HITRI plus
Heavy Ion Therapy Research Integration

Case Study Sacral Chordoma

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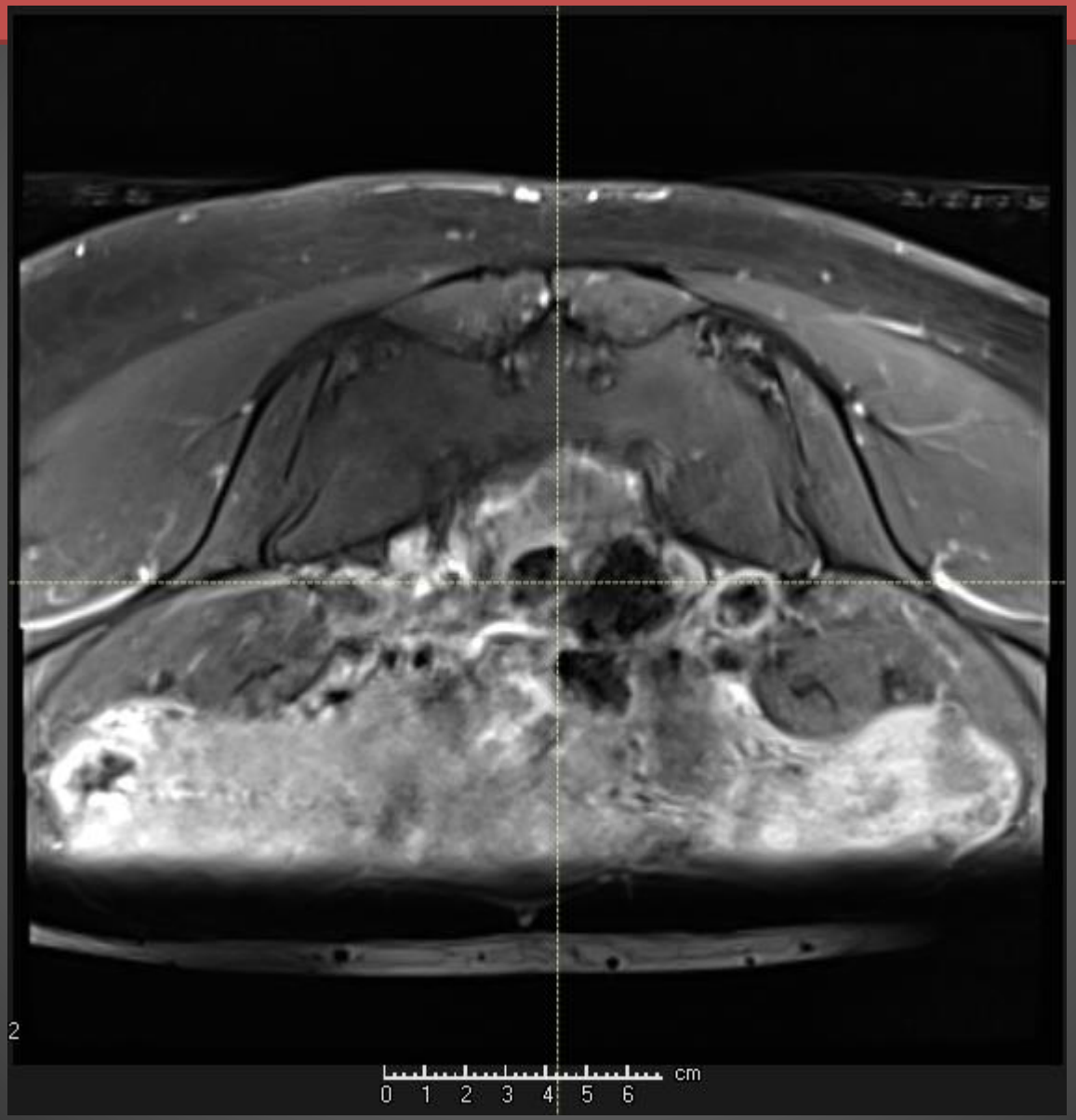
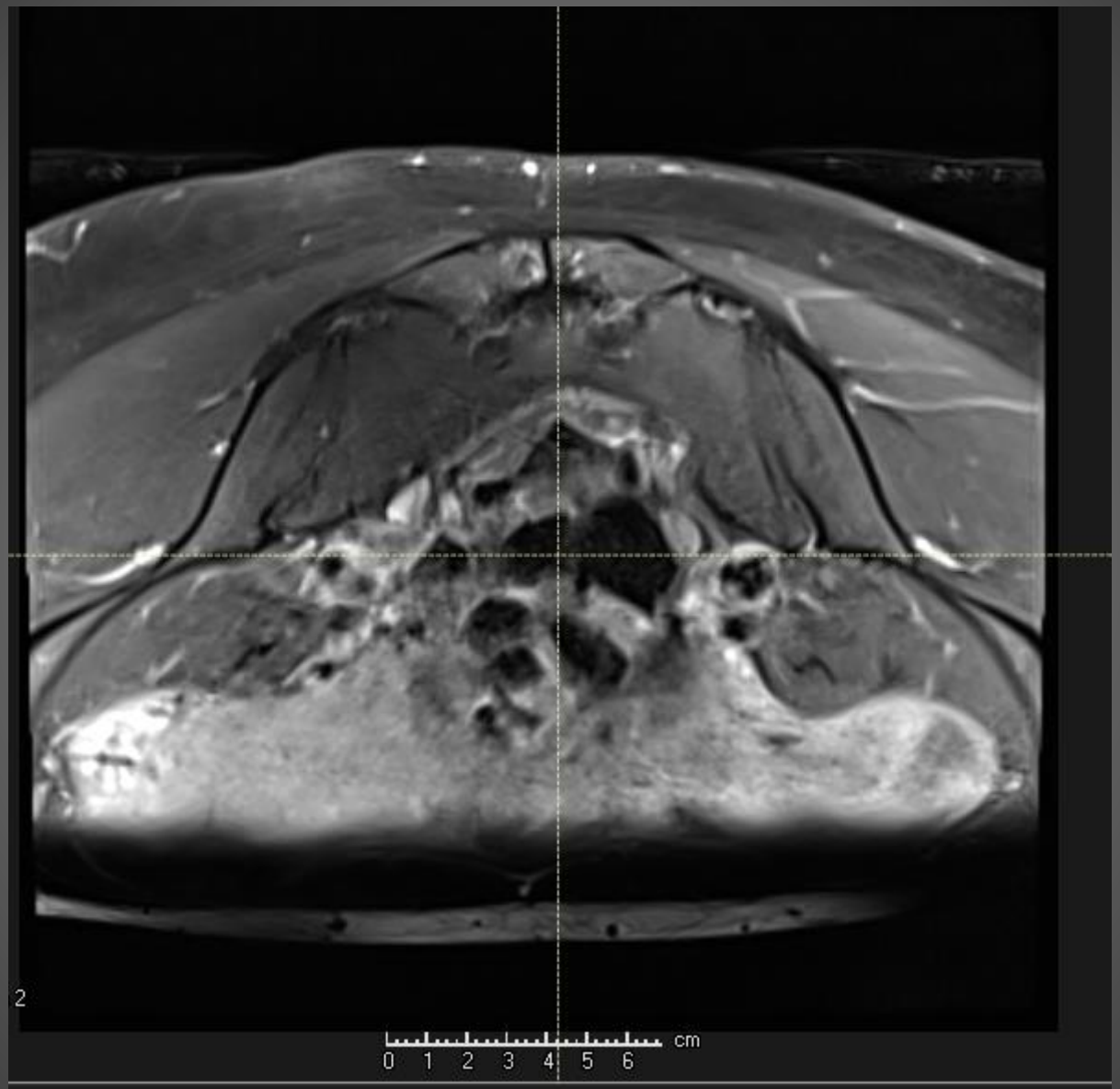
Sacral chordoma

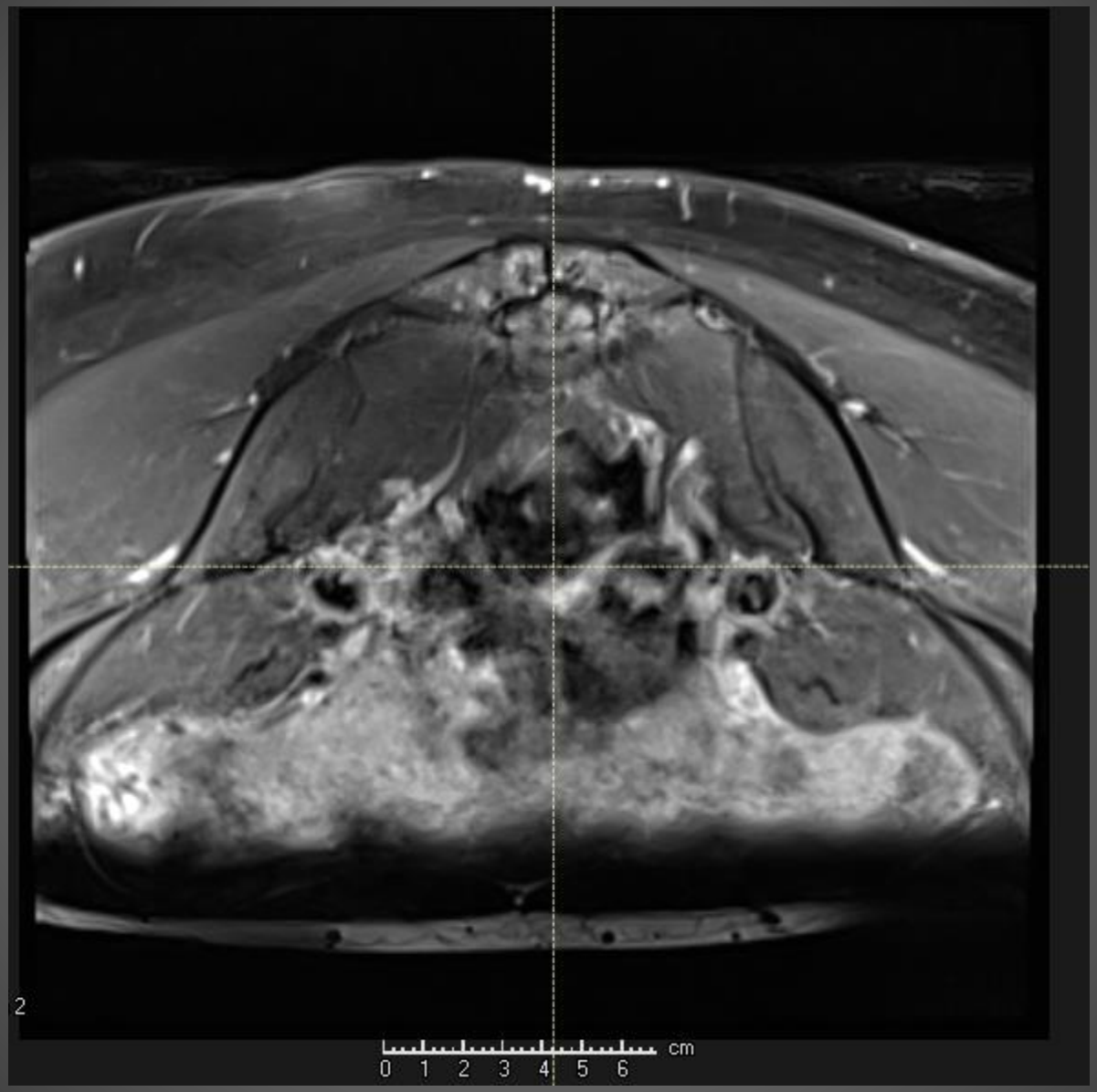
- **Female 35 YO**
- Presenting symtoms: Urinary retention
  Fecal retention
  Perineal hypoestesei
  Mild sacral pain

