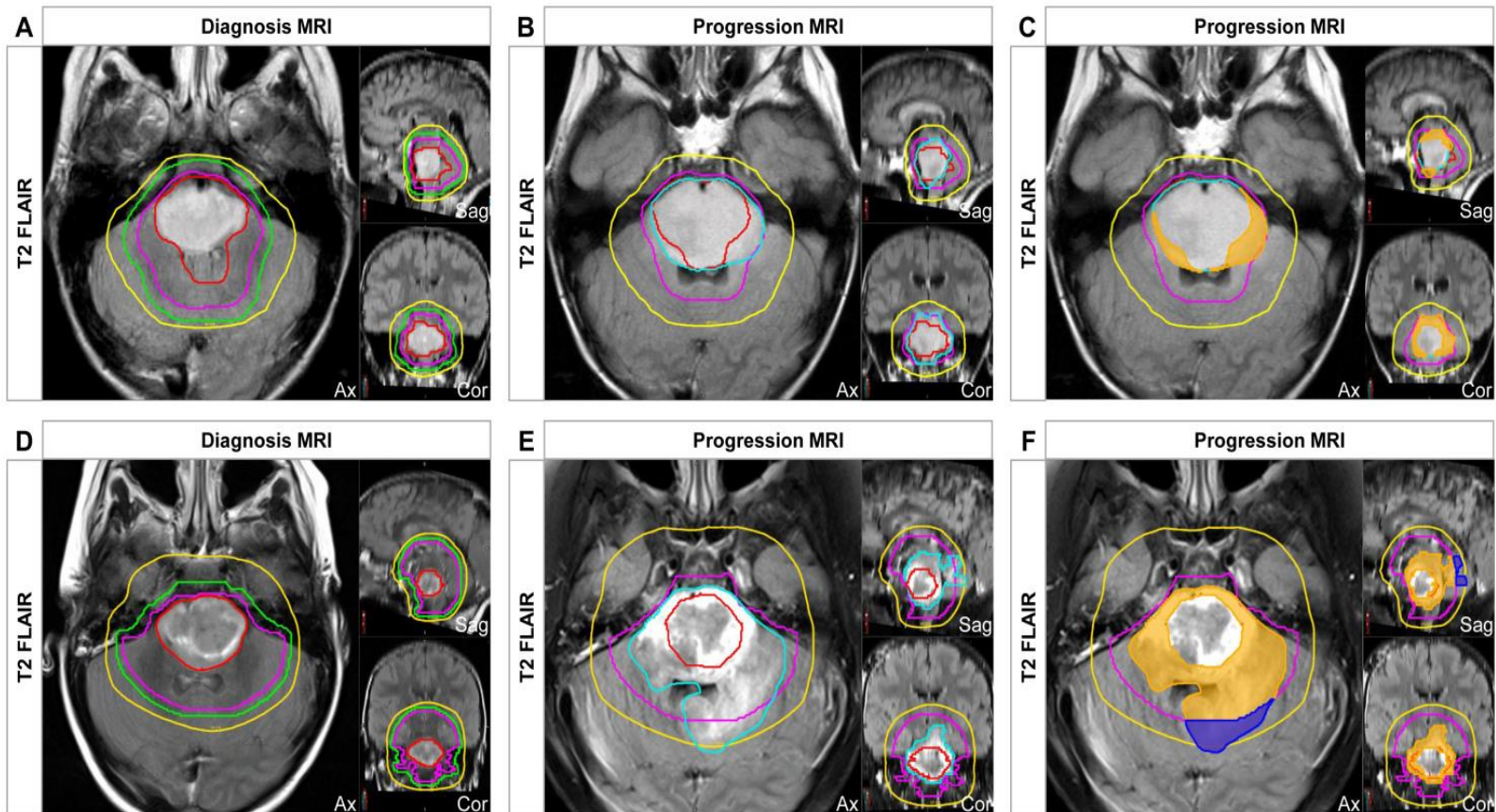
- Include tumors of the midbrain, pons and medulla.
- Focal (5-10%), dorsal exophytic (10-20%), cervicomedullary (5-10%) and diffuse tumors (75-85%).
- Focal, dorsal exophytic and cervicomedullary tumors are usually low grade astrocytomas.
- Treatment:
- **Surgical excision**
- **RT** reserved for inoperable tumors

# Brainstem tumors

- Most children with brainstem tumors have an H3 K27M-mutated diffuse midline glioma, usually a high-grade astrocytoma.
- Typical MRI presentation, and a biopsy is usually risky and contraindicated.
- Poor prognosis - RT should be started quickly
- Involved field radiotherapy is the primary treatment for midline diffuse infiltrative gliomas.
- GTV (MRI T2/FLAIR) with a uniform margin of 2 cm in all directions along the potential region of spread, superiorly, inferiorly, and posteriorly along the brainstem.