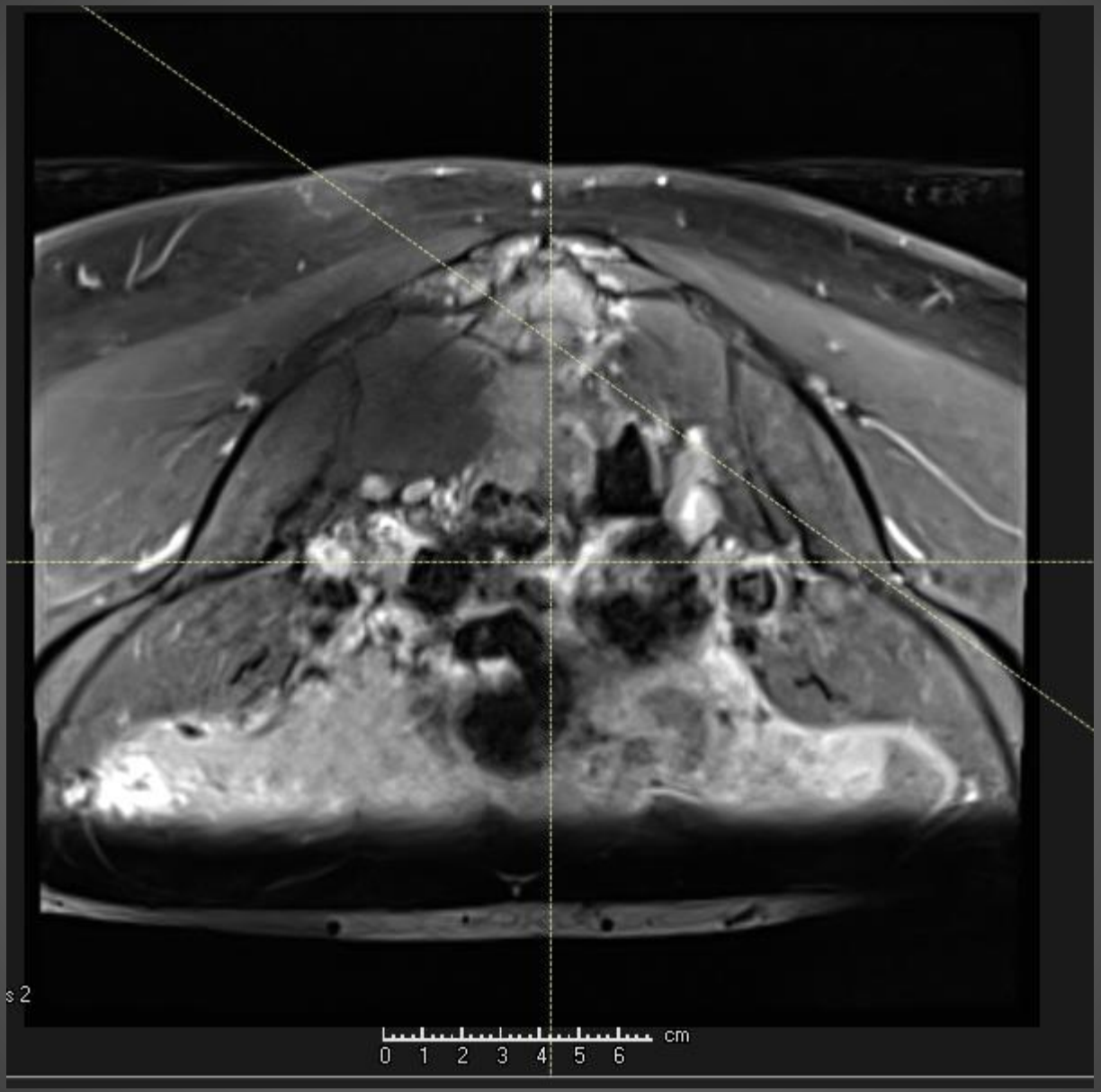
Comorbidities : unremarkable

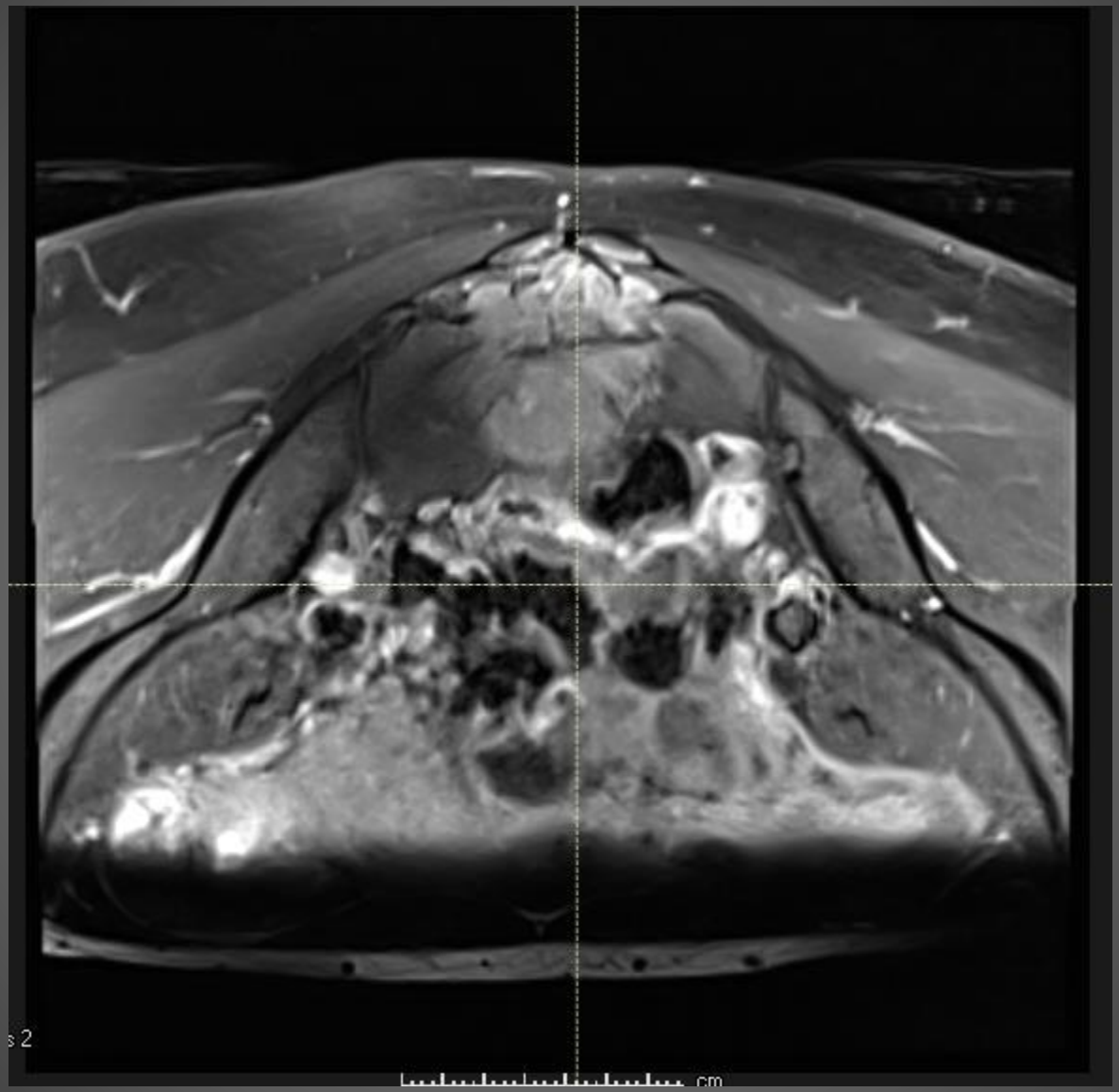
MRI




2
cm
0 1 2 3 4 5 6


2
cm
0 1 2 3 4 5 6


s 2
cm
0 1 2 3 4 5 6


s 2

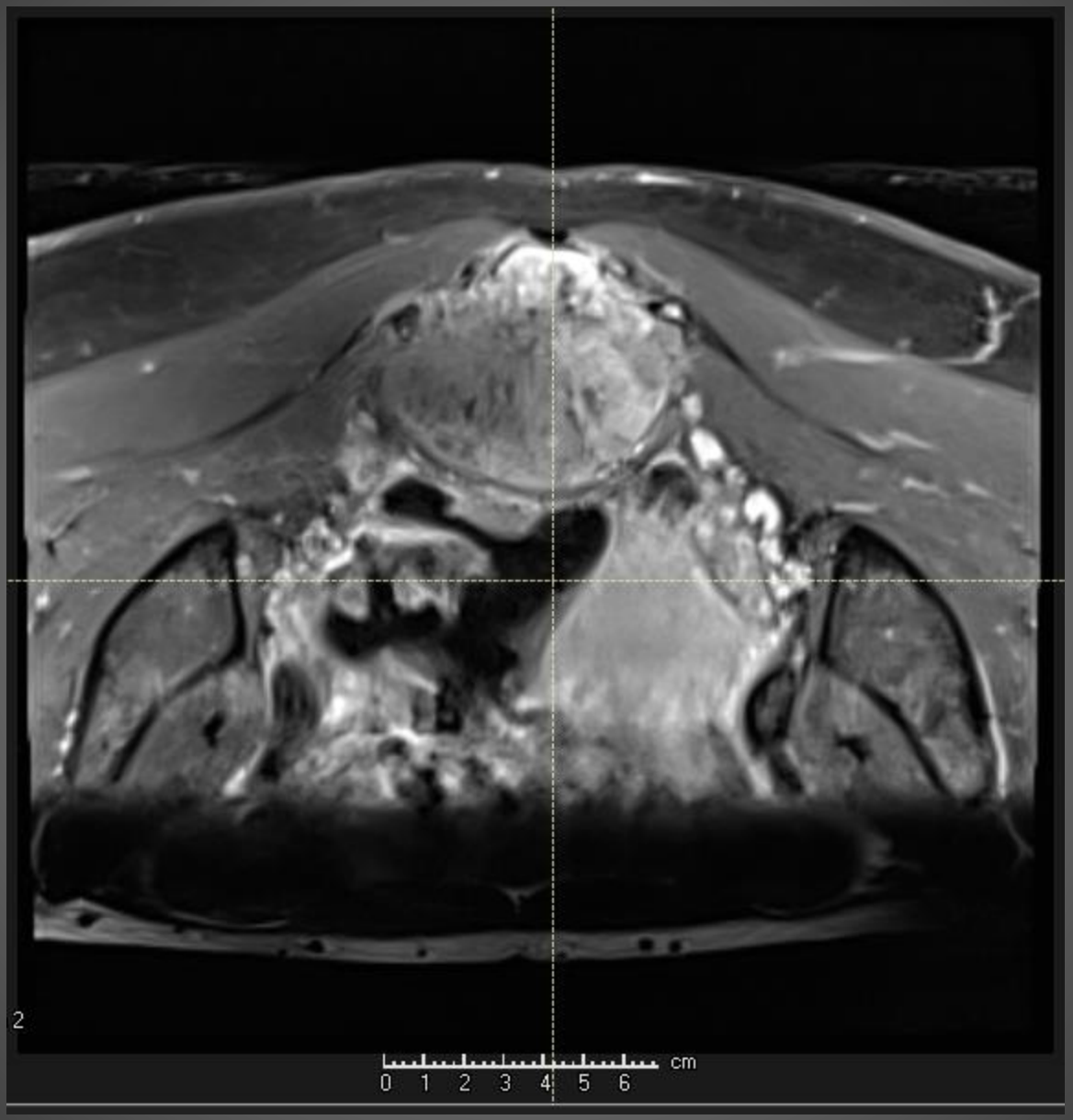

2
cm
0 1 2 3 4 5 6

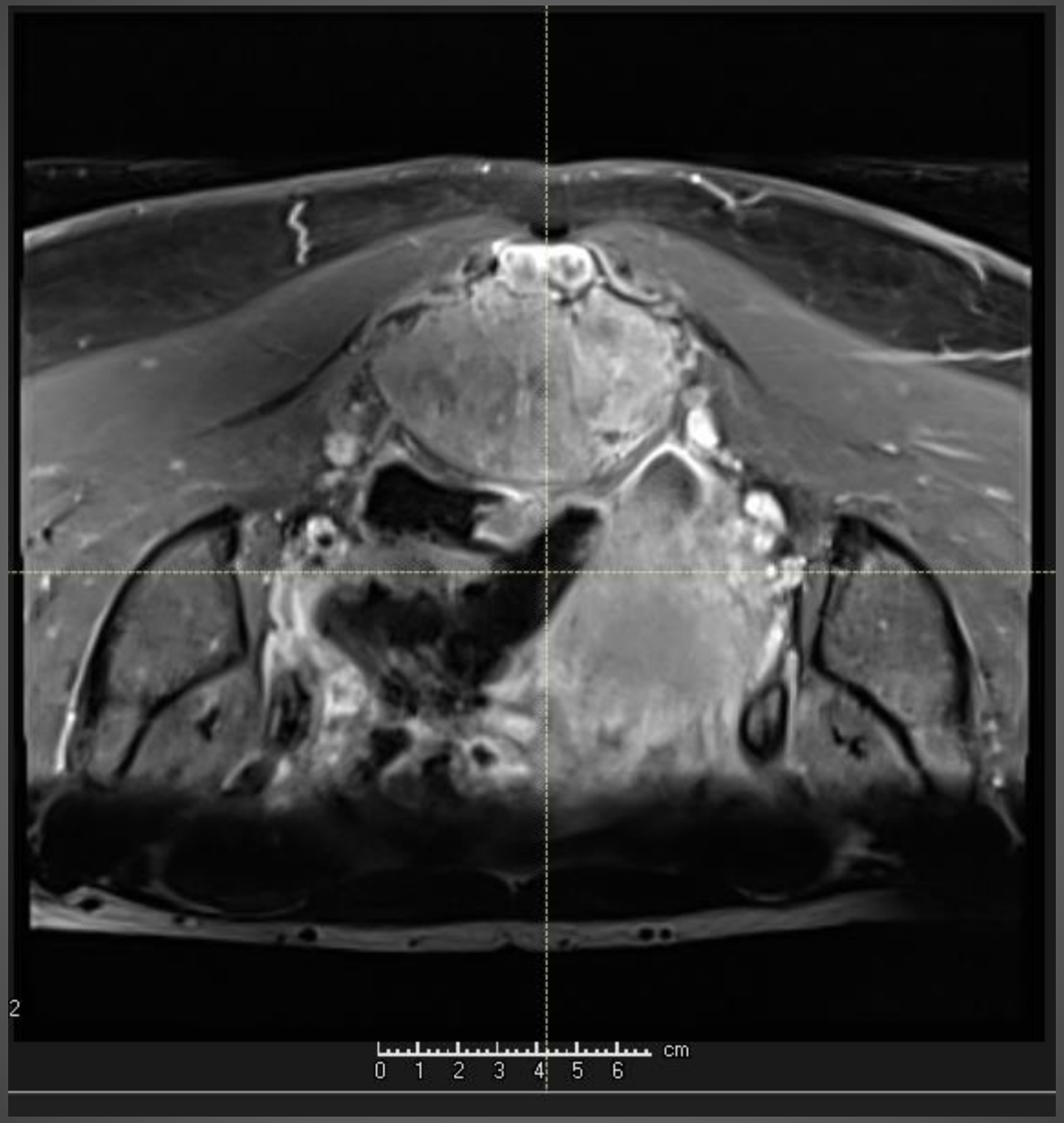

cm
0 1 2 3 4 5 6

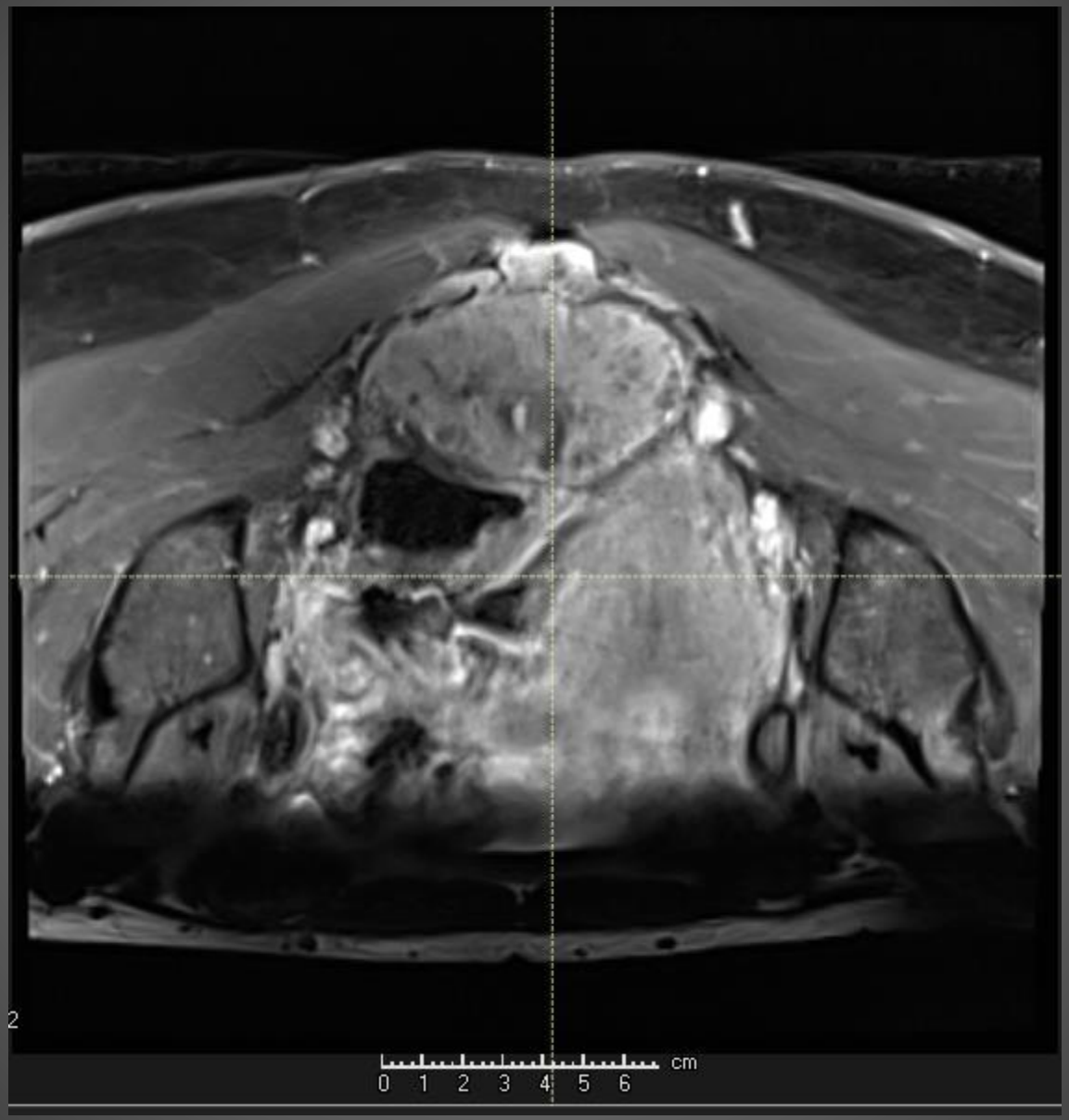

2
cm
0 1 2 3 4 5 6

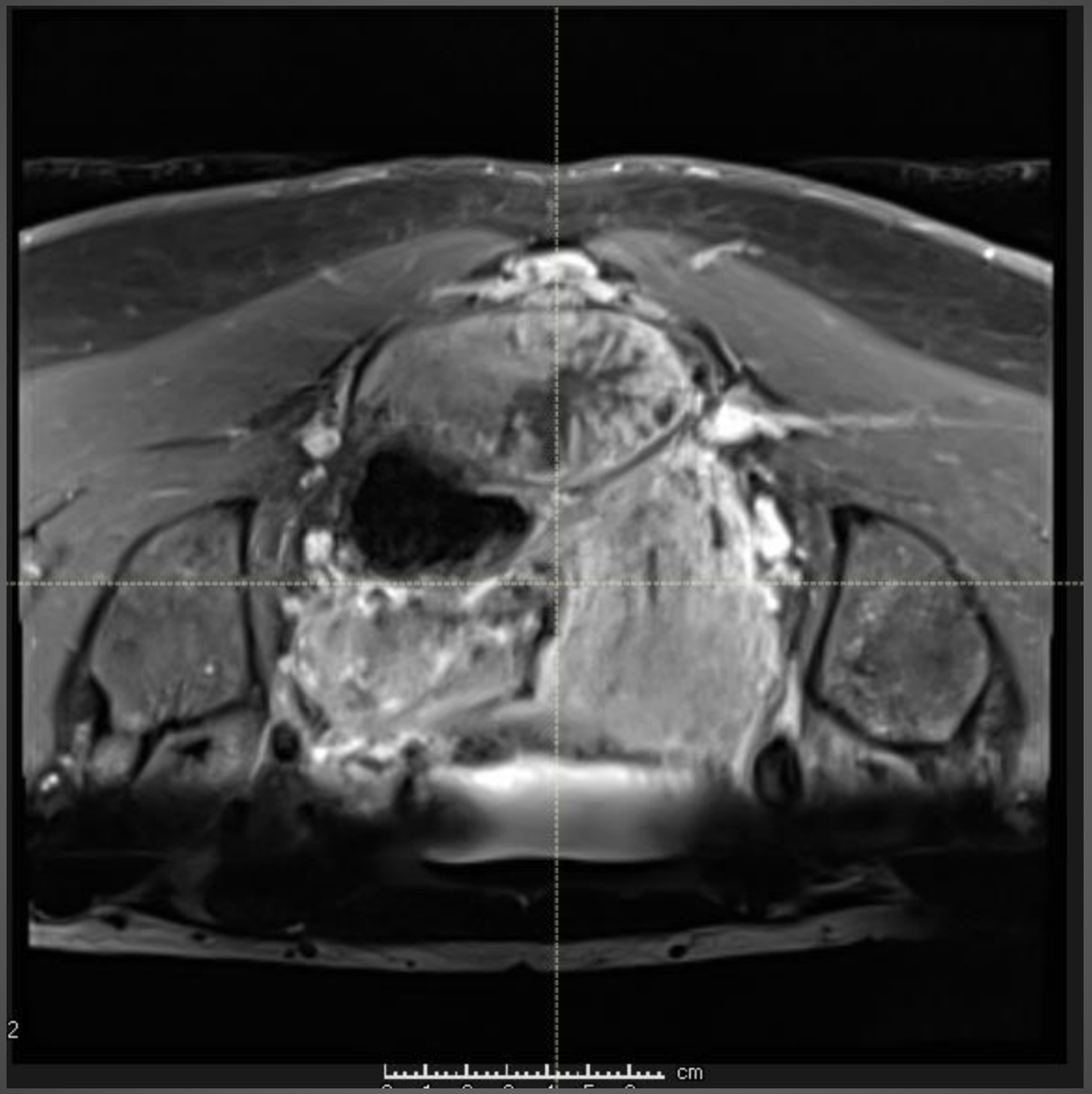

2
cm
0 1 2 3 4 5 6

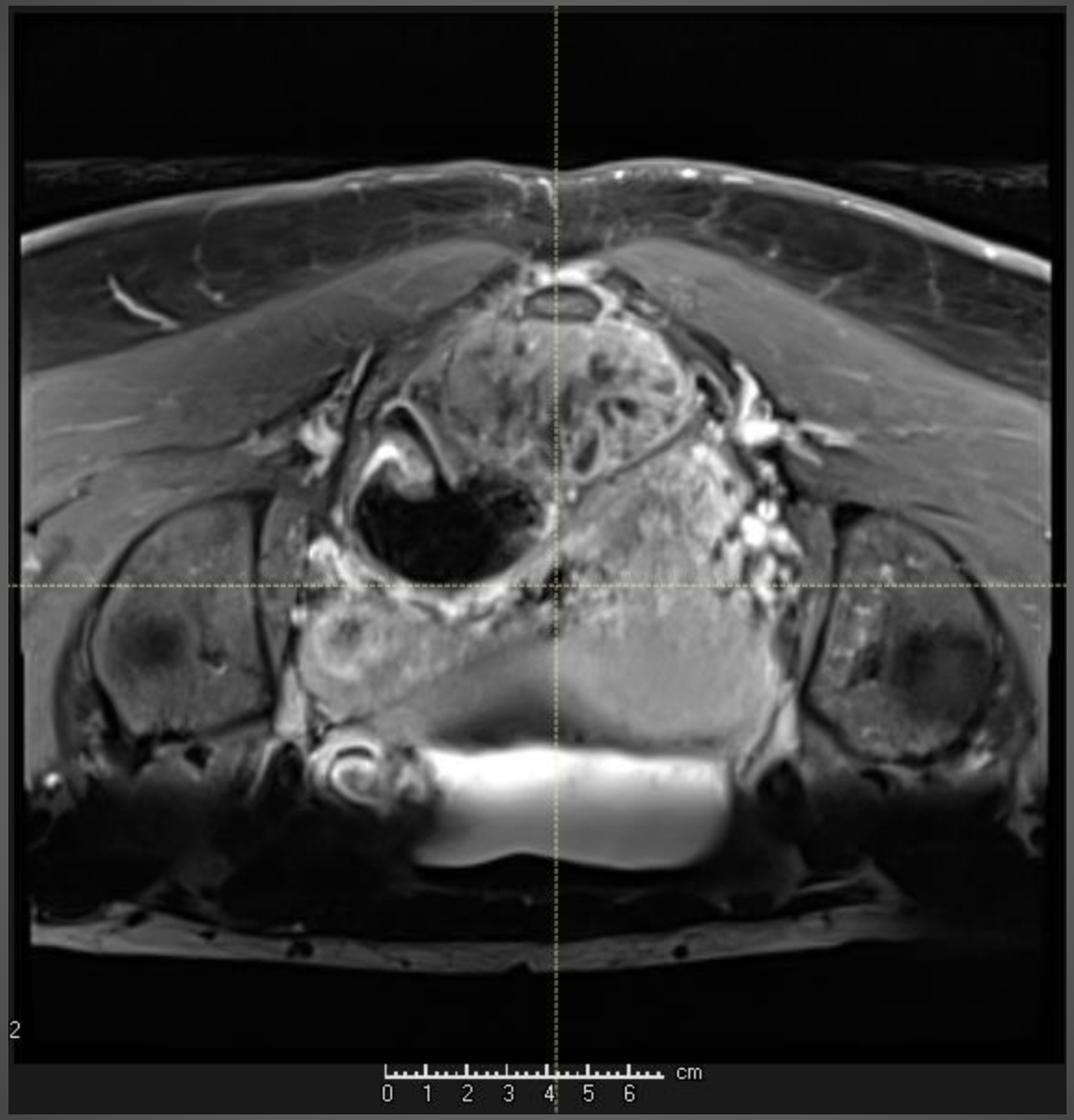

cm
0 1 2 3 4 5 6


2
cm
0 1 2 3 4 5 6

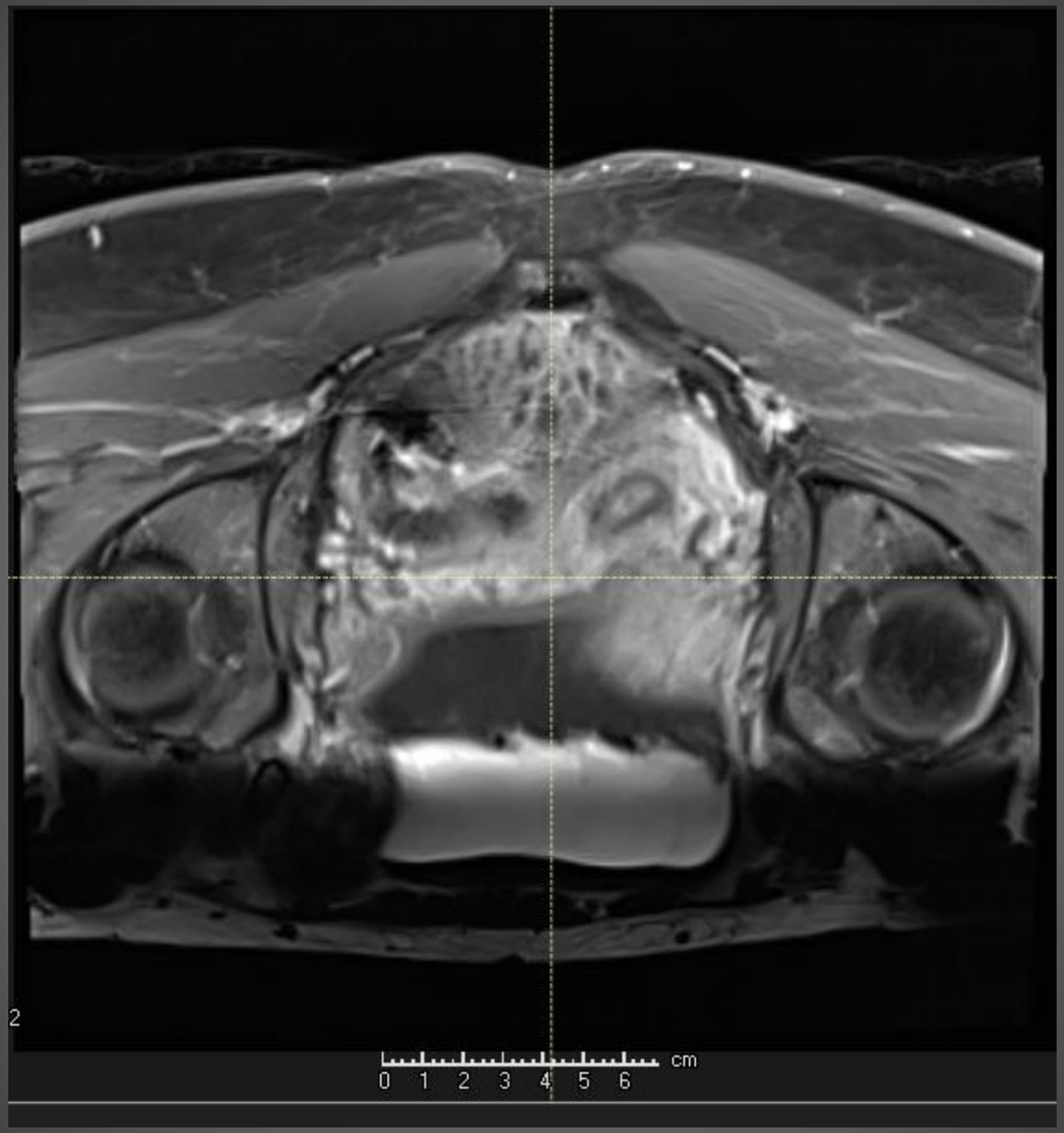

2
cm
0 1 2 3 4 5 6

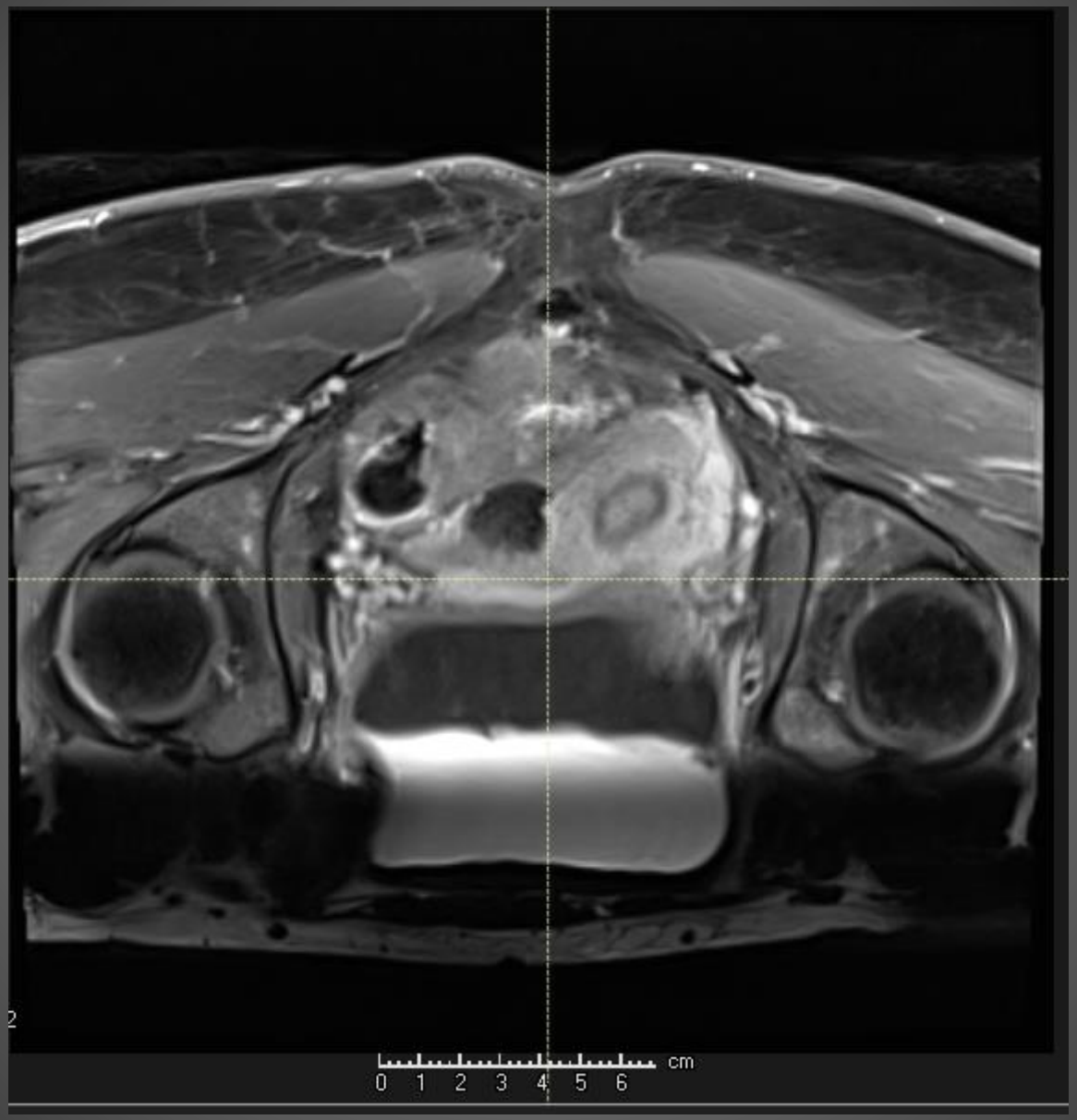

2
cm
0 1 2 3 4 5 6


2
cm

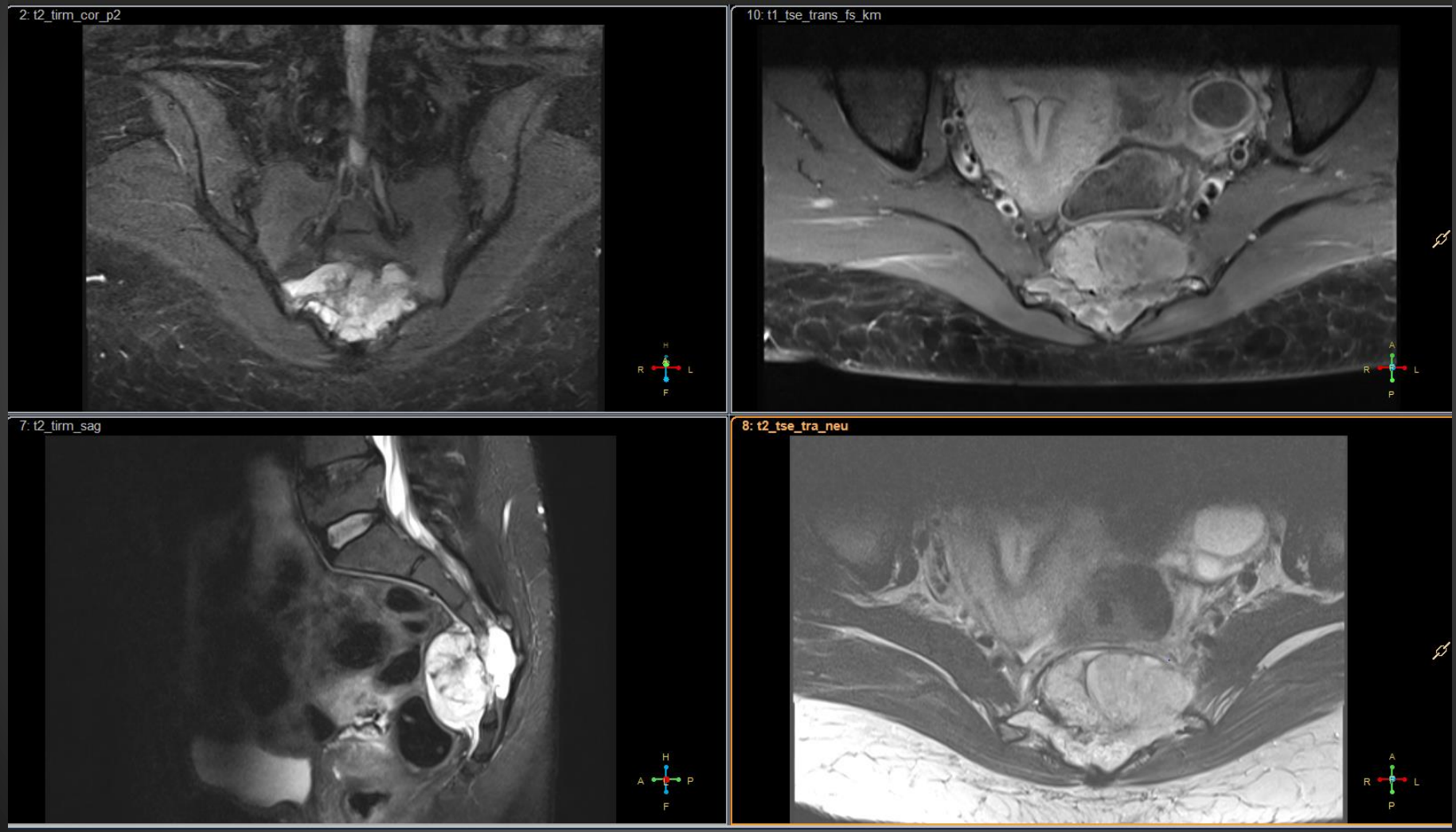

2
cm
0 1 2 3 4 5 6

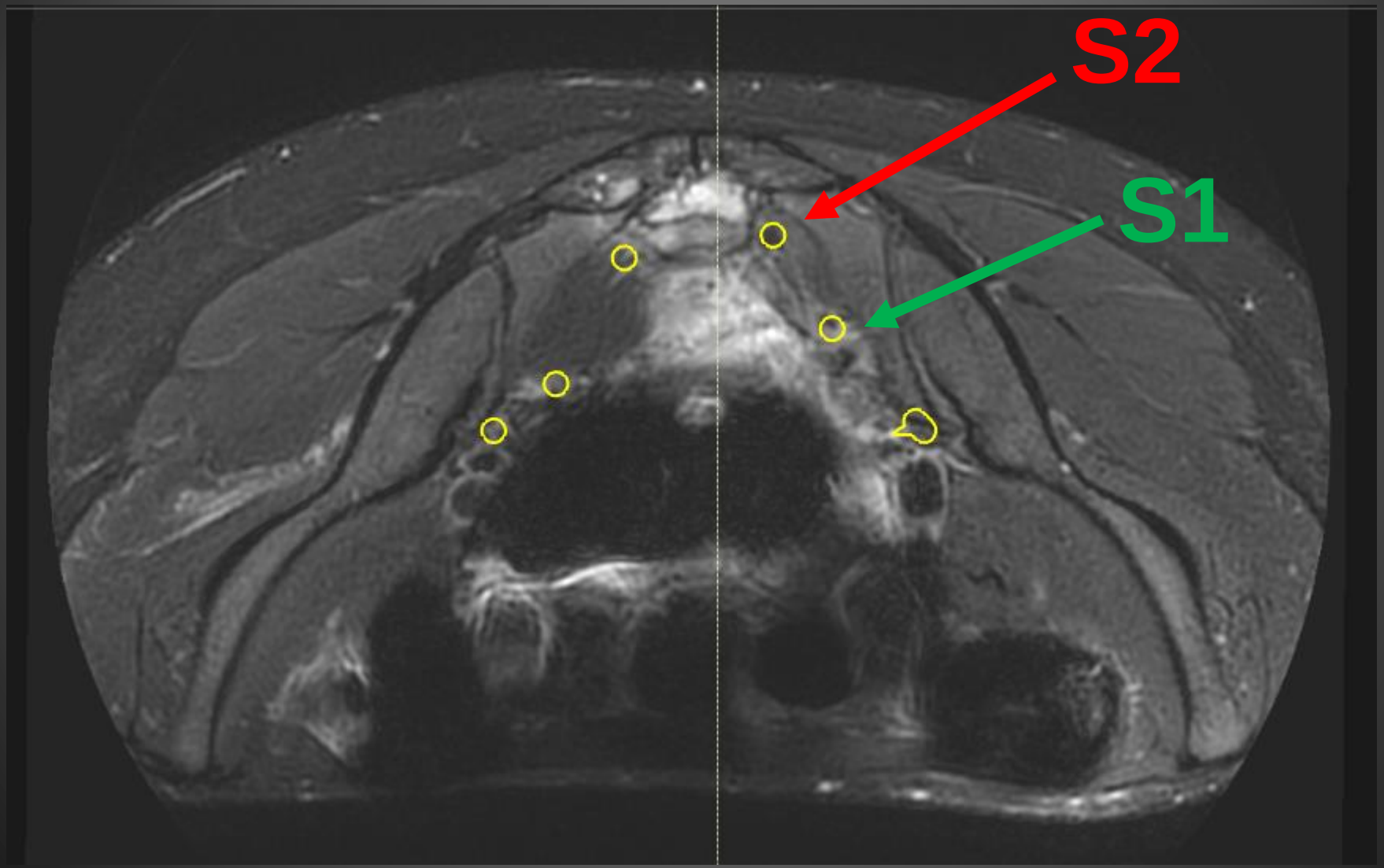

cm
0 1 2 3 4 5 6


2
cm
0 1 2 3 4 5 6


cm
0 1 2 3 4 5 6

Biopsy proven sacral chordoma of S3




S2
S1

Which therapy would you recommend?