# Radiotherapy techniques

TD54Gy in 30 fractions with 1.8Gy daily



# Rhabdomyosarcoma (RMS) in childhood

- Soft tissue sarcomas account for 7% of all childhood malignancies
- It is the most common soft tissue sarcoma in the first decade of life
- Localization: orbit, nasopharynx, extremities and urogenital system
- It metastasizes hematogenously, to the lungs, liver and bones, and lymphogenously to the regional lymph nodes.
- Three histopathological forms:
  - **embryonic RMS** (80% of RMS, urogenital system, children up to 5 years of age, has a favorable prognosis)
  - **alveolar RMS** (in children and adolescents, extremities, has a less favorable prognosis)
  - **pleomorphic RMS** (in adults).

# Intergroup Rhabdomyosarcoma Studies (IRS)

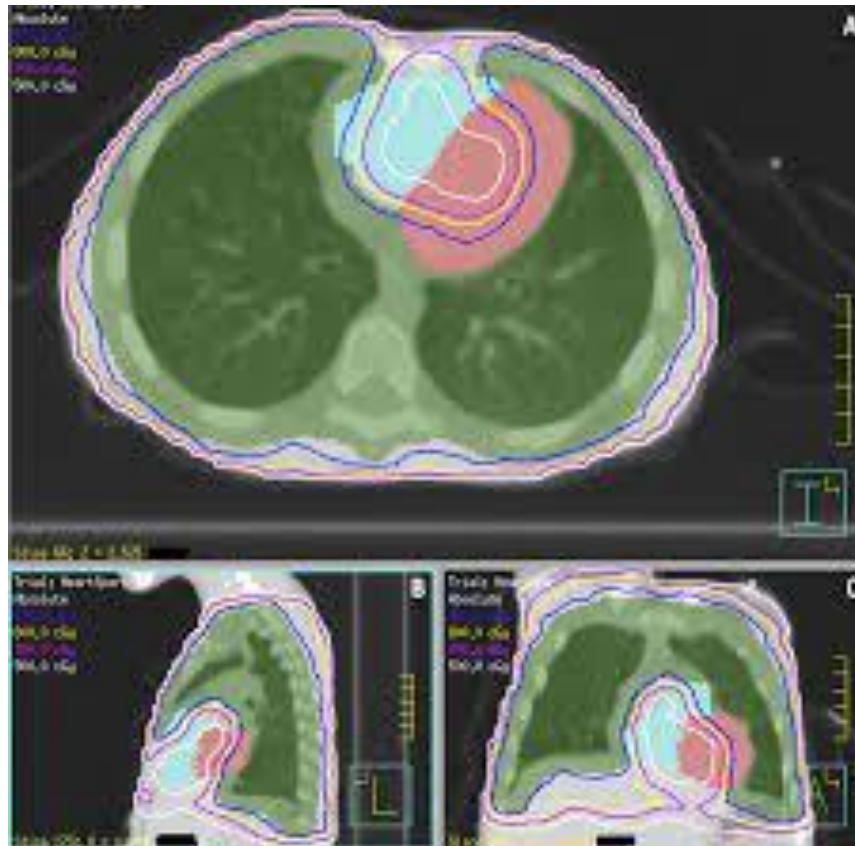
- **Group I** - the tumor was completely removed (R0), no malignant cells are present in the regional lymph nodes
- **Group II** - after removal of the tumor at the resection margin (R1), there are microscopic accumulations of residual tumor cells and/or extirpation of pathologically enlarged regional lymph nodes
- **Group III** - localized tumor that cannot be surgically removed in its entirety, macroscopic residual tumor is present at the resection margins (R2)
- **Group IV** - distant metastases are present