- **Radical surgery**
- **Particle therapy only if patient refuses surgery**
- **Particle therapy as alternative to surgery**
- **Enrollment in a trial**

Prescritpion

exclusive CIRT
PTV1 : 4.6 Gy RBE x 9 (41.4 Gy RBE)
PTV2 : 4.6 Gy RBE x 7 (32.2 Gy RBE)

Total dose 73.6 Gy RBE
in 16 fr in 4 weeks

LEM vs mMKM

LEM 73.6 Gy

should be equivalent to

mMKM 67.2 Gy RBE

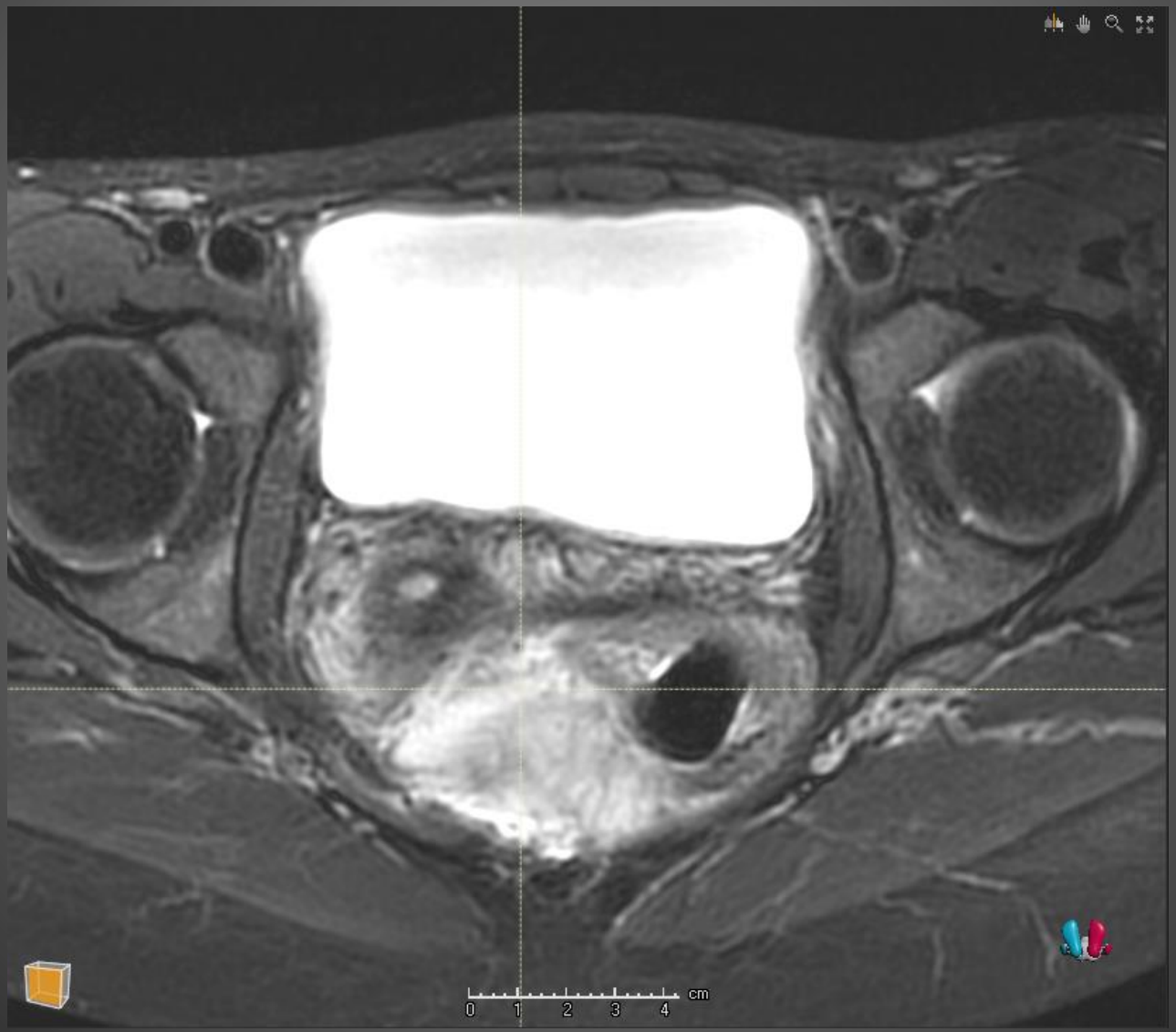
Dose constraints

Rectum
D (RBE, 1 ccm) < 66 Gy
D (RBE, 5 ccm) < 63 Gy
D (RBE, 10 ccm) < 55 Gy

Cauda Equina
D (RBE, max) < 70 Gy
Nerve roots
D (RBE, 5%) < 70 Gy

Contralateral ovary
D (RBE, mean) < 2 Gy

Would you require a spacer?



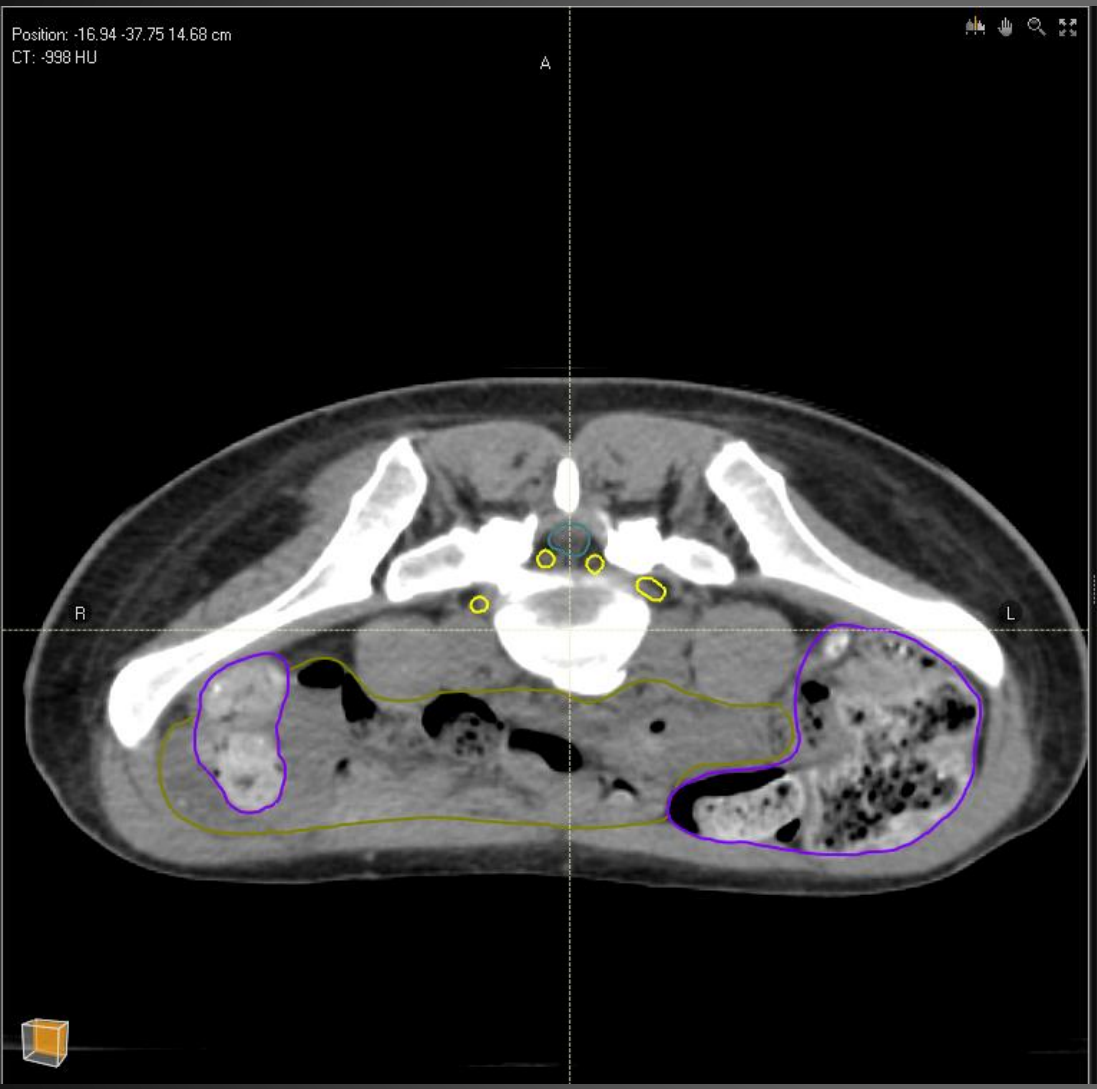
Contouring

Contouring :

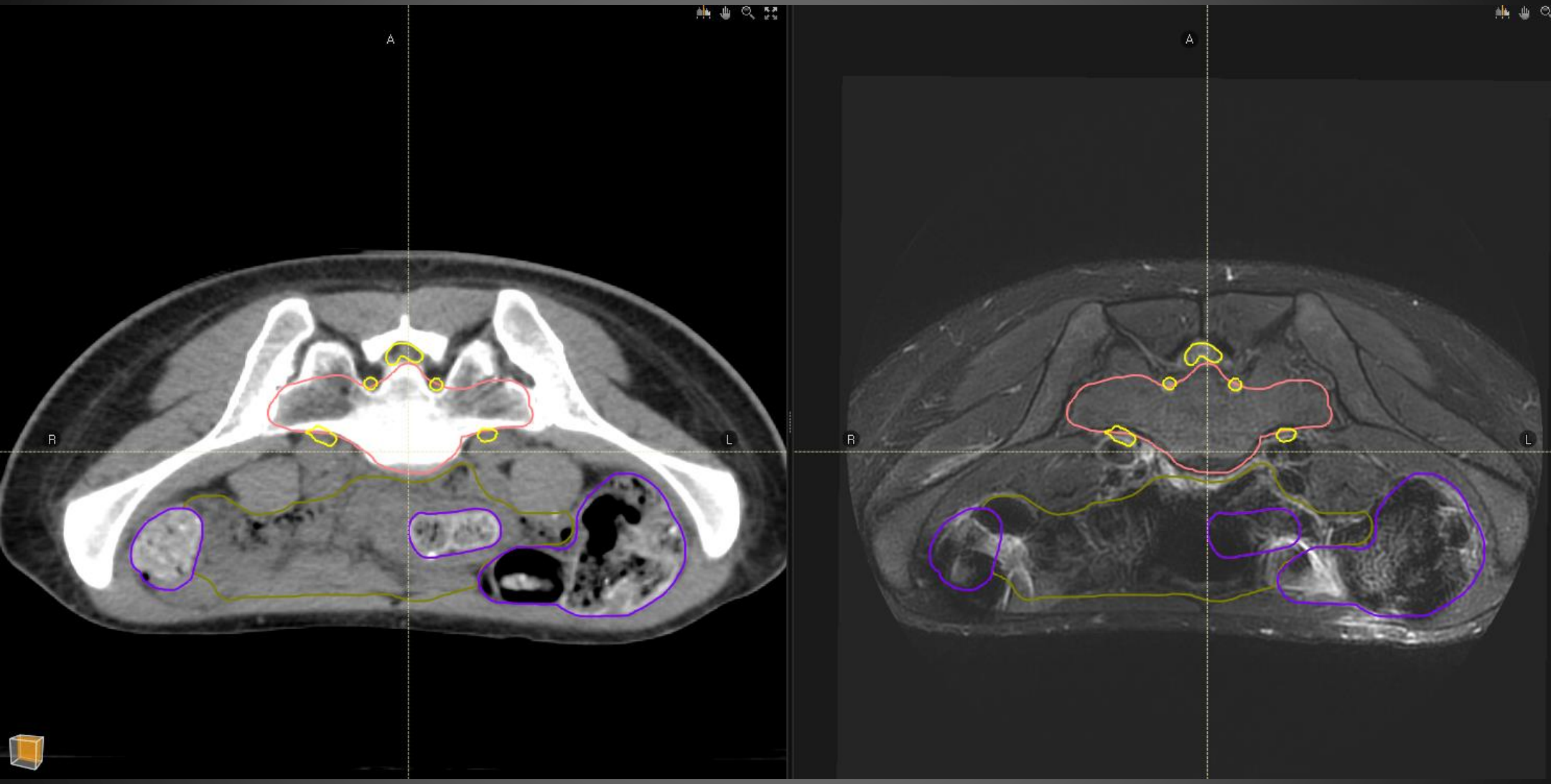
Include piriform muscle

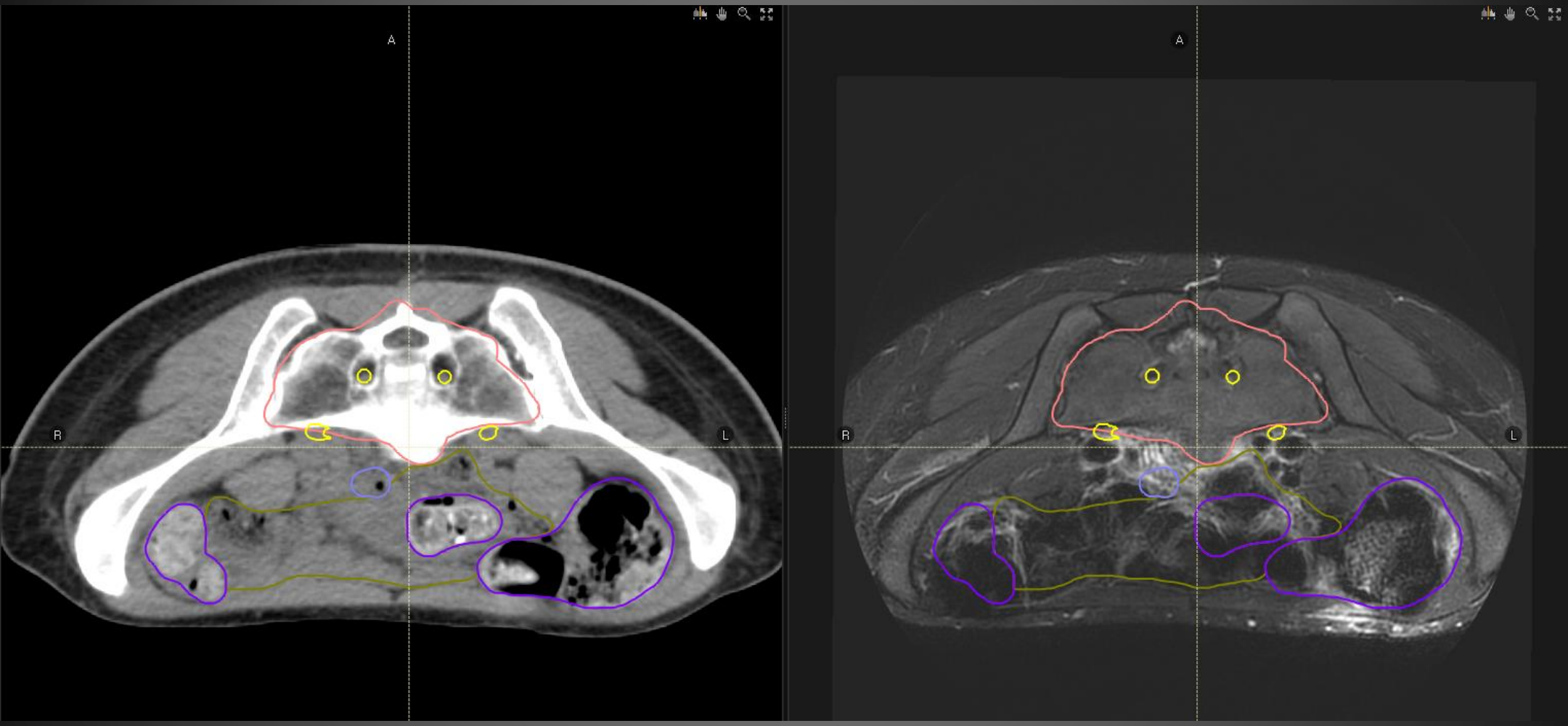
Adequate bone margins

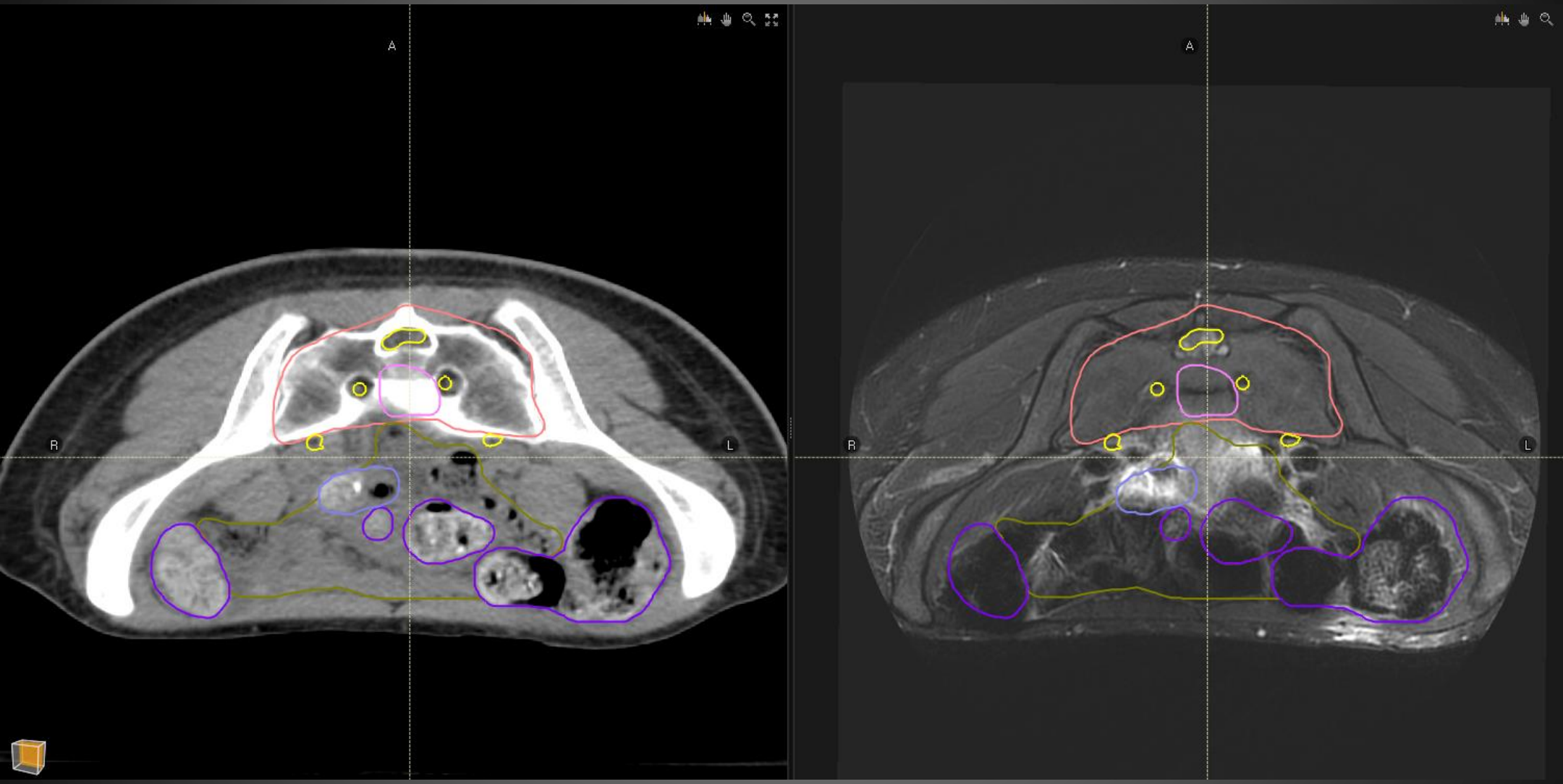
Adequate gluteus margins

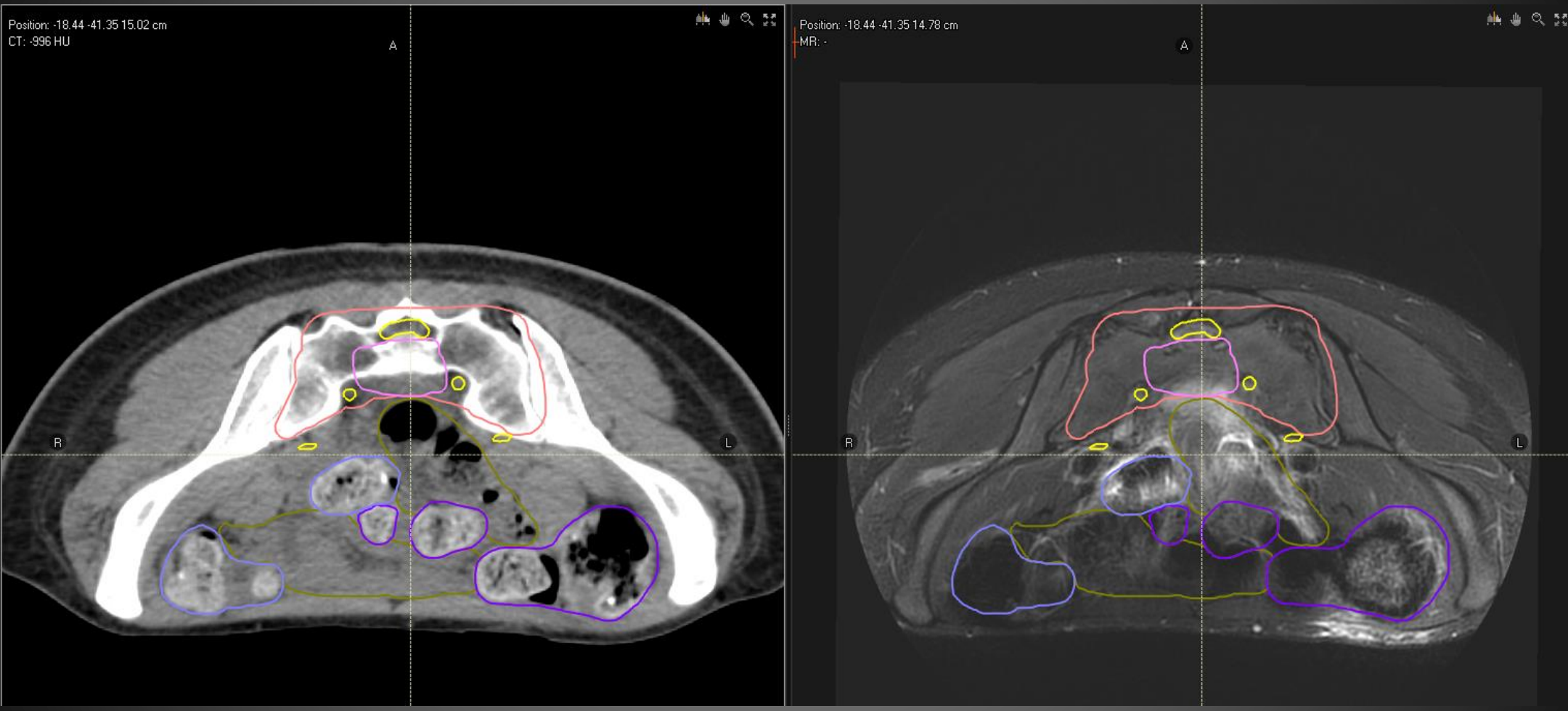

Position: -16.94 -37.75 14.68 cm
CT: -998 HU
A
R
L

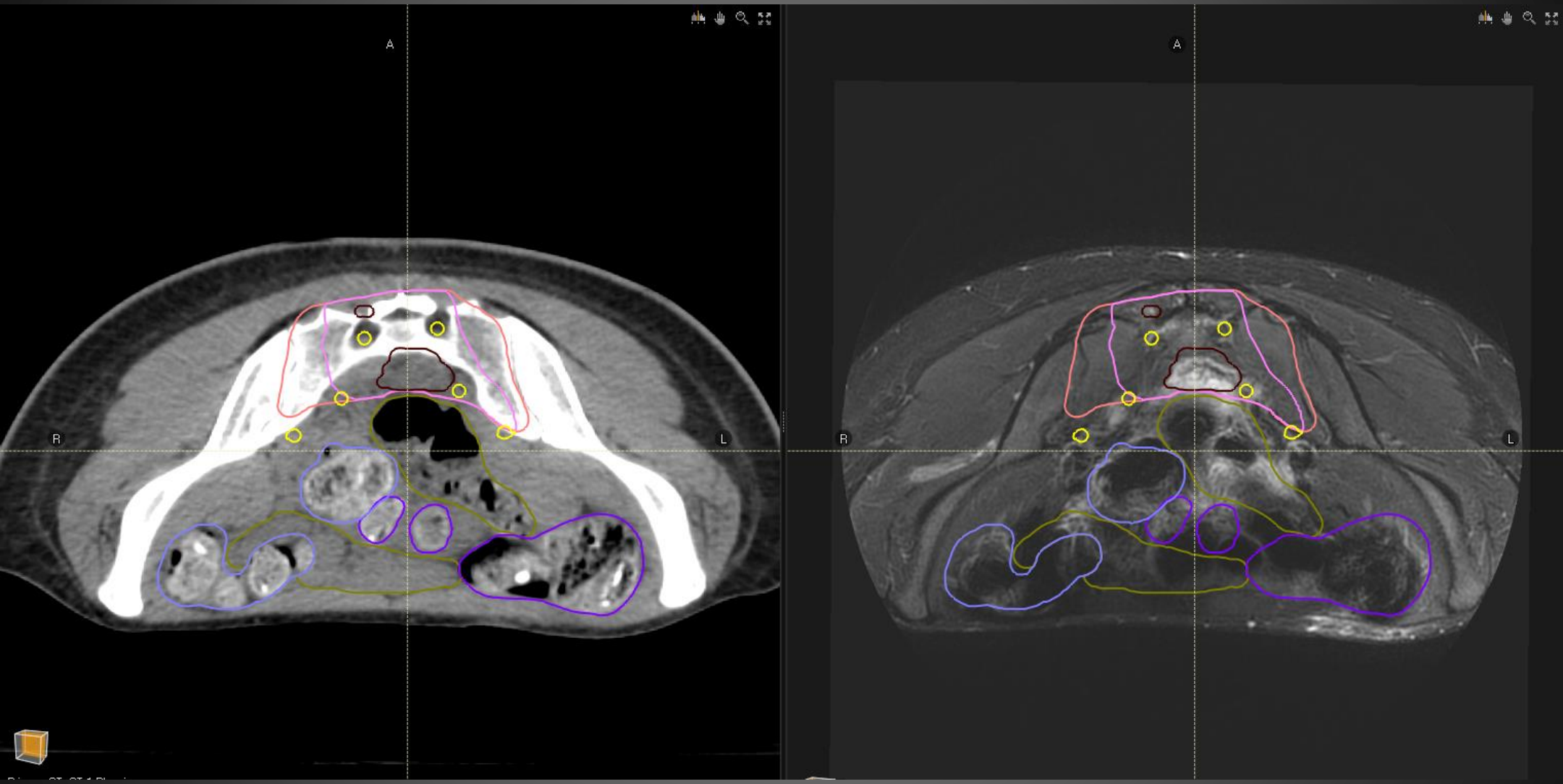

Position: -16.94 -37.75 14.68 cm
MR:
A
R
L


A
R
L
A
R
L


A
R
L
A
R
L

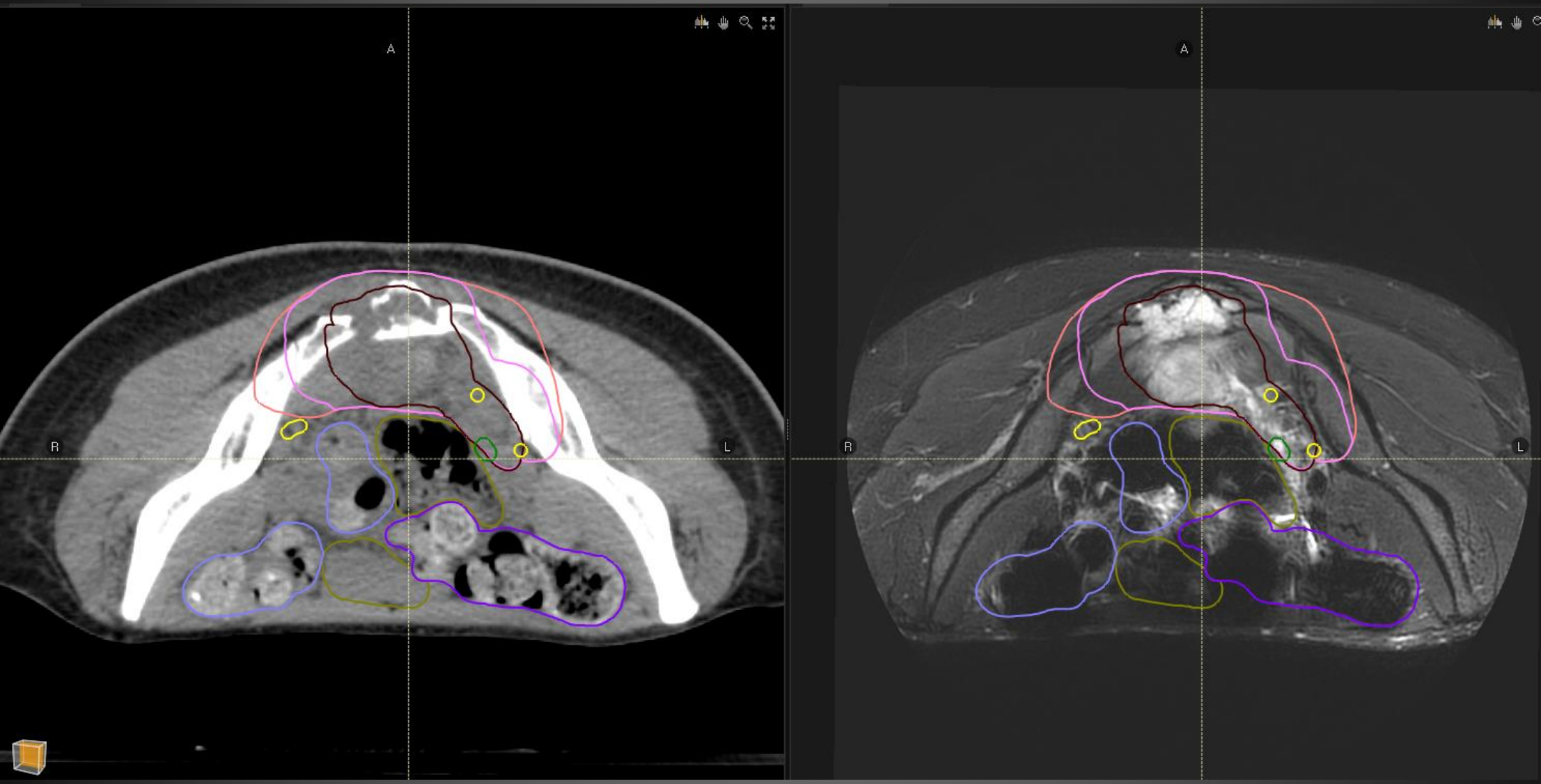

A
R
L
A
R
L

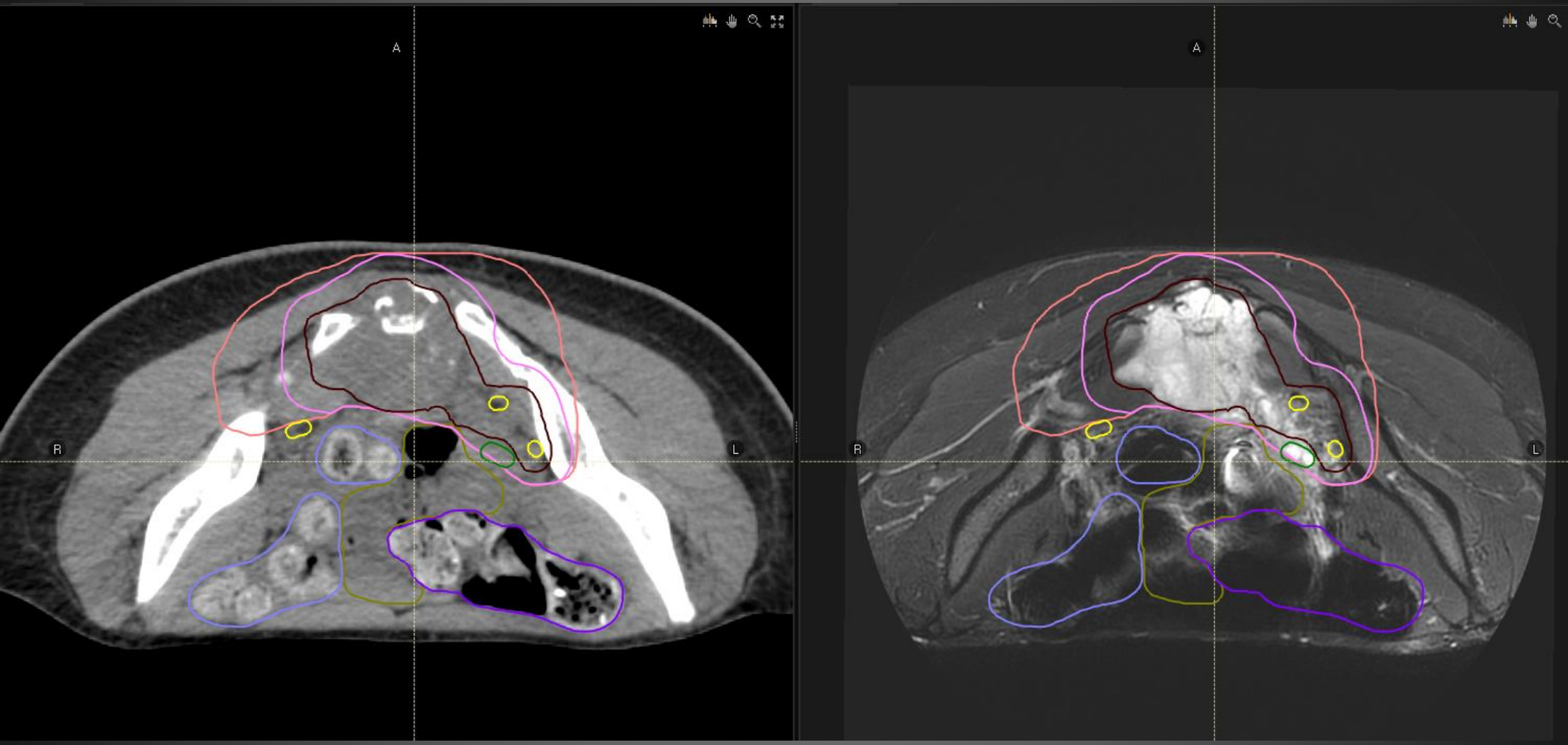

Position: -18.44 -41.35 15.02 cm
CT: -996 HU
A
R
L
Position: -18.44 -41.35 14.78 cm
MR: -
A
R
L