# Treatment of rhabdomyosarcoma in childhood

- **Surgery**
- **HT**
- **RT** (The target volume is defined in accordance with the recommendations of IGRU 50 and IGRU 62)
- The dose depends on the radicality of the surgical procedure and the locoregional stage of the disease
- Microscopic residual disease (after R1 resection) – TD 41.4 Gy (1.8 Gy per fraction)
- Macroscopically present tumor - TD from 50.4 to 54 Gy
- Unfavorable histological type localized in the orbit - TD 45 Gy
- Microscopic disease of favorable histological subtype, without spread to regional lymph nodes TD - 36 Gy
  
- GTV (Initial or residual tumor)
- CTV= GTV + margin 1-2cm
- PTV = CTV + margin 5-10 mm
- OAR (depending on localization)



- Lung metastases:
- Whole lung irradiation (WLI) – TD 15 Gy in 10 fractions
- Whole lung irradiation (WLI) – TD 12 Gy in 8 fractions (in children up to 6 years old)



Kalapurakal JA, et al. Cardiac-Sparing Whole Lung IMRT in Patients With Pediatric Tumors and Lung Metastasis: Final Report of a Prospective Multicenter Clinical Trial. *Int J Radiat Oncol Biol Phys* 2019;103(1):28-37.

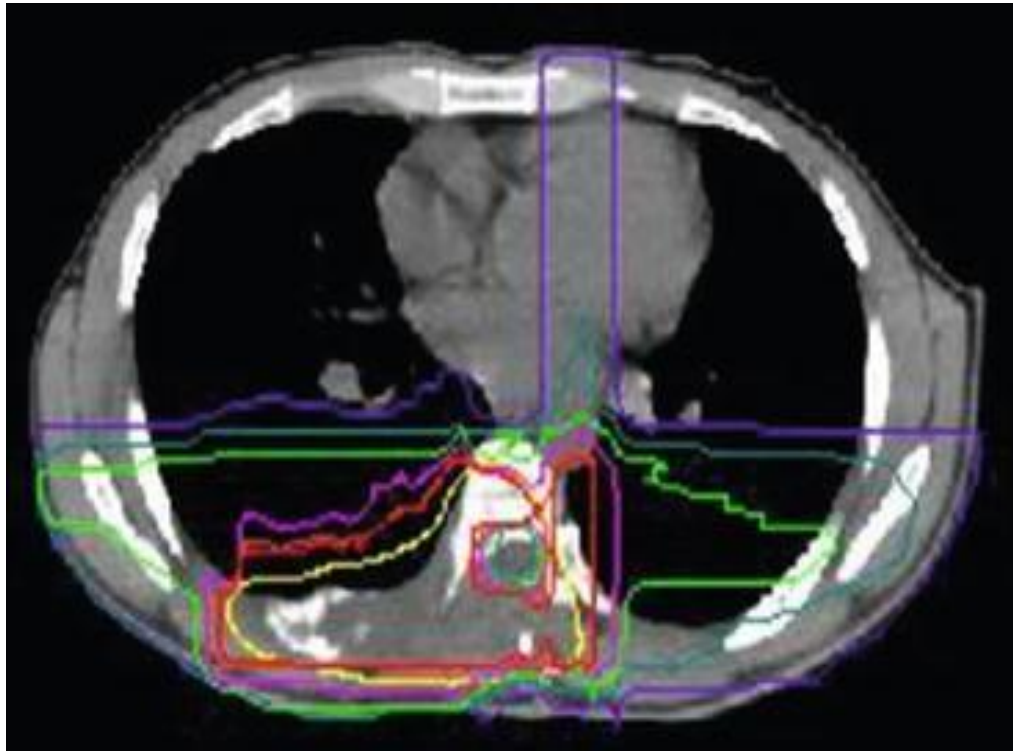
# Bone tumors in children

- The most common solid tumors in adolescents and young adults are second in incidence, behind malignant diseases of the hematopoietic system.
- Half of bone tumors in childhood are malignant.
- **Osteosarcoma** (metaphyses of long bones of the extremity: distal femur, proximal tibia, proximal or middle part of femur, proximal humerus)
- **Ewing sarcoma** (bones of the pelvis, ribs, diaphyses of long bones of the lower limbs)



# Bone tumors in children

- The advantage of using protons over photons
- RT is carried out according to the same principles as in adults



# THANK YOU FOR YOUR ATTENTION!