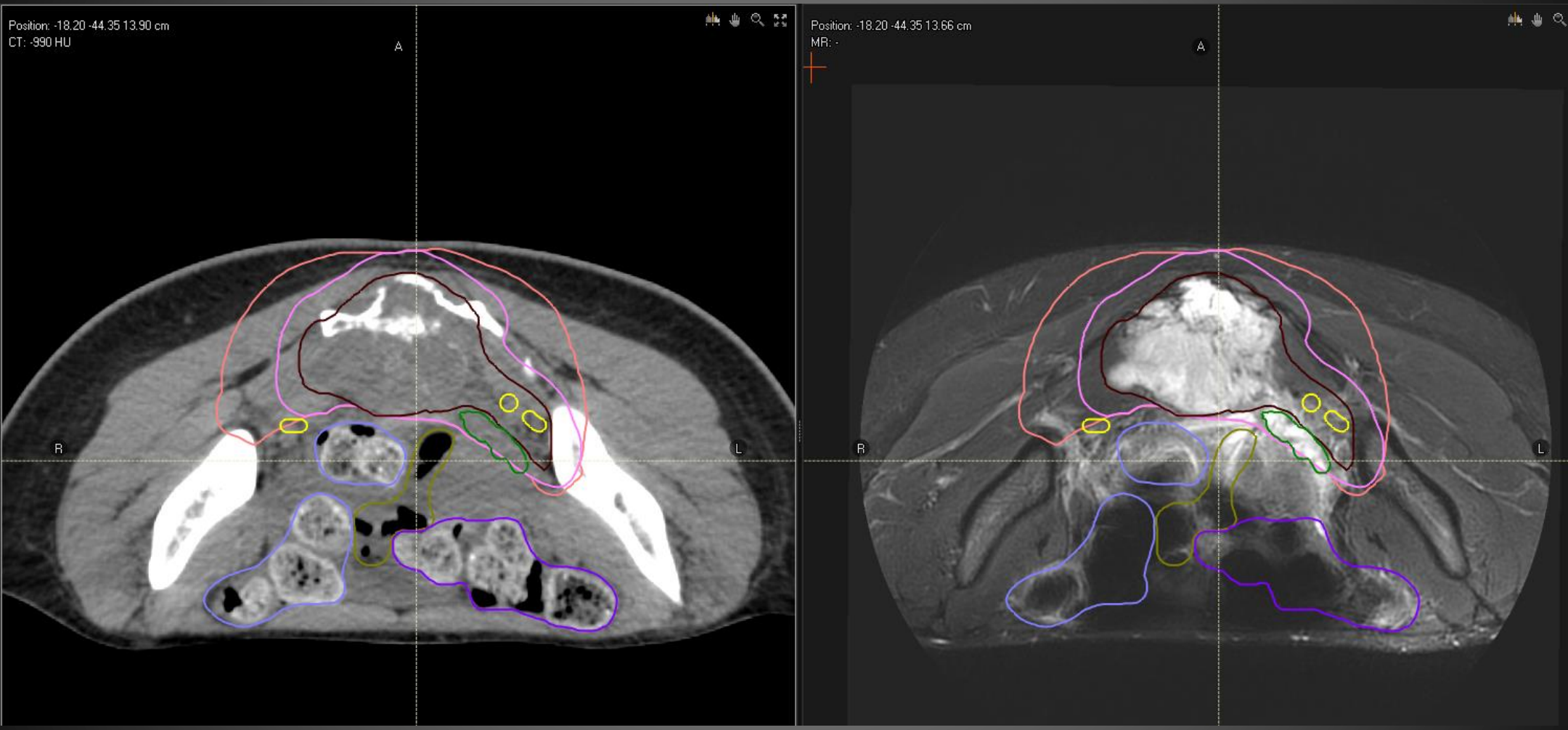

A
R
L
A
R
L

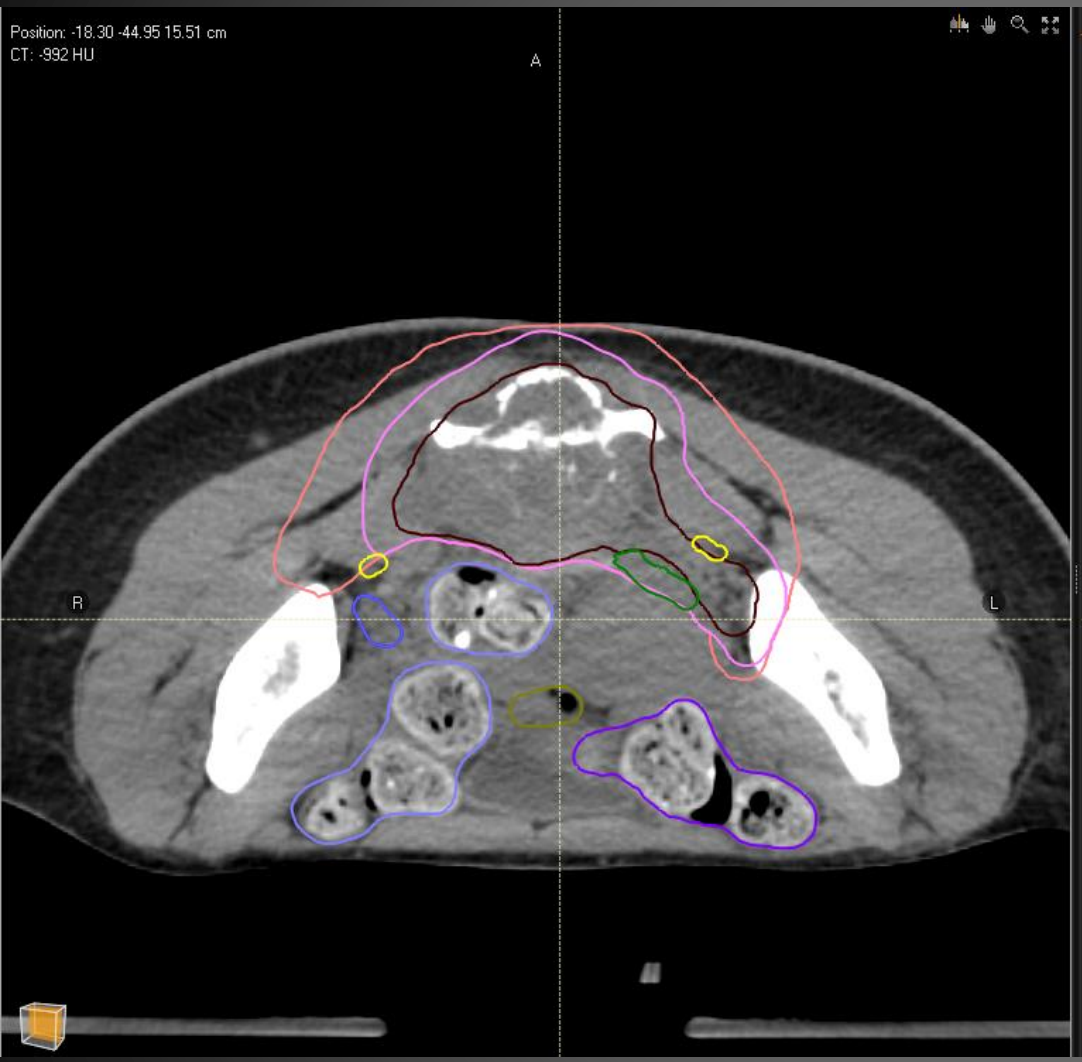

Position: -0.81 -42.55 10.70 cm
CT: -999 HU
A
R
L

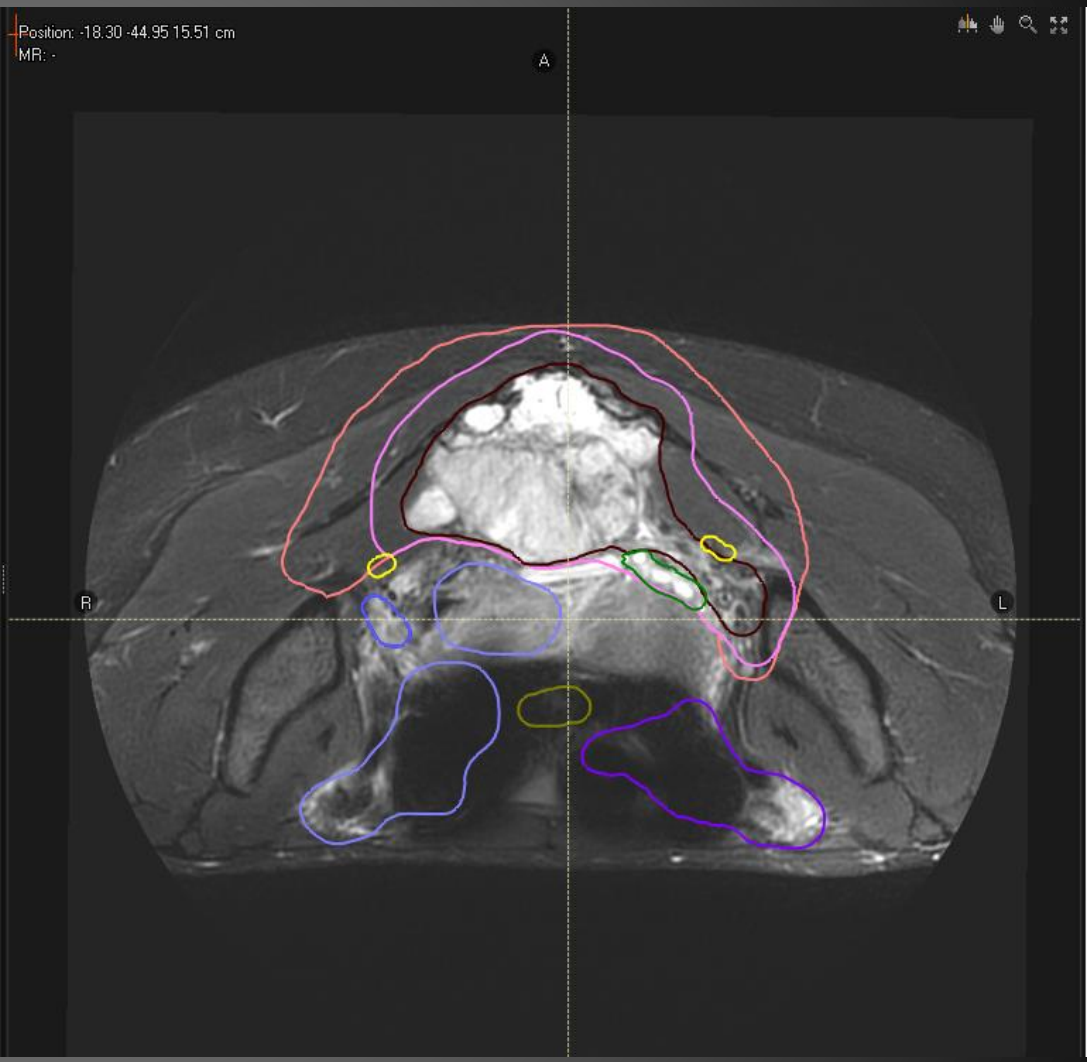

Position: -1.54 -42.55 11.18 cm
MR: 3
A
R
L

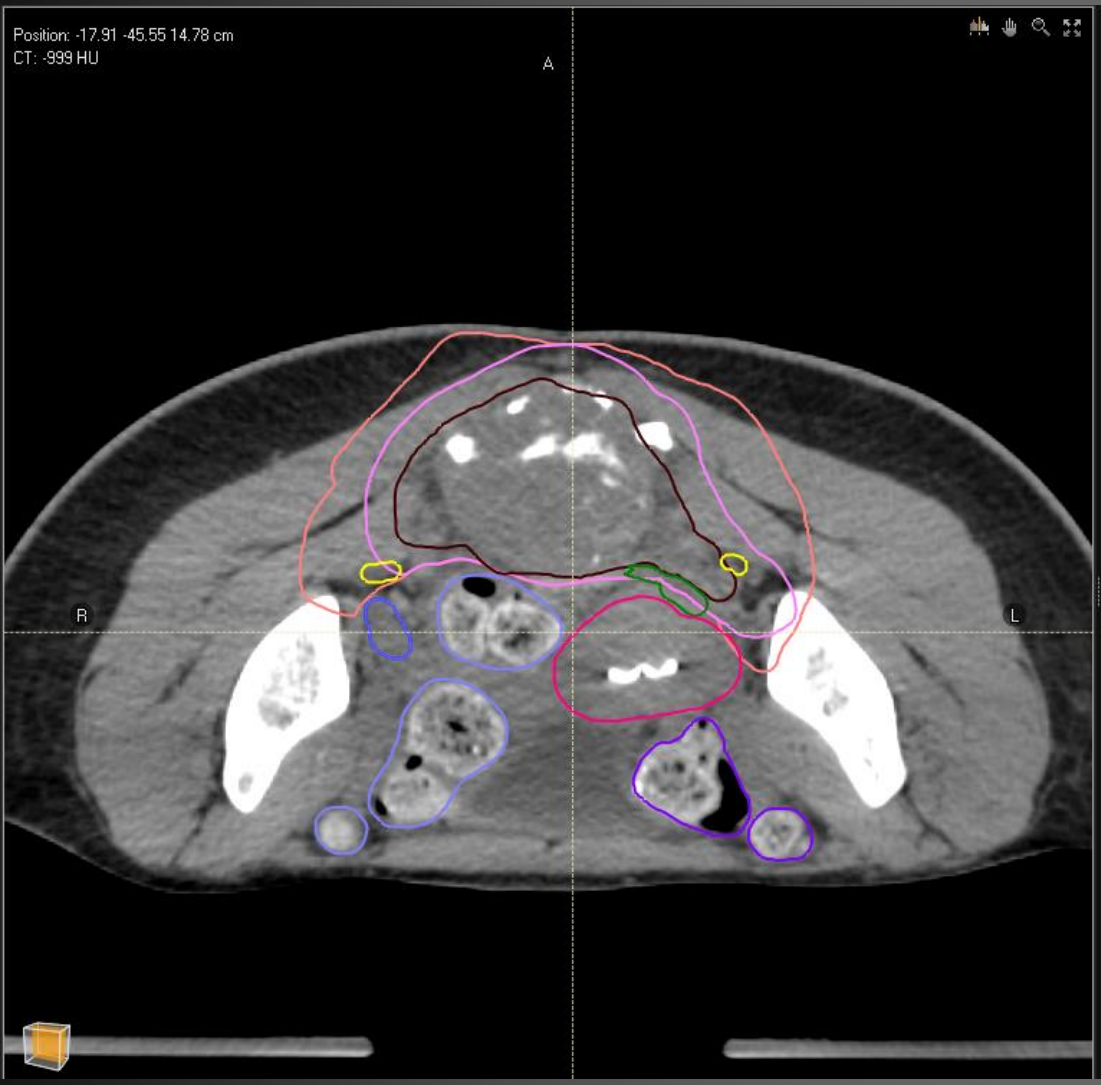

A
R
L
A
R
L

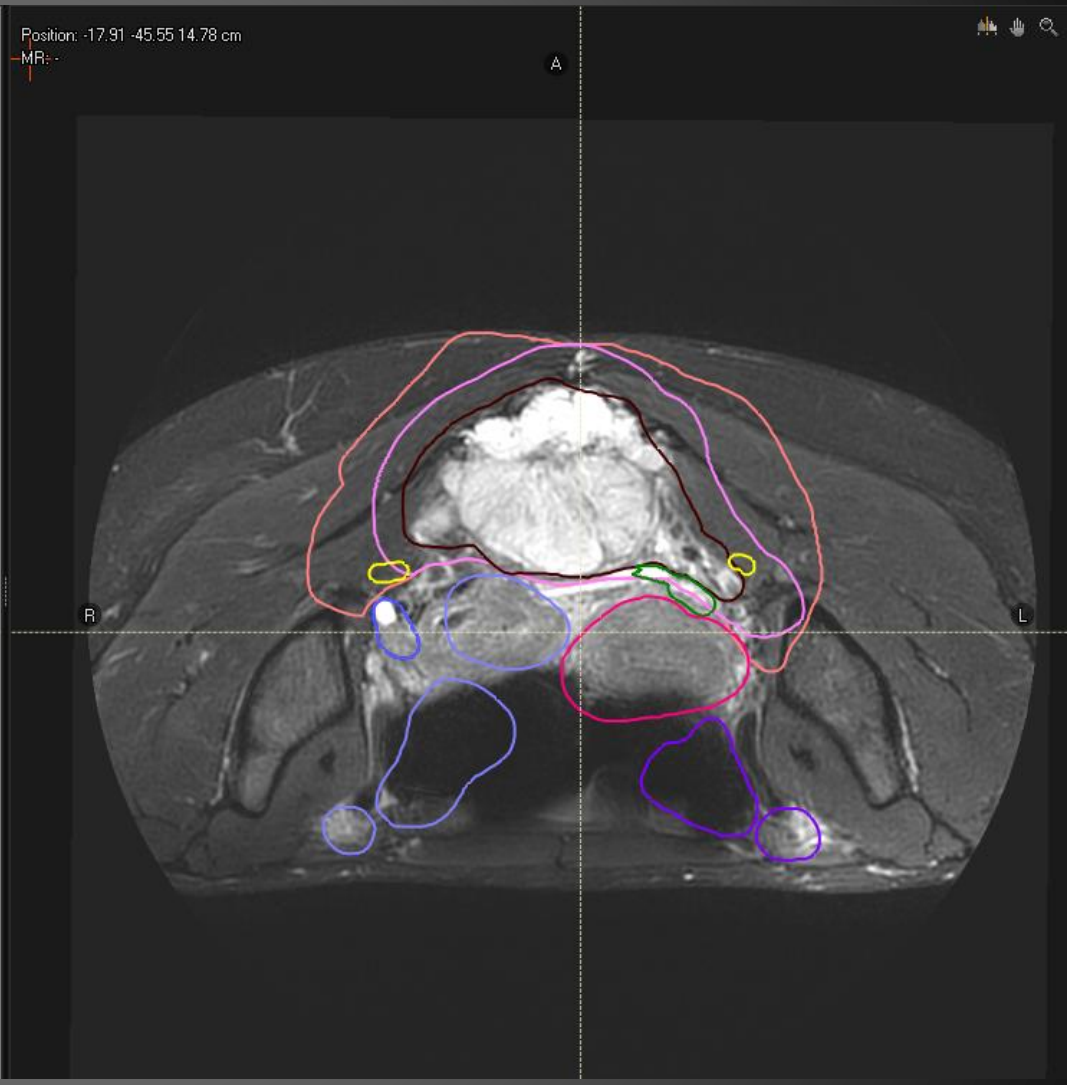

A
R
L
A
R
L


Position: -18.20 -44.35 13.90 cm
CT: -990 HU
A
R
L
Position: -18.20 -44.35 13.66 cm
MR: -
A
R
L

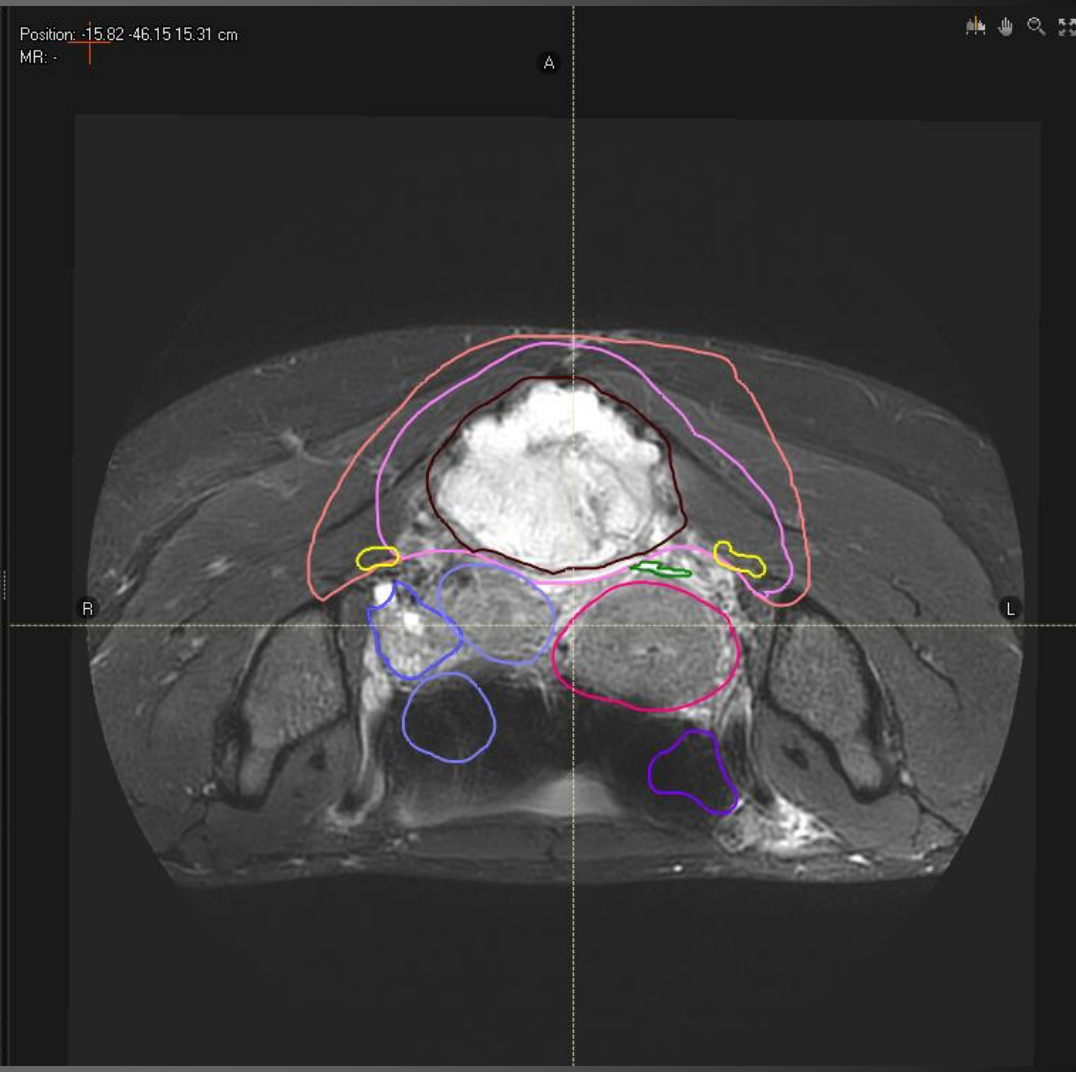

Position: -18.30 -44.95 15.51 cm
CT: -992 HU
A
R
L

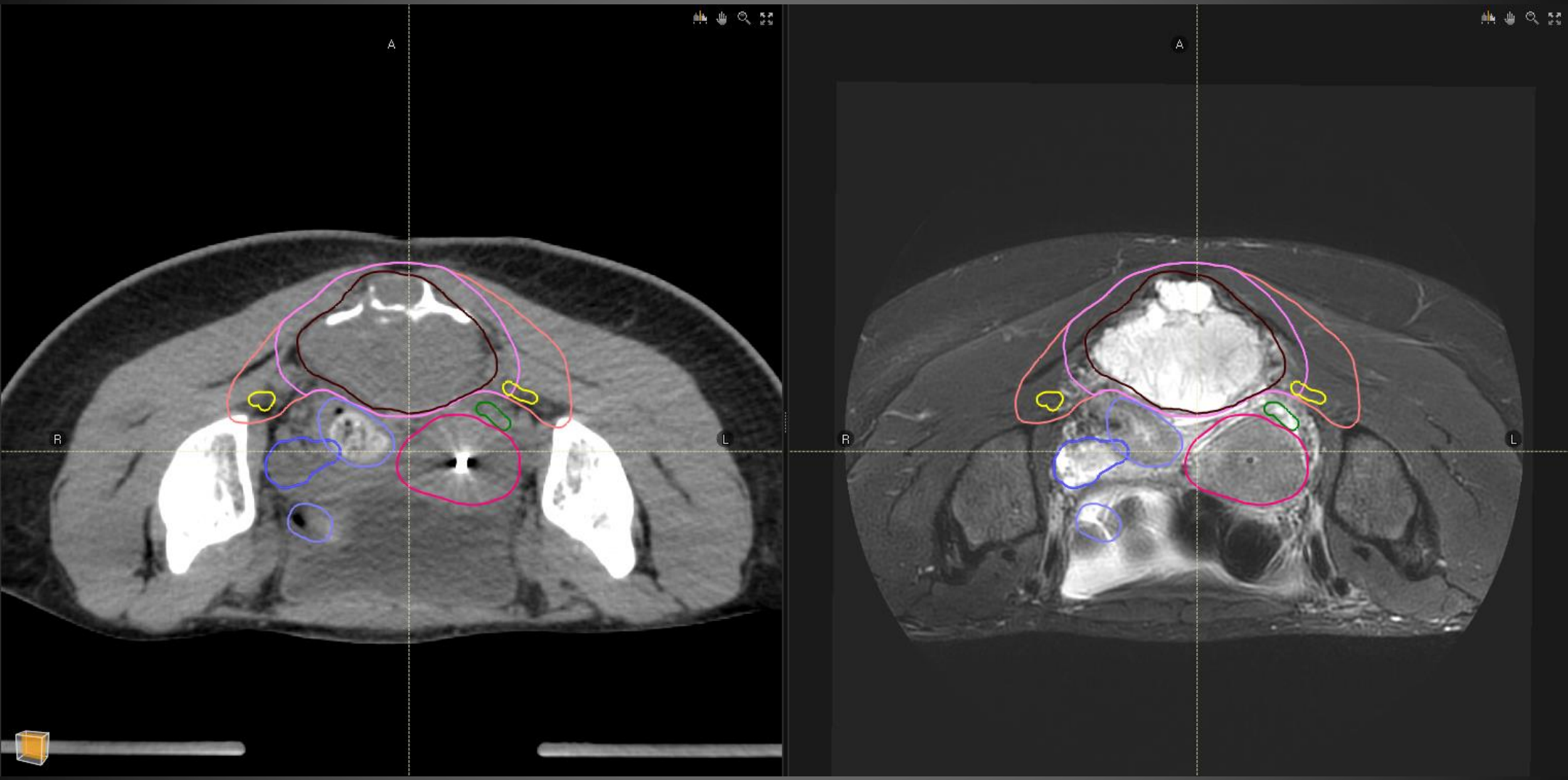

Position: -18.30 -44.95 15.51 cm
MR: -
A
R
L

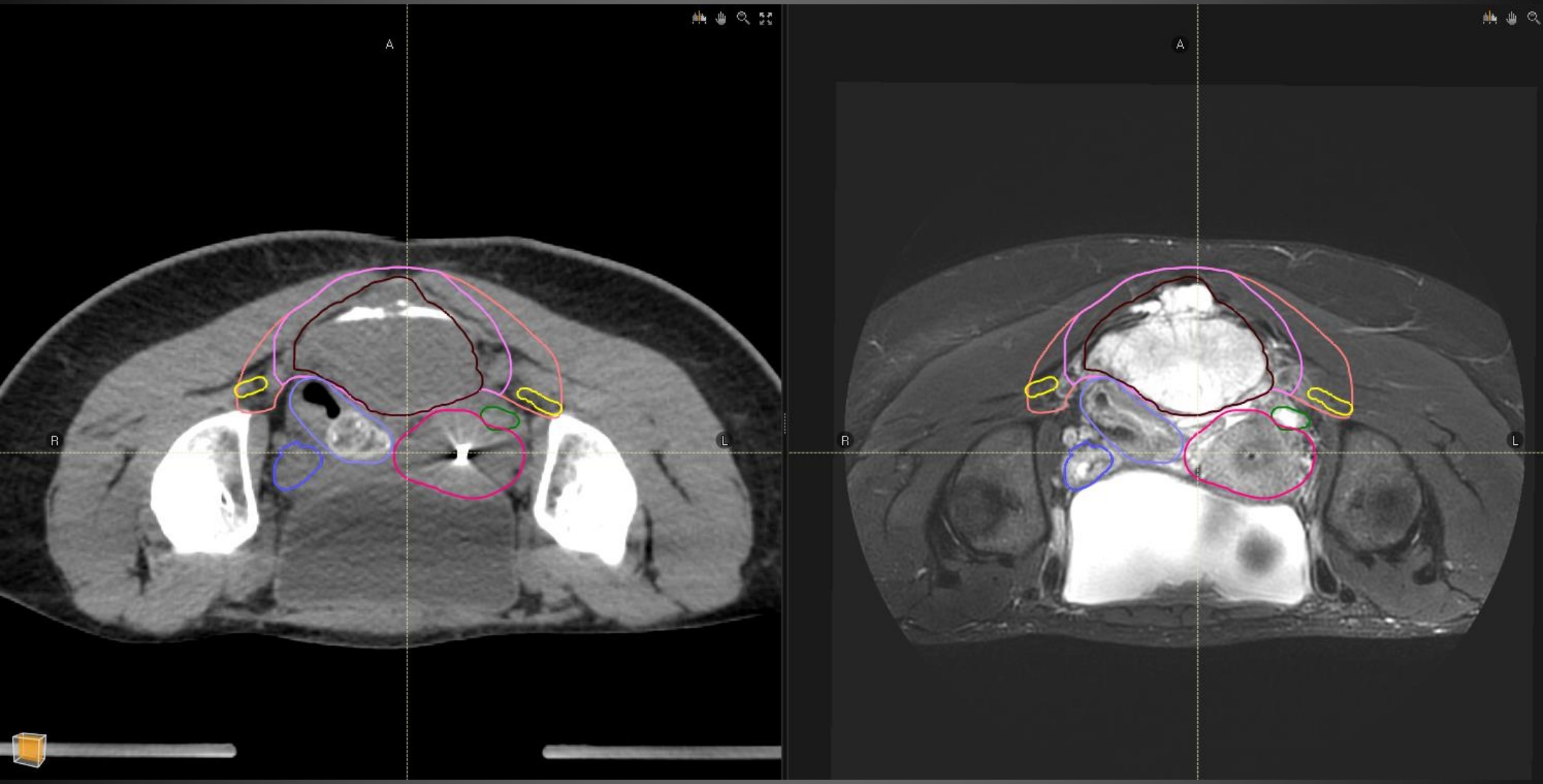

Position: -17.91 -45.55 14.78 cm
CT: -999 HU
A
R
L

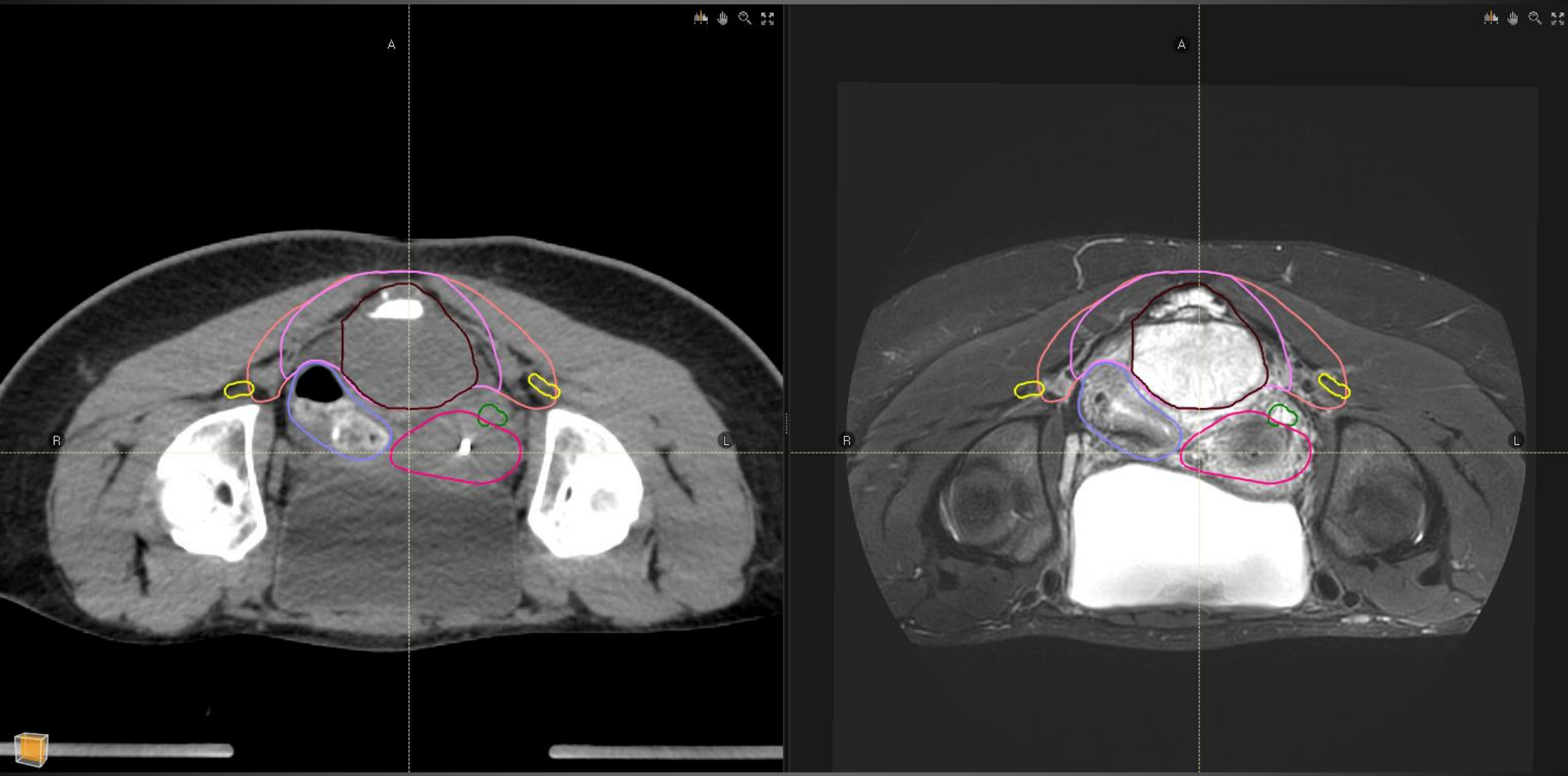

Position: -17.91 -45.55 14.78 cm
MR: -
A
R
L

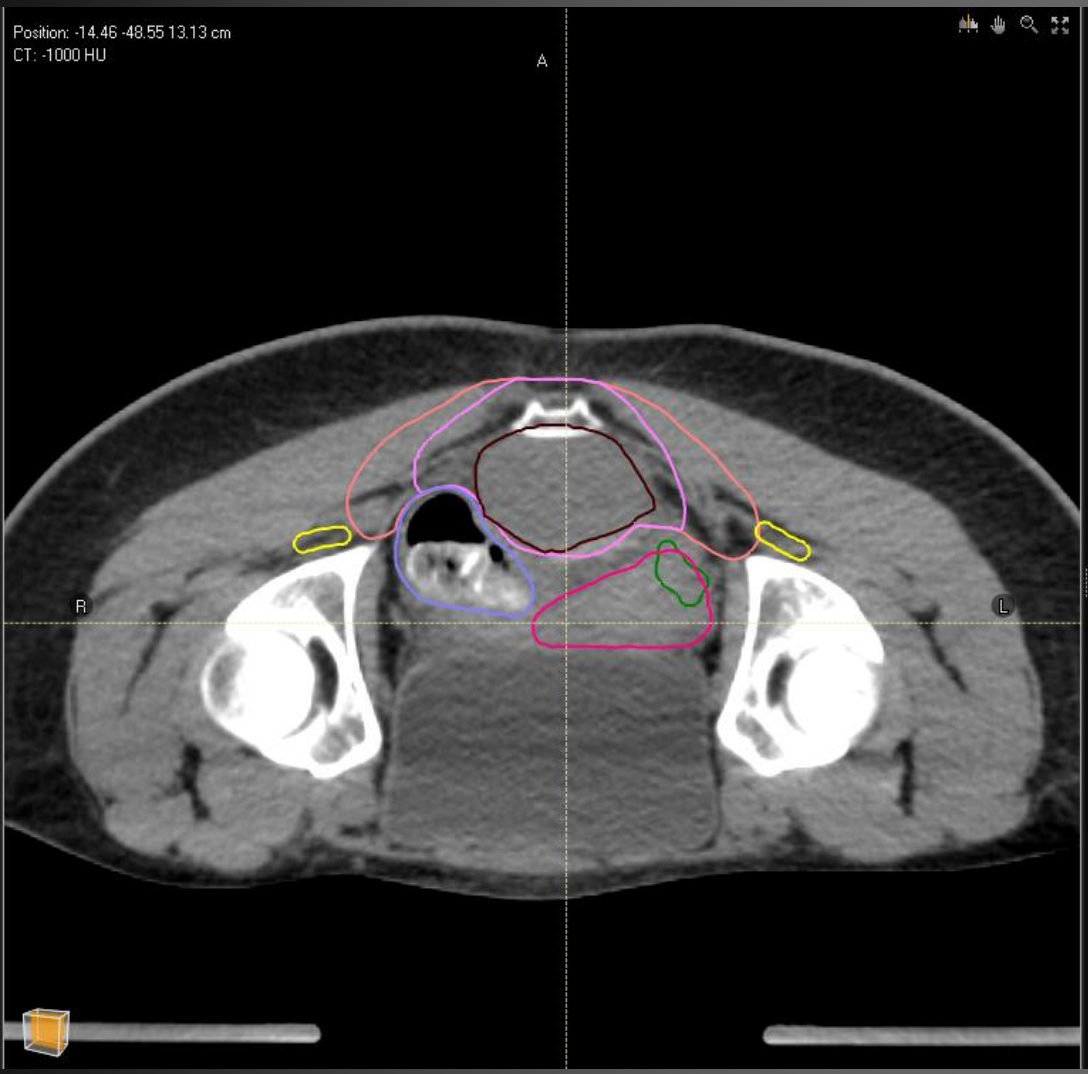

Position: -16.02 -46.15 15.56 cm
CT: -998 HU
A
R
L

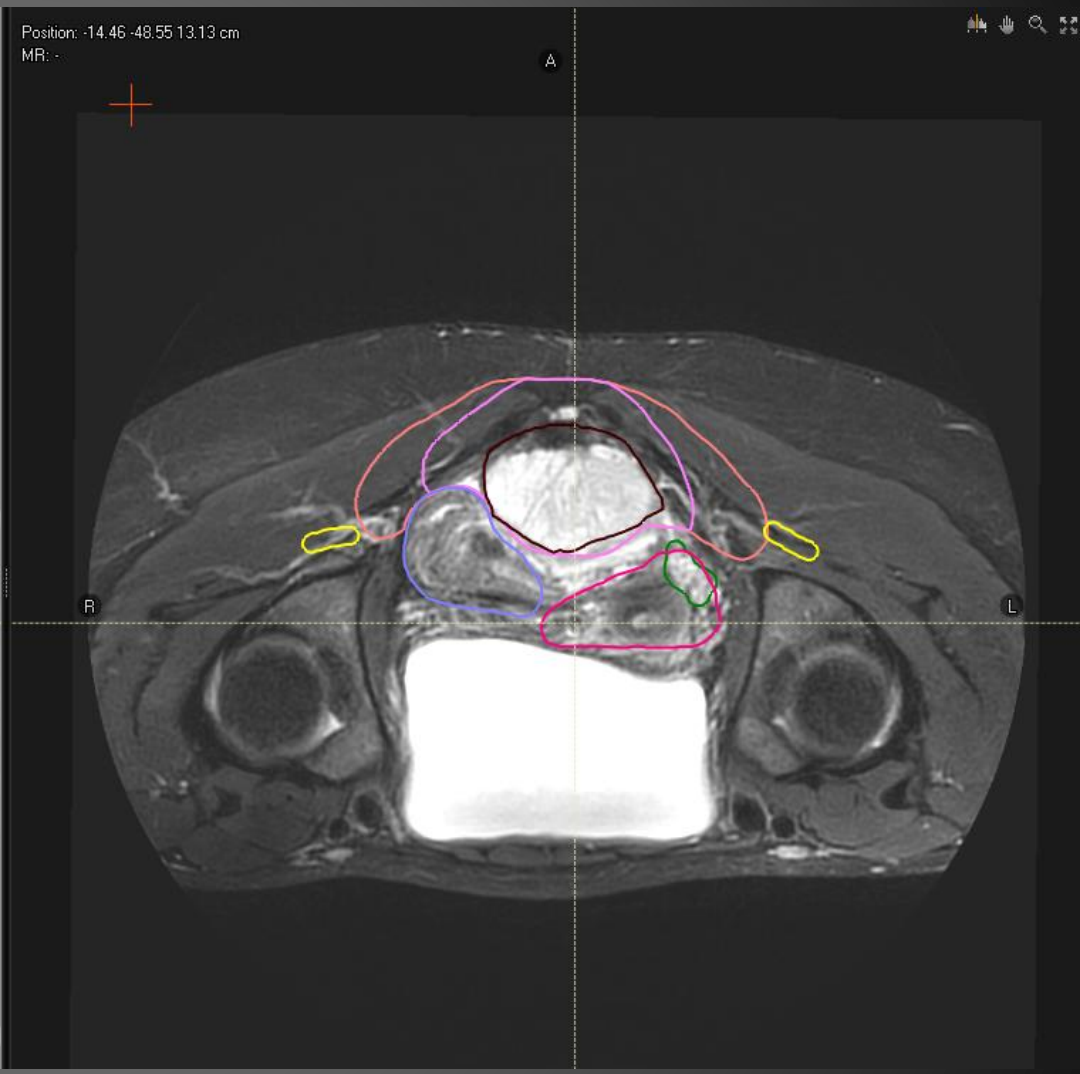

Position: -15.82 -46.15 15.31 cm
MR: -
A
R
L

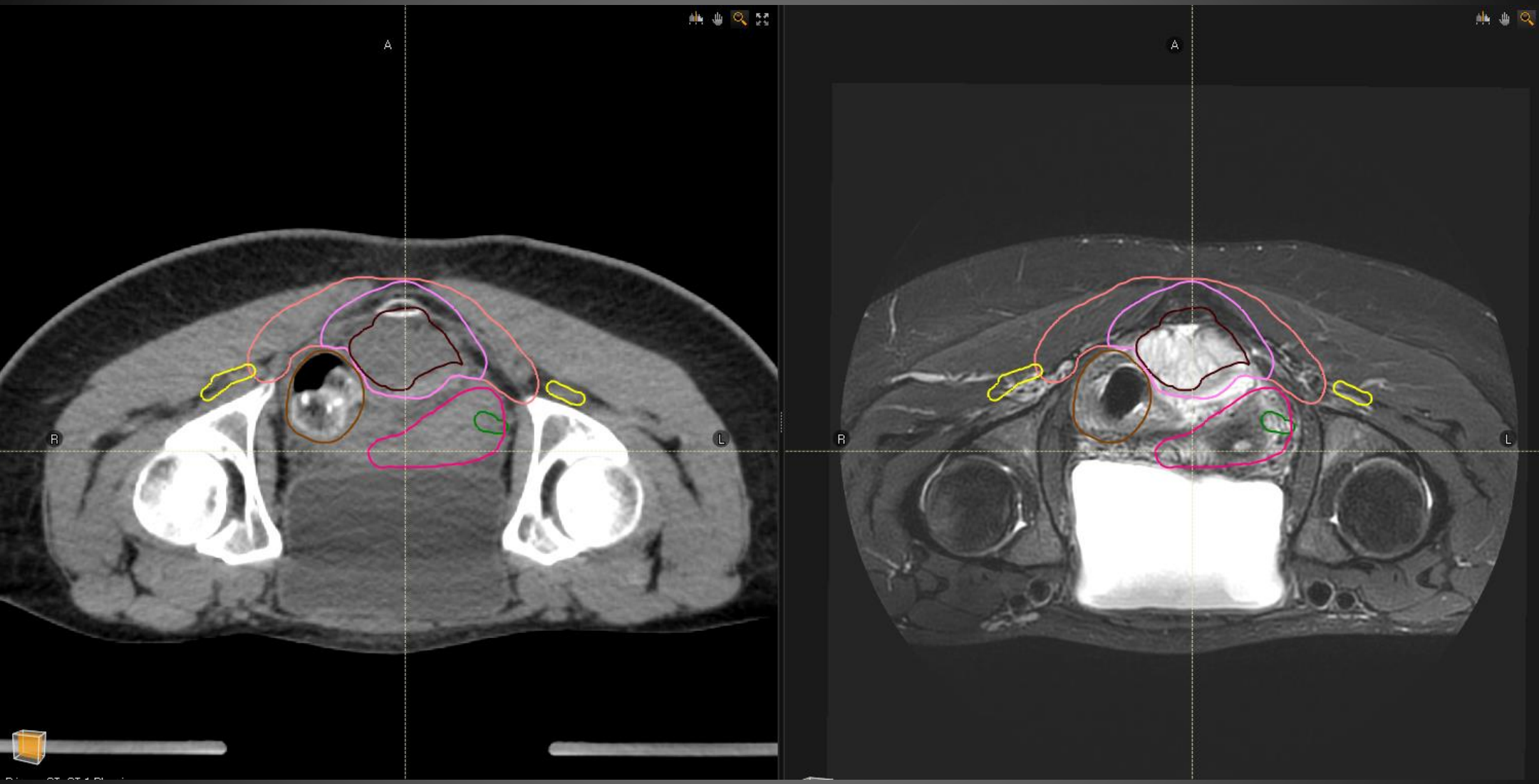

A
R
L
A
R
L

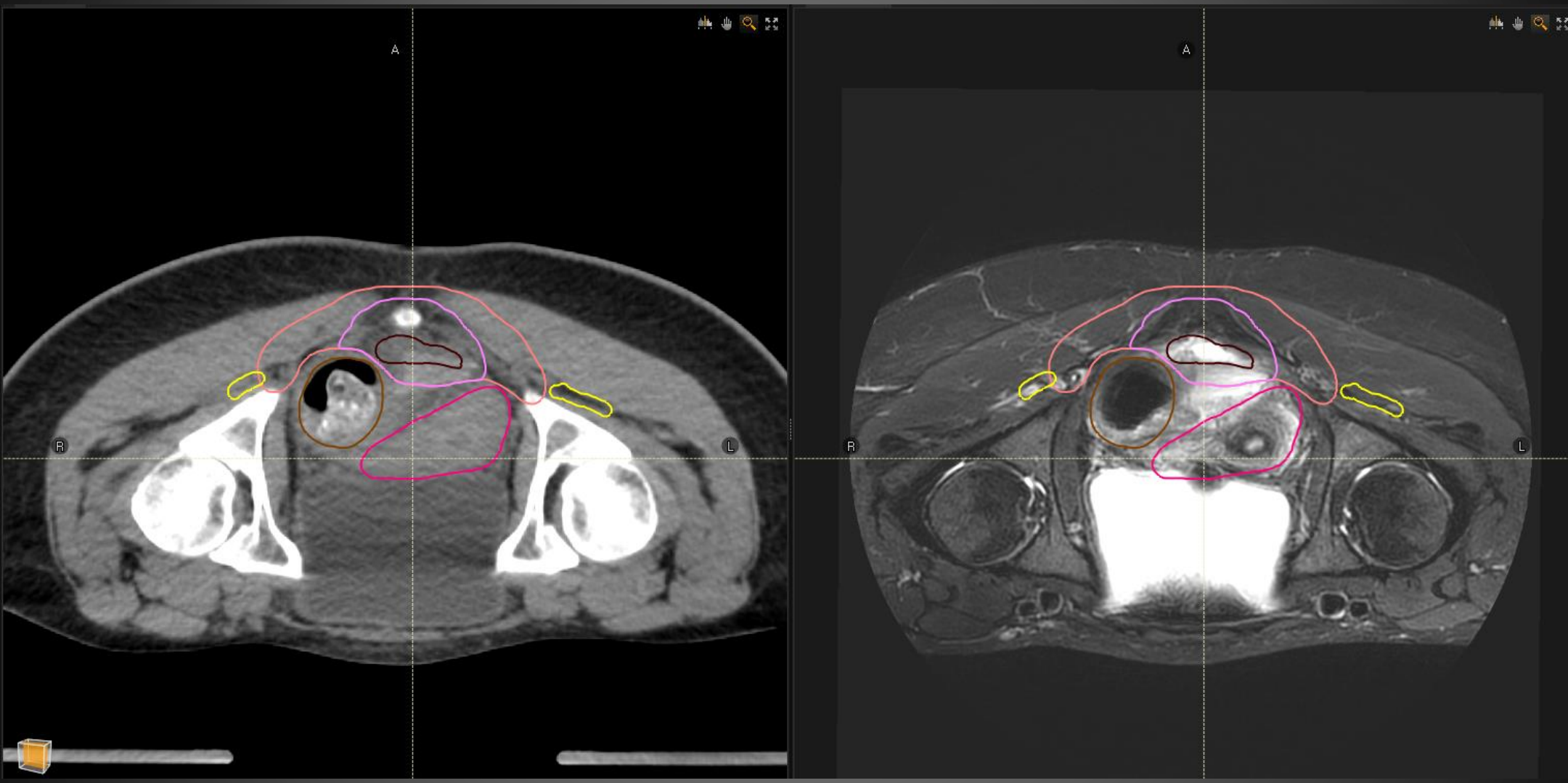

A
R
L
A
R
L

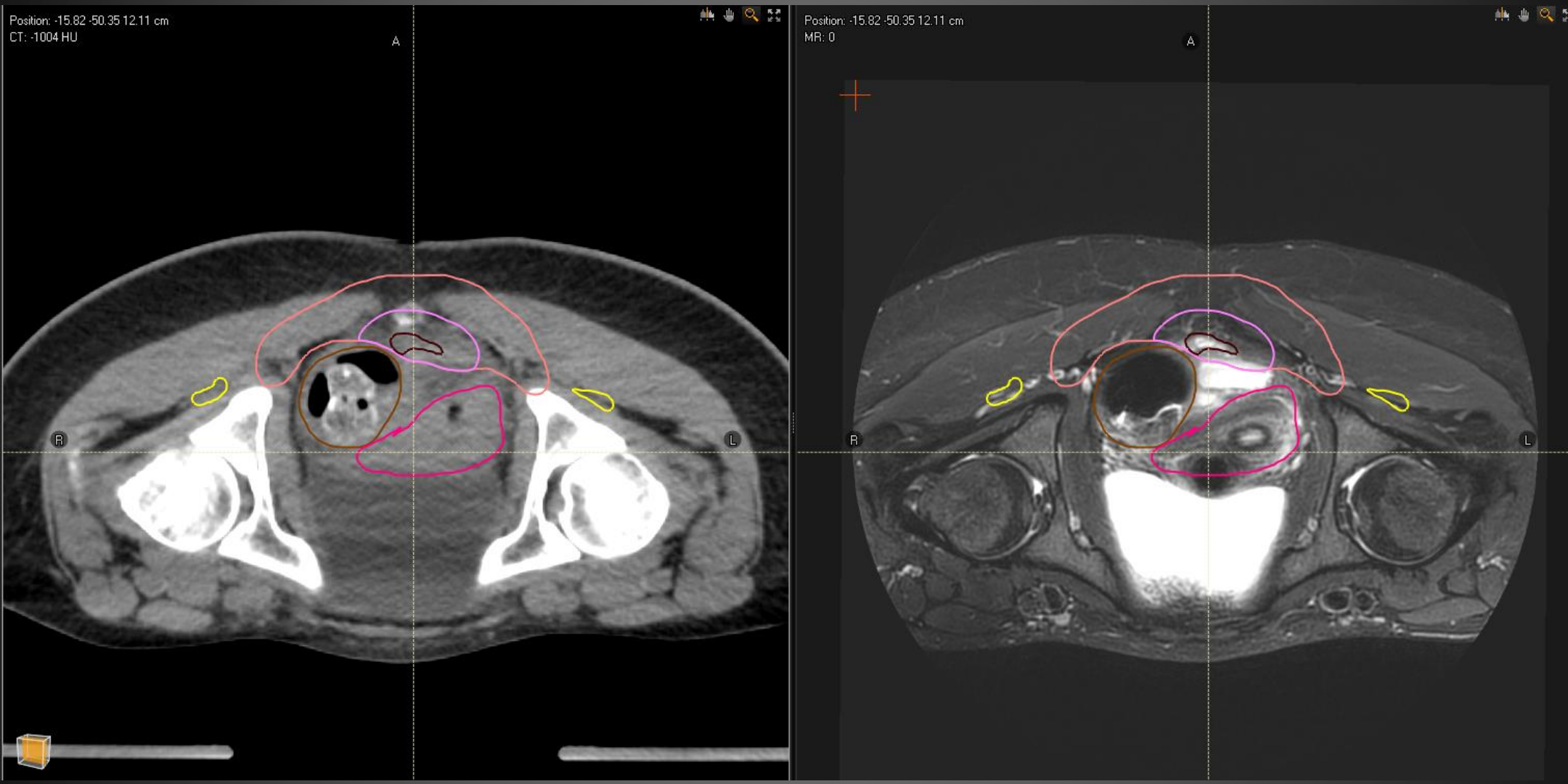

A
R
L
A
R
L

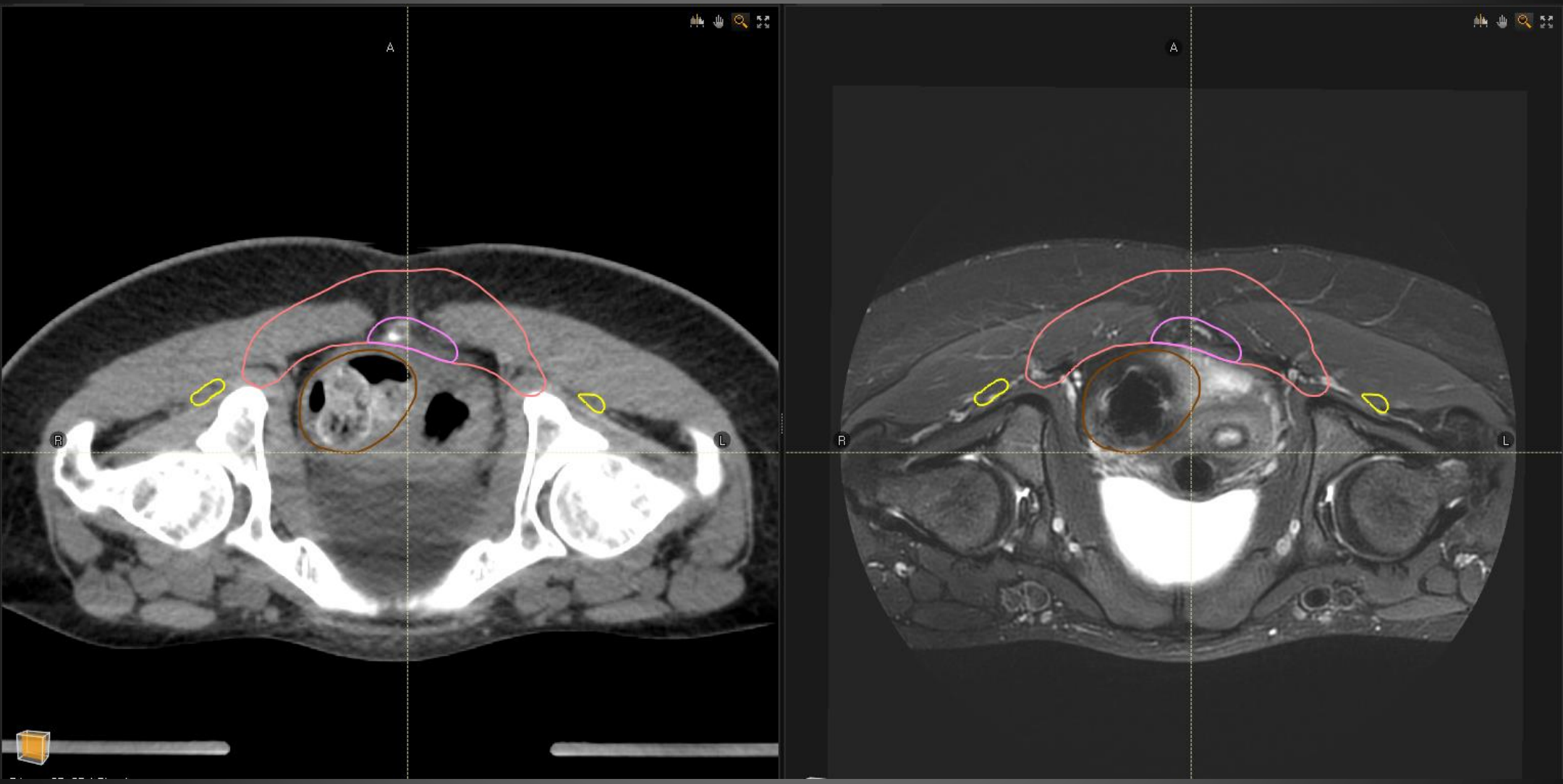

Position: -14.46 -48.55 13.13 cm
CT: -1000 HU
A
R
L

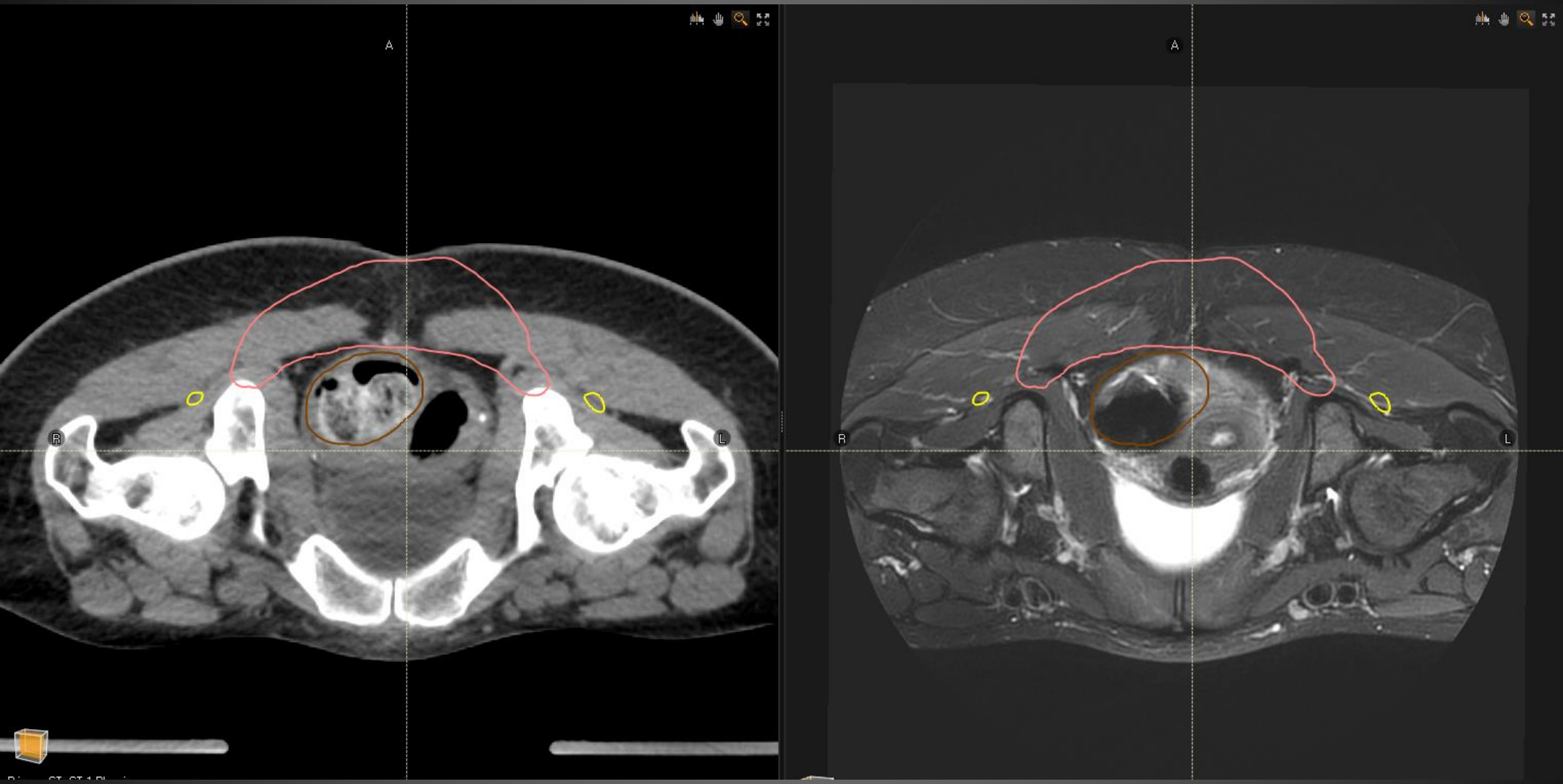

Position: -14.46 -48.55 13.13 cm
MR: -
A
R
L

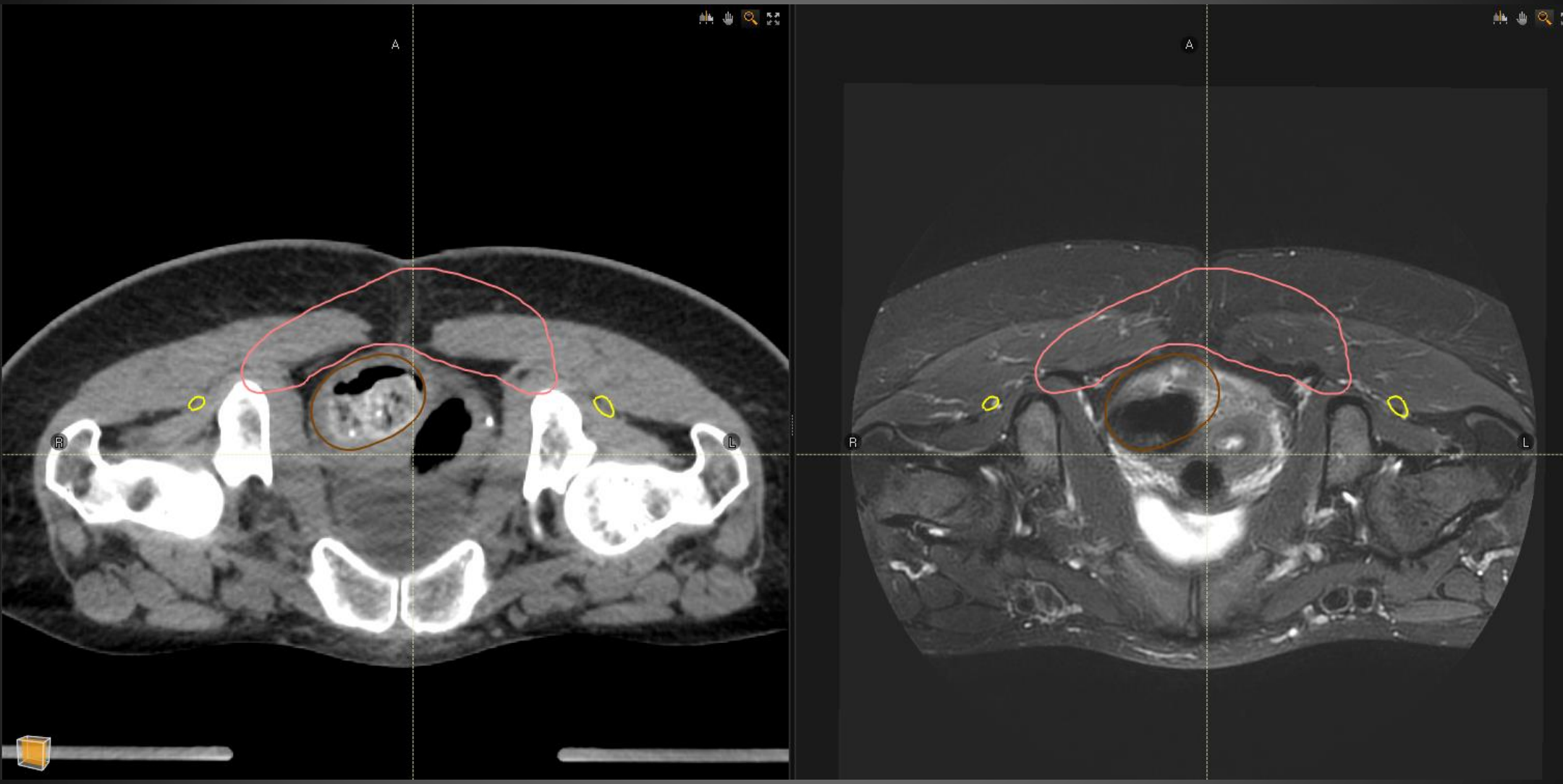

A
R
L
A
R
L

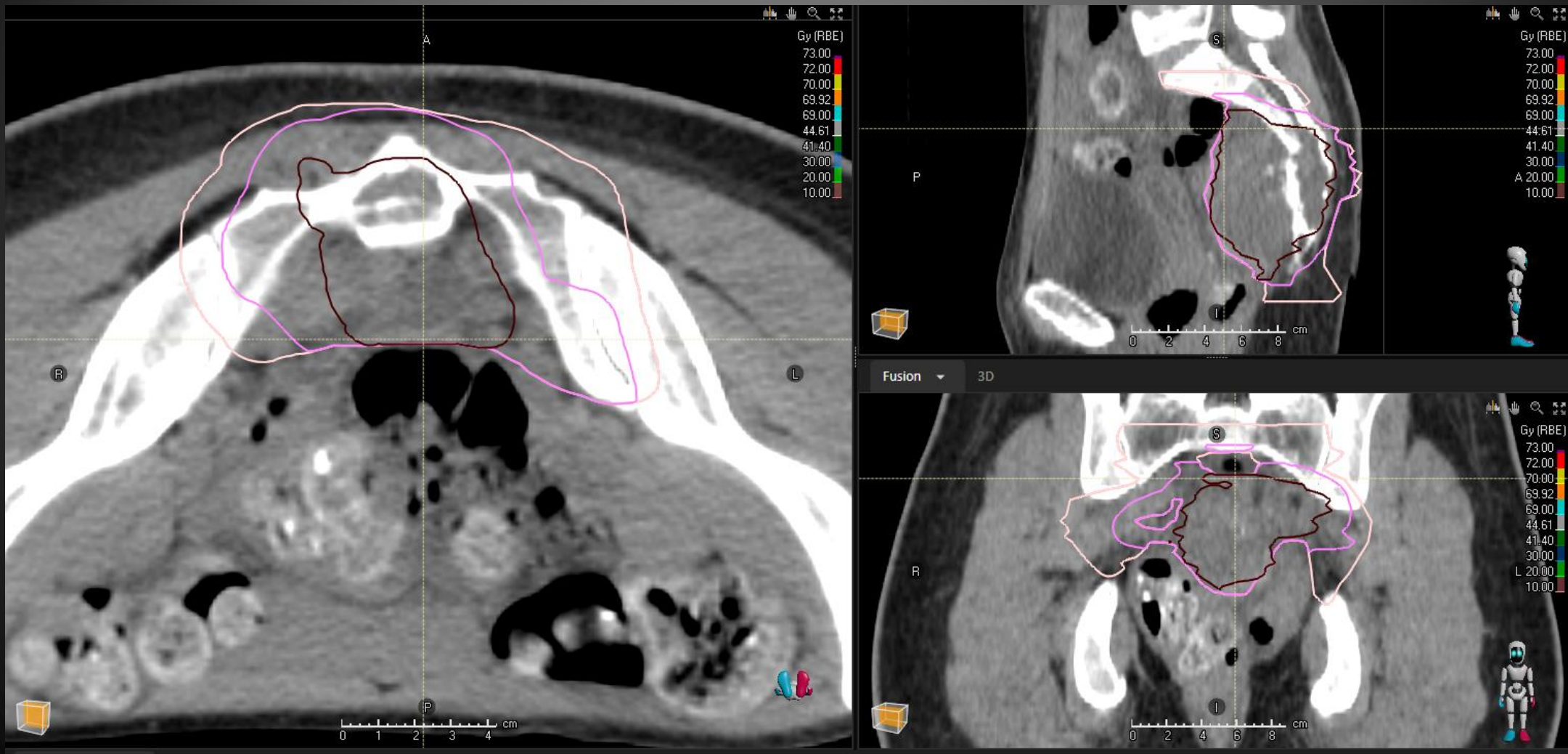

A
R
L
A
R
L


Position: -15.82 -50.35 12.11 cm
CT: -1004 HU
A
R
L
Position: -15.82 -50.35 12.11 cm
MR: 0
A
R
L

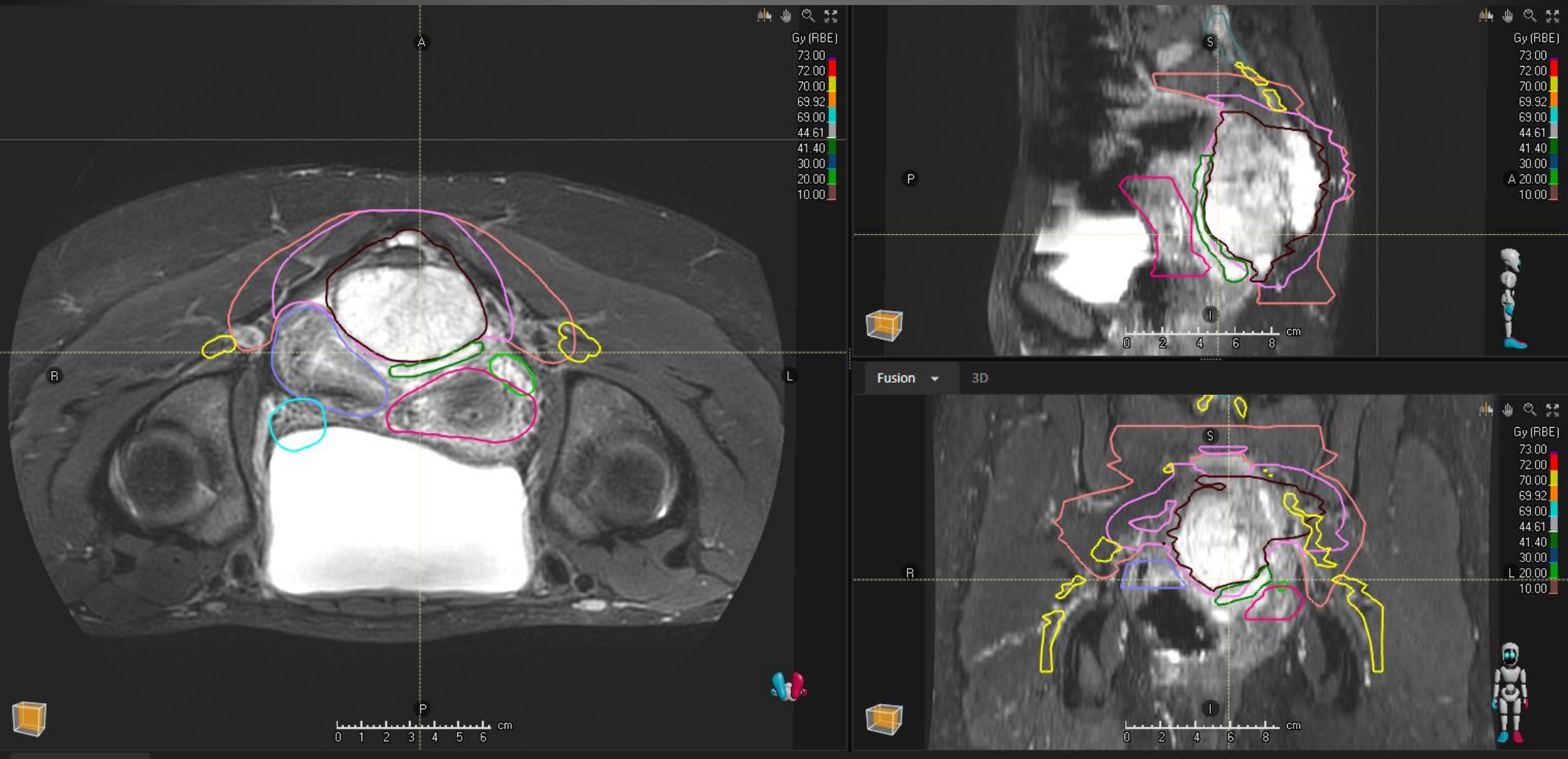

A
R
L
A
R
L

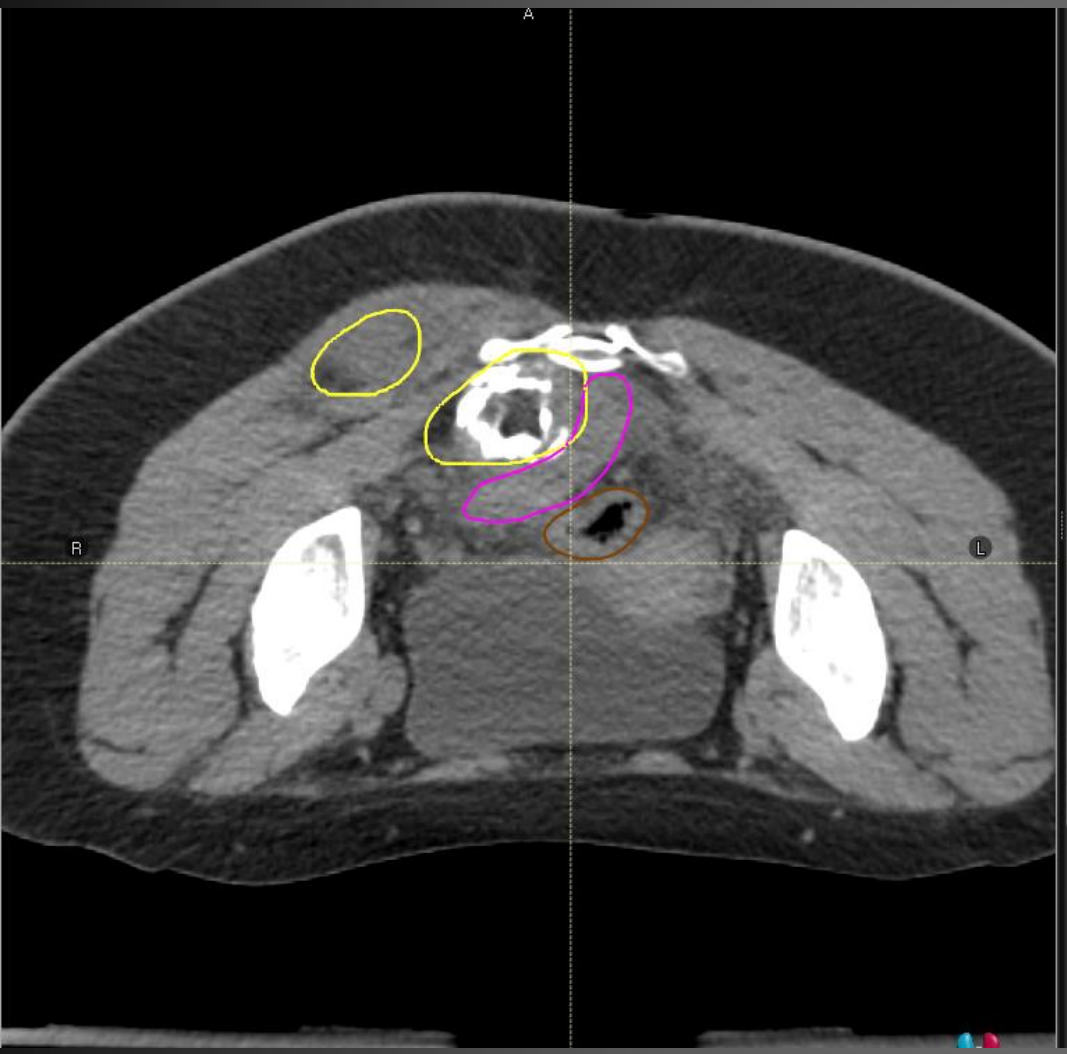

A
R
L
A
R
L

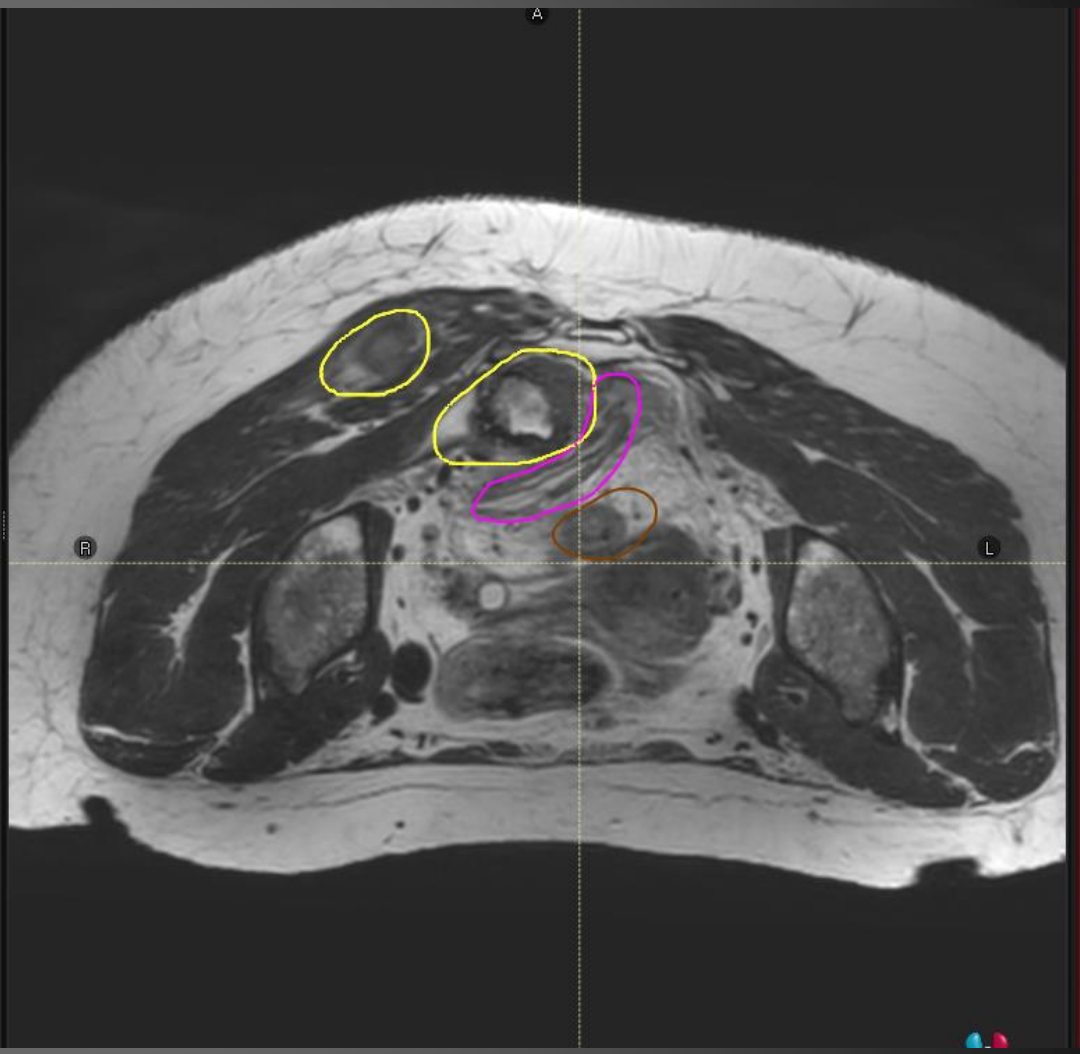

A
R
L
A
R
L

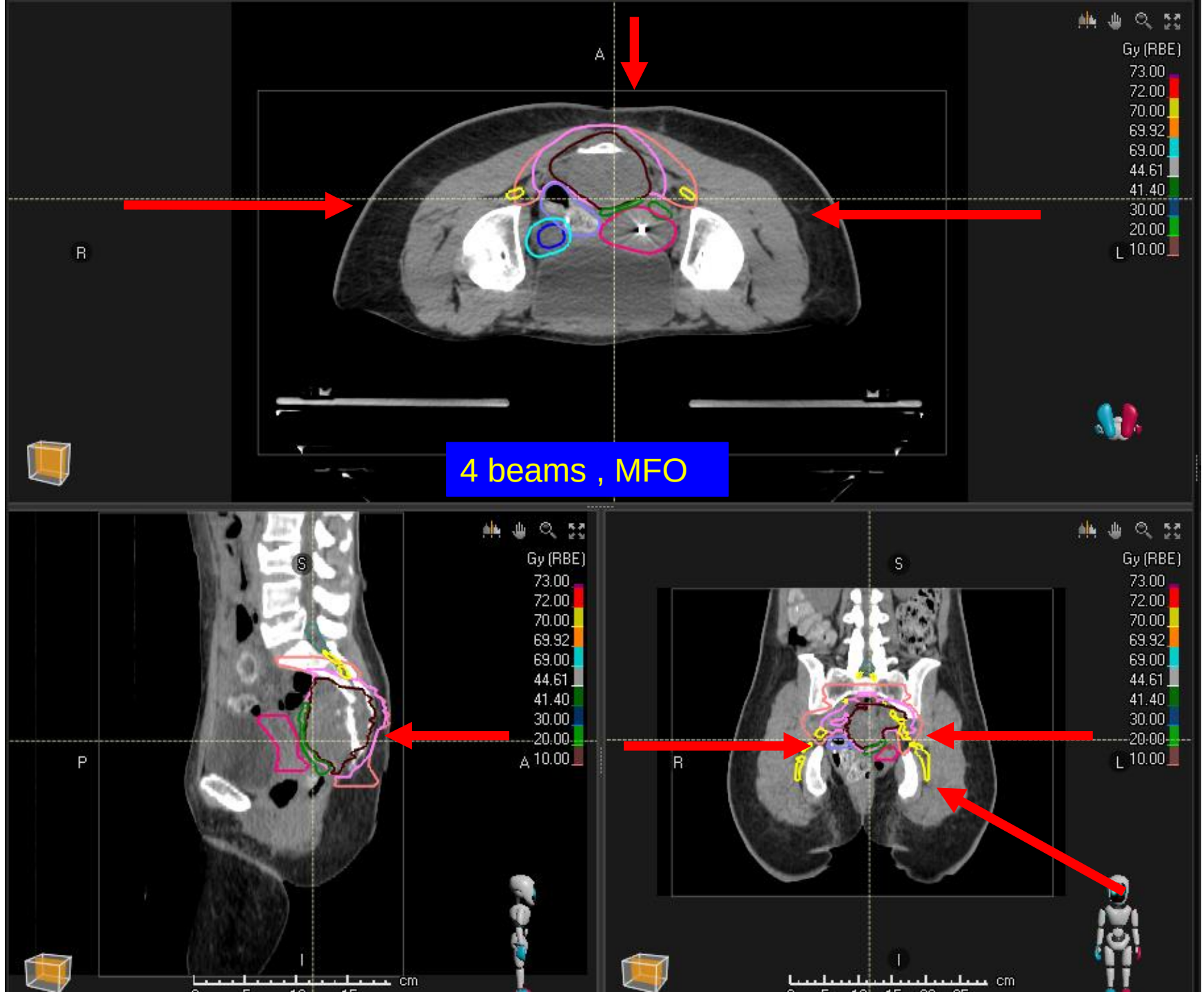

A
R
L
P
Gy (RBE)
73.00
72.00
70.00
69.92
69.00
44.61
41.40
30.00
20.00
10.00
0 1 2 3 4 cm
S
P
I
A 20.00
0 2 4 6 8 cm
Fusion
3D
R
L 20.00

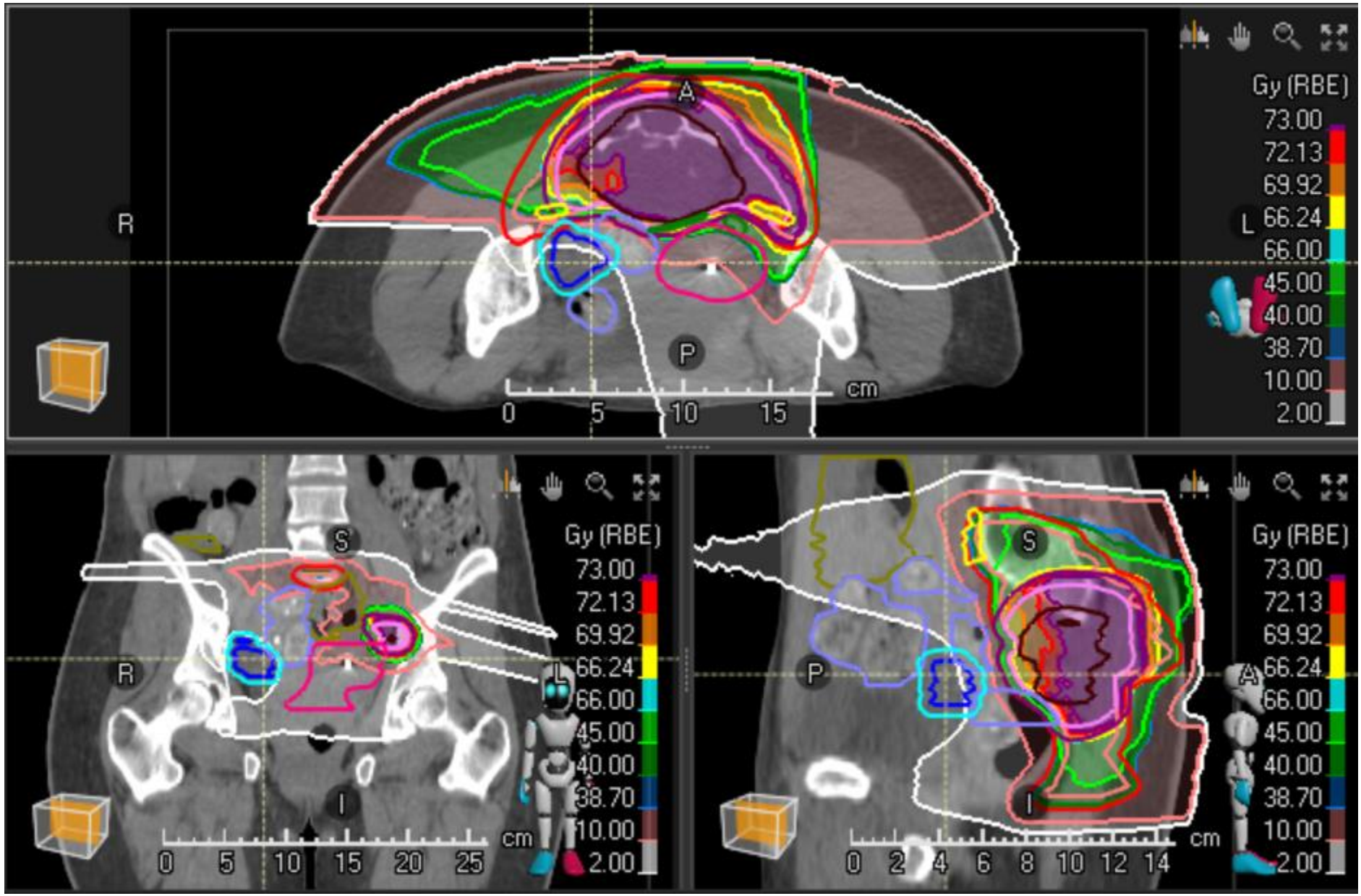

Gy (RBE)
73.00
72.00
70.00
69.92
69.00
44.61
41.40
30.00
20.00
10.00
A
R
L
P
0 1 2 3 4 5 6 cm
S
P
I
0 2 4 6 8 cm
A 20.00
Fusion
3D
R
L 20.00

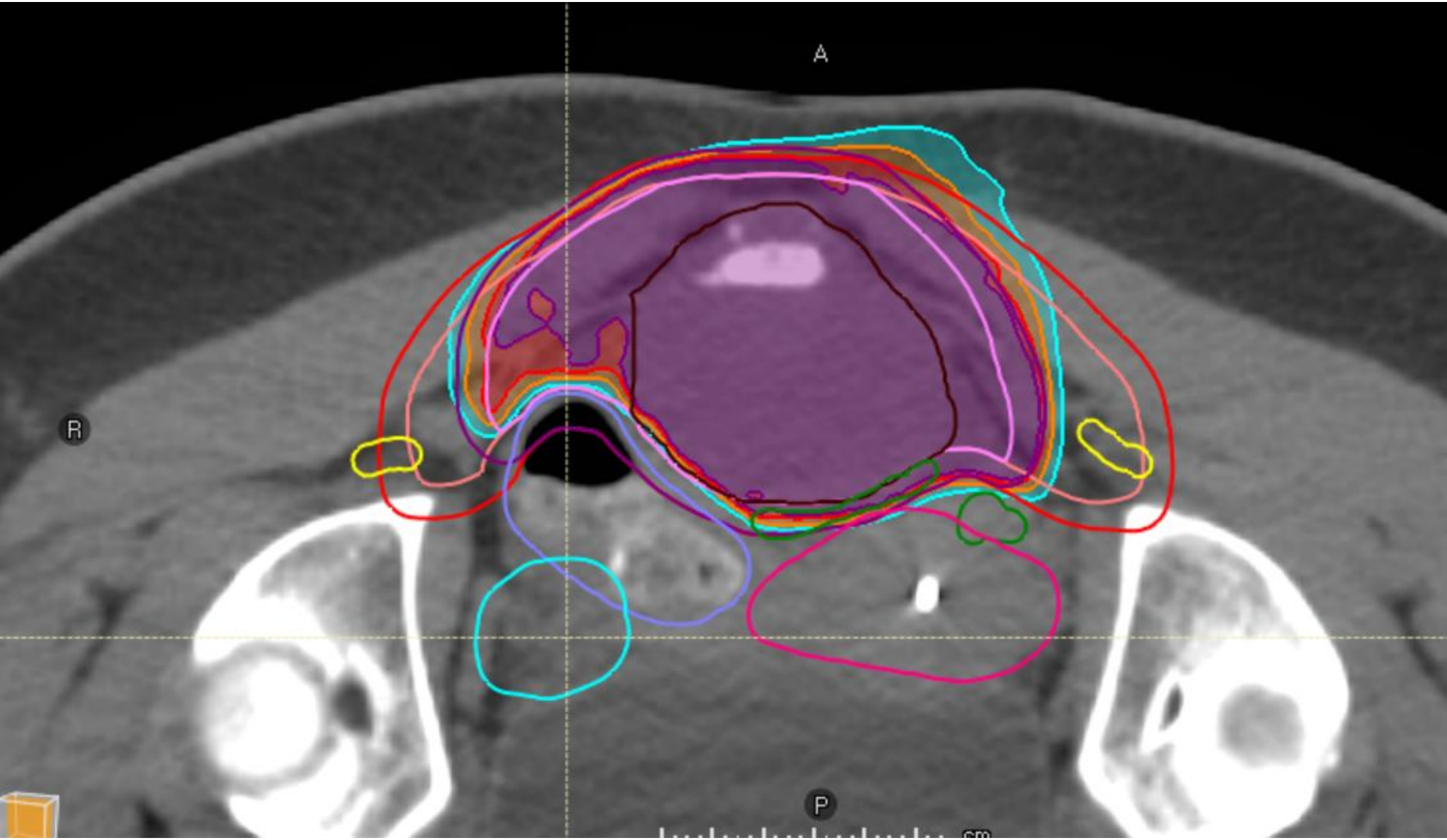

A
R
L
P
Gy (RBE)
73.00
72.00
70.00
69.92
69.00
44.61
41.40
30.00
20.00
10.00
0 1 2 3 4 5 6 cm
S
P
I
0 2 4 6 8 cm
A
Fusion
3D
R
L

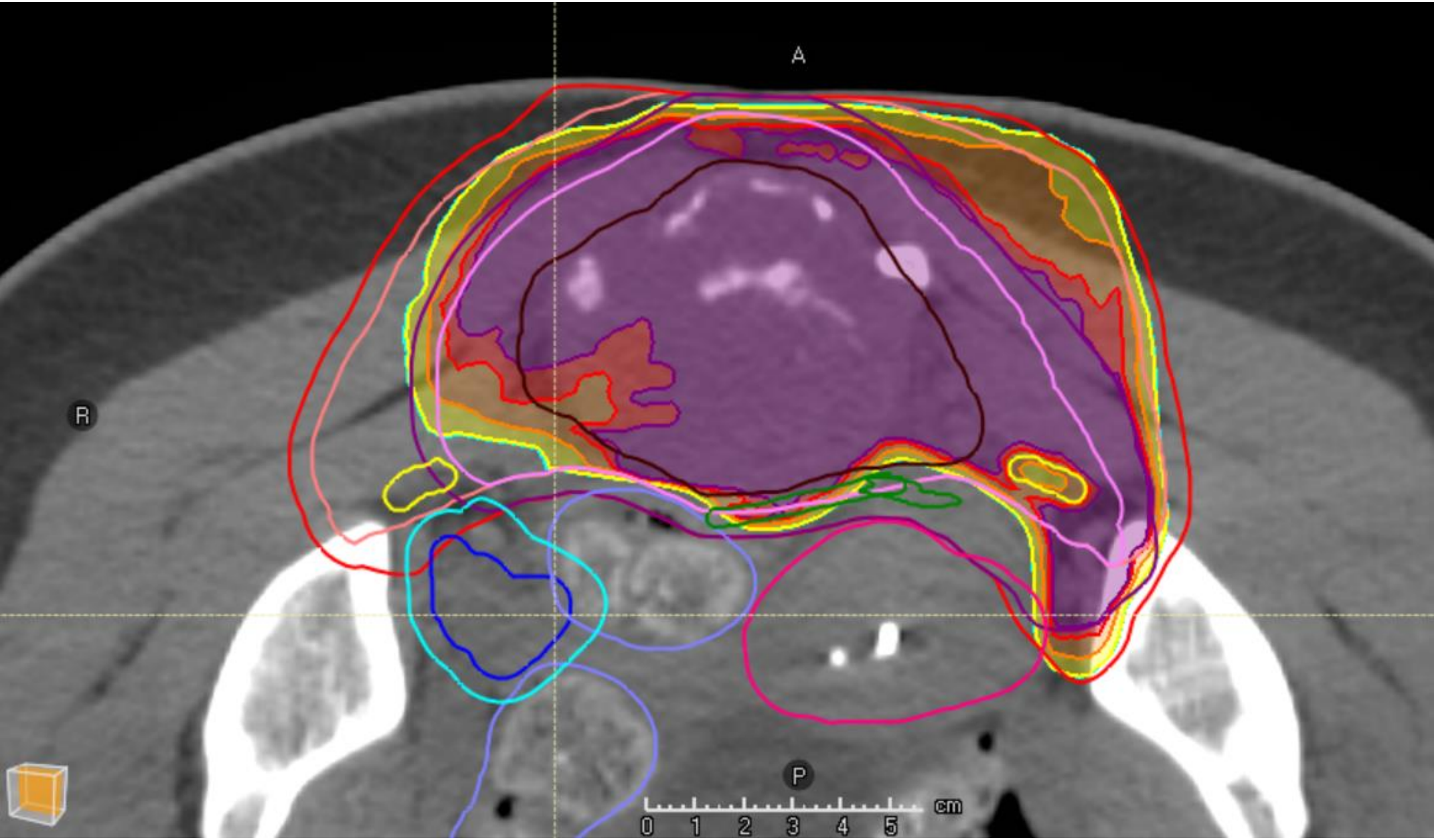

A
R
L

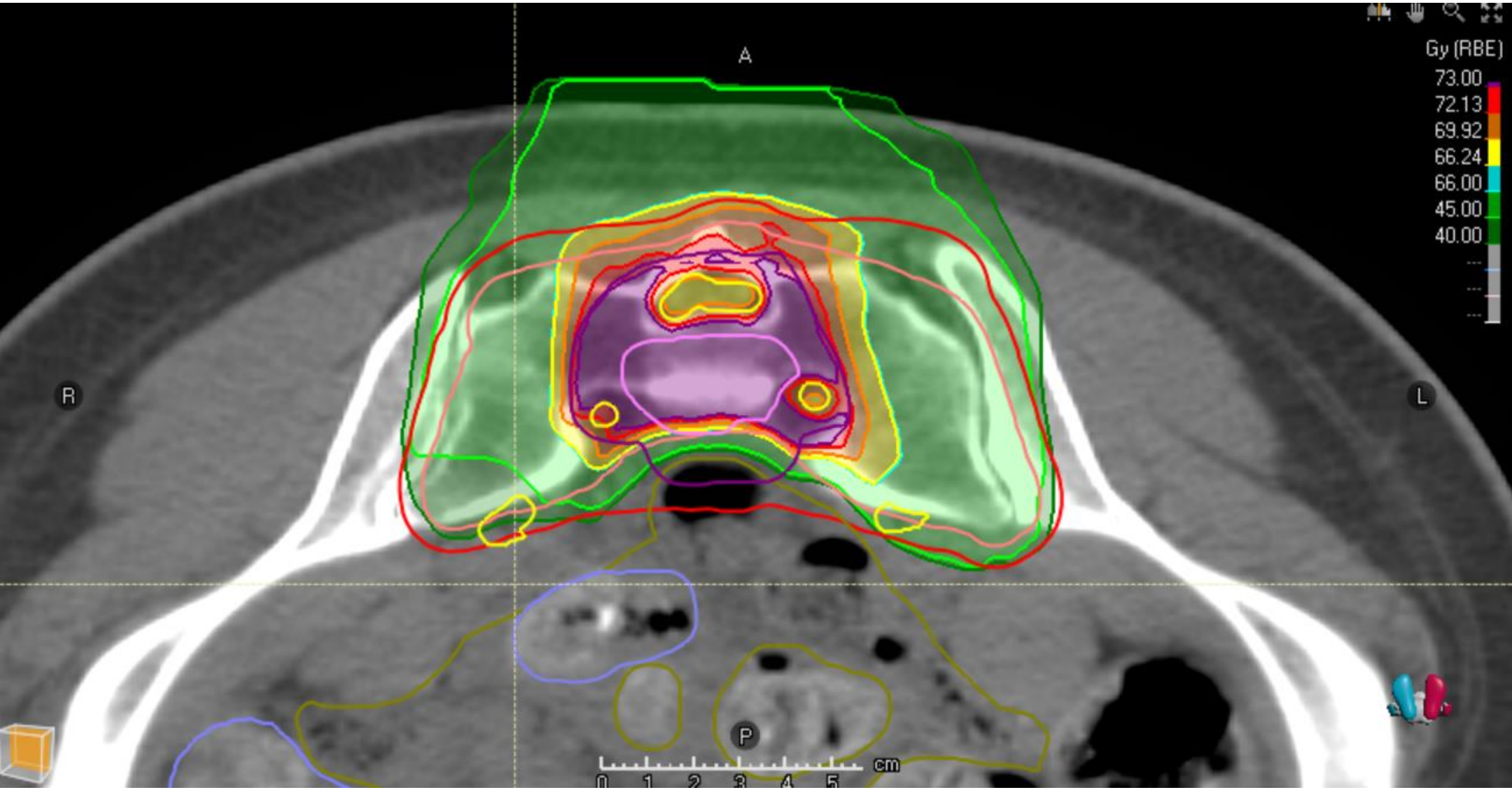

A
R
L

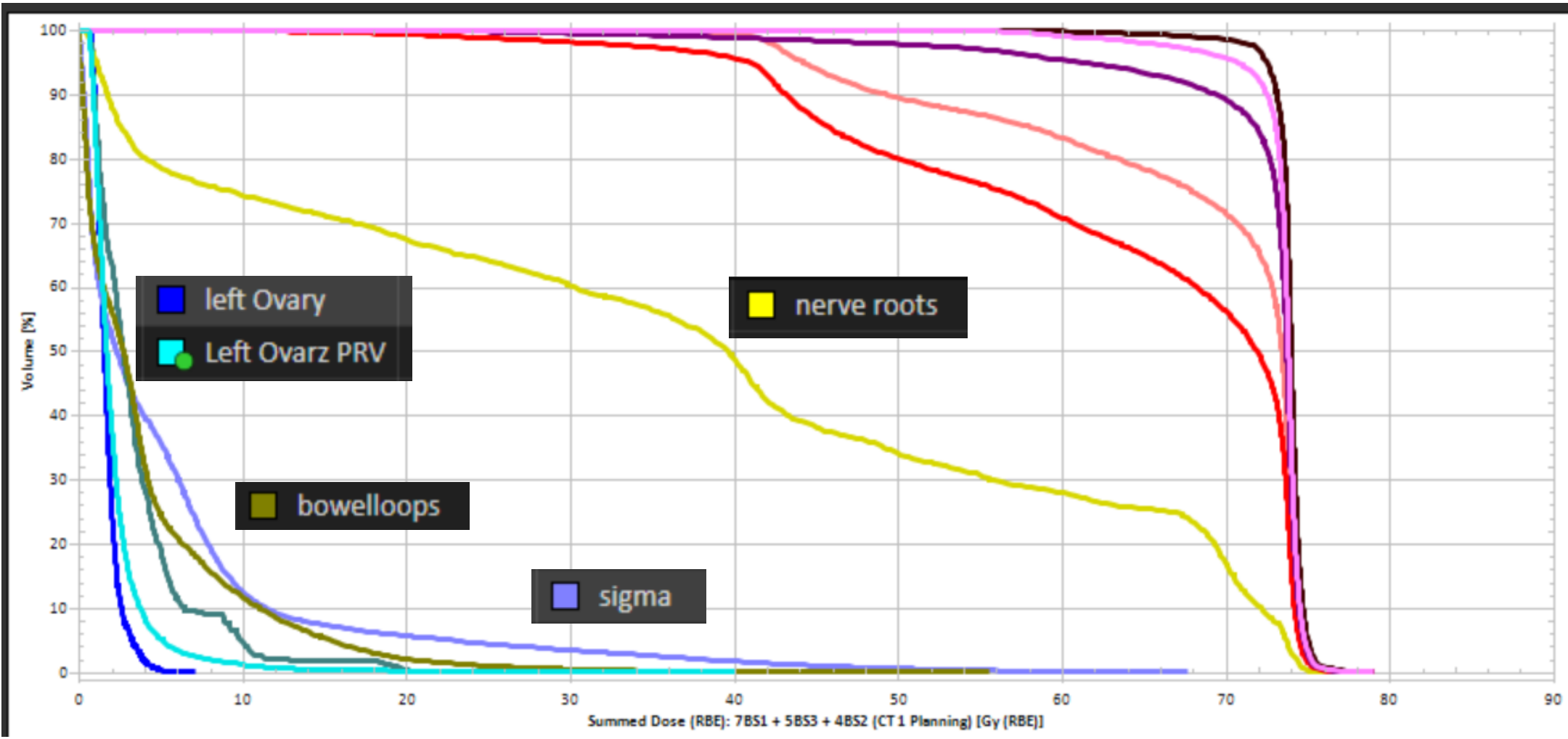

A
R
Gy (RBE)
73.00
72.00
70.00
69.92
69.00
44.61
41.40
30.00
20.00
10.00
L
4 beams , MFO
S
P
A
I
cm
S
R
L
I
cm


A
R
L
P
cm
0 5 10 15
Gy (RBE)
73.00
72.13
69.92
66.24
66.00
45.00
40.00
38.70
10.00
2.00
S
R
I
cm
0 5 10 15 20 25
Gy (RBE)
73.00
72.13
69.92
66.24
66.00
45.00
40.00
38.70
10.00
2.00
S
P
I
cm
0 2 4 6 8 10 12 14
A
Gy (RBE)
73.00
72.13
69.92
66.24
66.00
45.00
40.00
38.70
10.00
2.00


A
R
P


A
R
P
cm
0 1 2 3 4 5


A
R
L
P
Gy (RBE)
73.00
72.13
69.92
66.24
66.00
45.00
40.00
cm
0 1 2 3 4 5


left Ovary
Left Ovarz PRV
nerve roots
bowelloops
sigma
Volume [%]
Summed Dose (RBE): 7BS1 + 5BS3 + 4BS2 (CT 1 Planning) [Gy (RBE)]
0
10
20
30
40
50
60
70
80
90
100

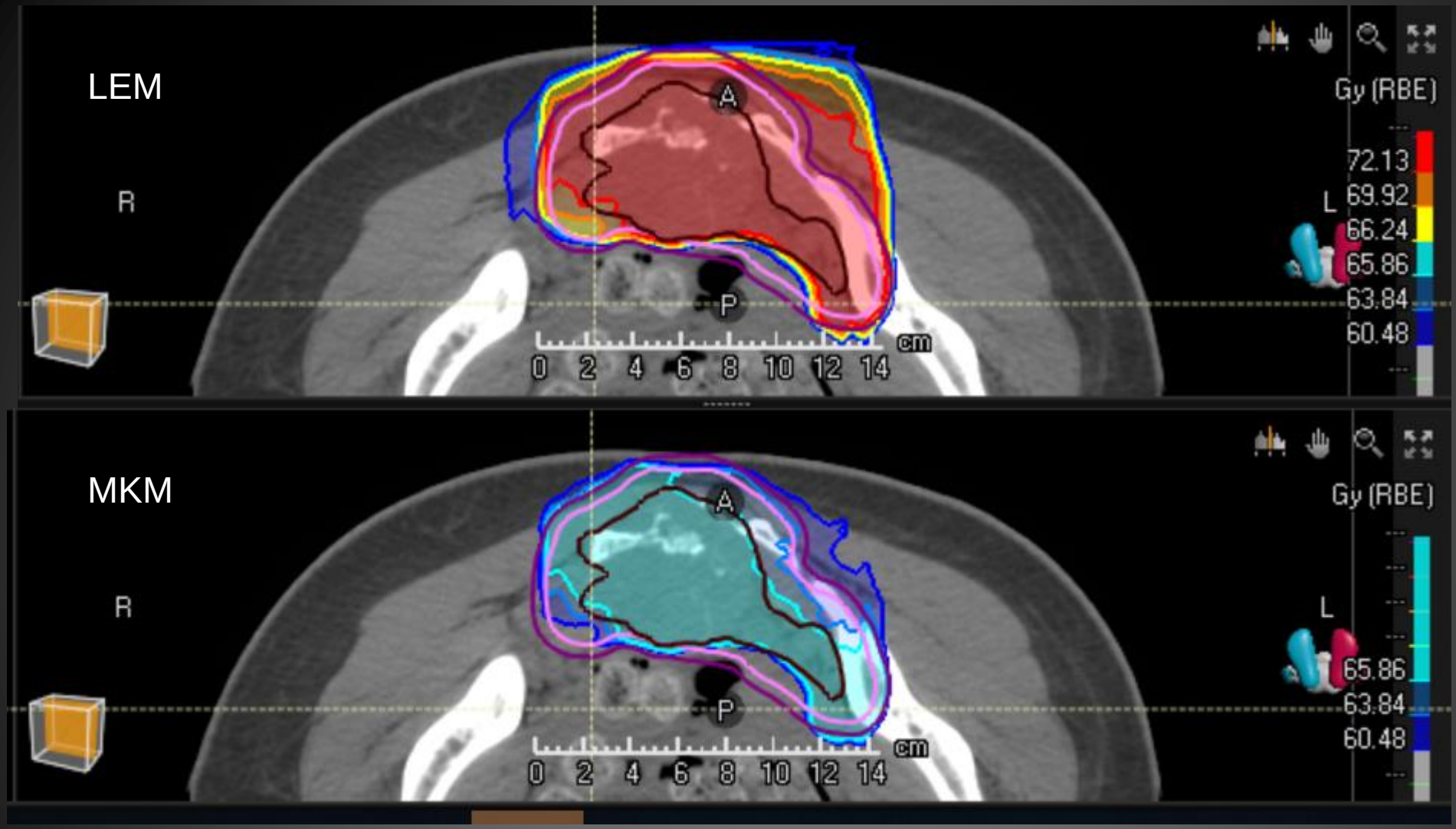
Priority	Dose	ROI/POI	Clinical goal	Value	Result
1	Summed Dose...	cauda	At most 66.00 Gy (RBE) dose at 0.05 % volume	21.35 Gy (RBE)	✓
1	Summed Dose...	colon	At most 55.00 Gy (RBE) dose at 10.00 cm³ volume	10.21 Gy (RBE)	✓
1	Summed Dose...	colon	At most 58.00 Gy (RBE) dose at 5.00 cm³ volume	11.29 Gy (RBE)	✓
1	Summed Dose...	colon	At most 60.00 Gy (RBE) dose at 1.00 cm³ volume	13.18 Gy (RBE)	✓
1	Summed Dose...	left Ovary	At most 1.50 Gy (RBE) average dose	1.72 Gy (RBE)	!
1	Summed Dose...	left Ovary	At most 7.50 Gy (RBE) dose at 10.00 % volume	2.62 Gy (RBE)	✓
1	Summed Dose...	rectum	At most 55.00 Gy (RBE) dose at 10.00 cm³ volume	26.97 Gy (RBE)	✓
1	Summed Dose...	rectum	At most 63.00 Gy (RBE) dose at 5.00 cm³ volume	35.48 Gy (RBE)	✓
1	Summed Dose...	rectum	At most 66.00 Gy (RBE) dose at 1.00 cm³ volume	51.02 Gy (RBE)	✓
1	Summed Dose...	sigma	At most 55.00 Gy (RBE) dose at 10.00 cm³ volume	21.67 Gy (RBE)	✓
1	Summed Dose...	sigma	At most 63.00 Gy (RBE) dose at 5.00 cm³ volume	34.48 Gy (RBE)	✓
1	Summed Dose...	sigma	At most 66.00 Gy (RBE) dose at 1.00 cm³ volume	50.30 Gy (RBE)	✓
2	Summed Dose...	GTV1	At least 69.90 Gy (RBE) dose at 98.00 % volume	71.20 Gy (RBE)	✓
2	Summed Dose...	GTV1	At least 100.00 % volume at 69.90 Gy (RBE) dose	98.57 %	!
3	Summed Dose...	Nerves root to spare	At most 70.00 Gy (RBE) dose at 2.80 cm³ volume	70.02 Gy (RBE)	!
4	Summed Dose...	CTV2	At least 69.90 Gy (RBE) dose at 98.00 % volume	64.95 Gy (RBE)	!
4	Summed Dose...	CTV2	At least 100.00 % volume at 69.90 Gy (RBE) dose	95.73 %	!
6	Summed Dose...	CTV1	At least 39.33 Gy (RBE) dose at 98.00 % volume	42.19 Gy (RBE)	✓
6	Summed Dose...	CTV1	At least 100.00 % volume at 39.33 Gy (RBE) dose	99.16 %	!

LEM vs mMKM

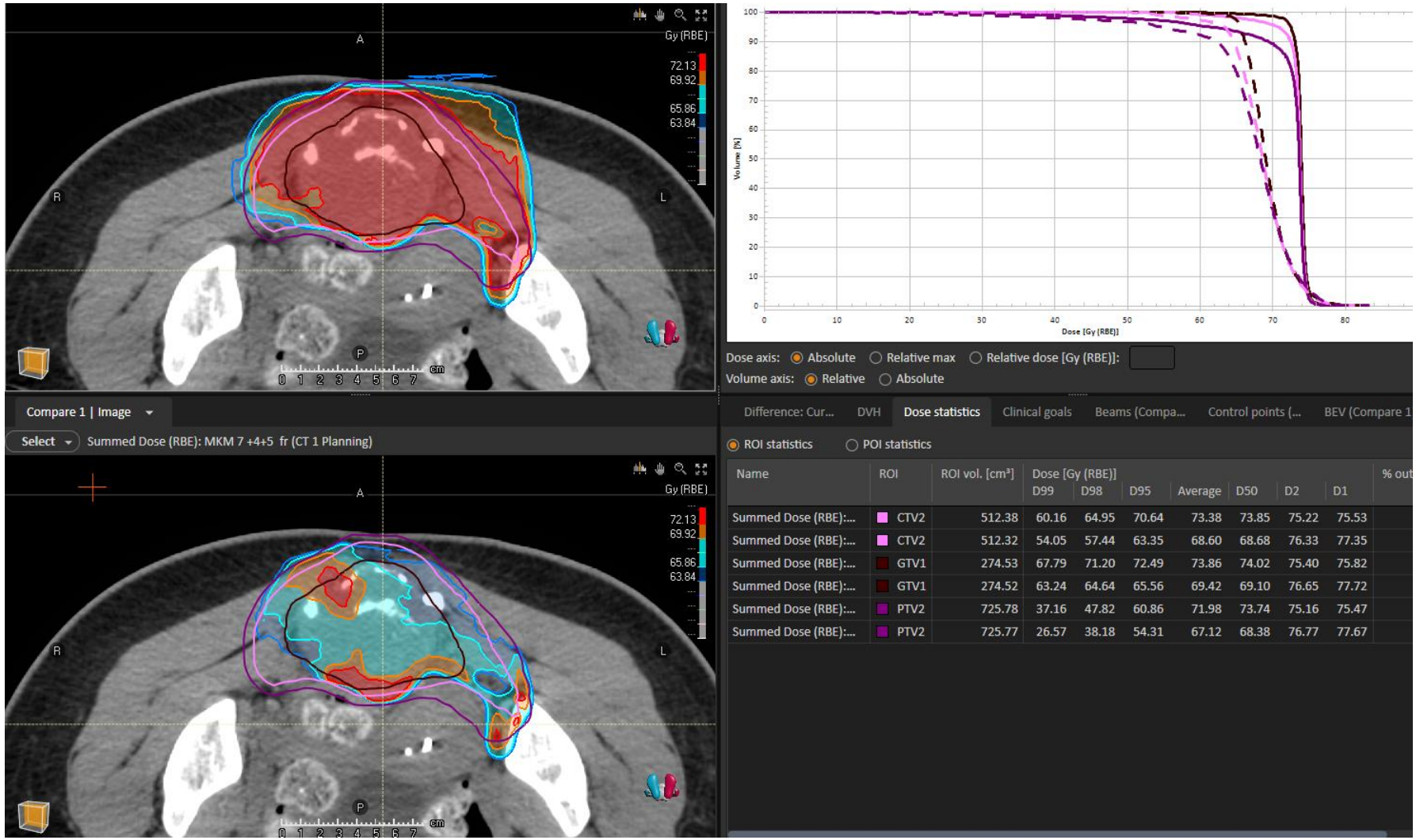
LEM 73.6 Gy

should be equivalent to

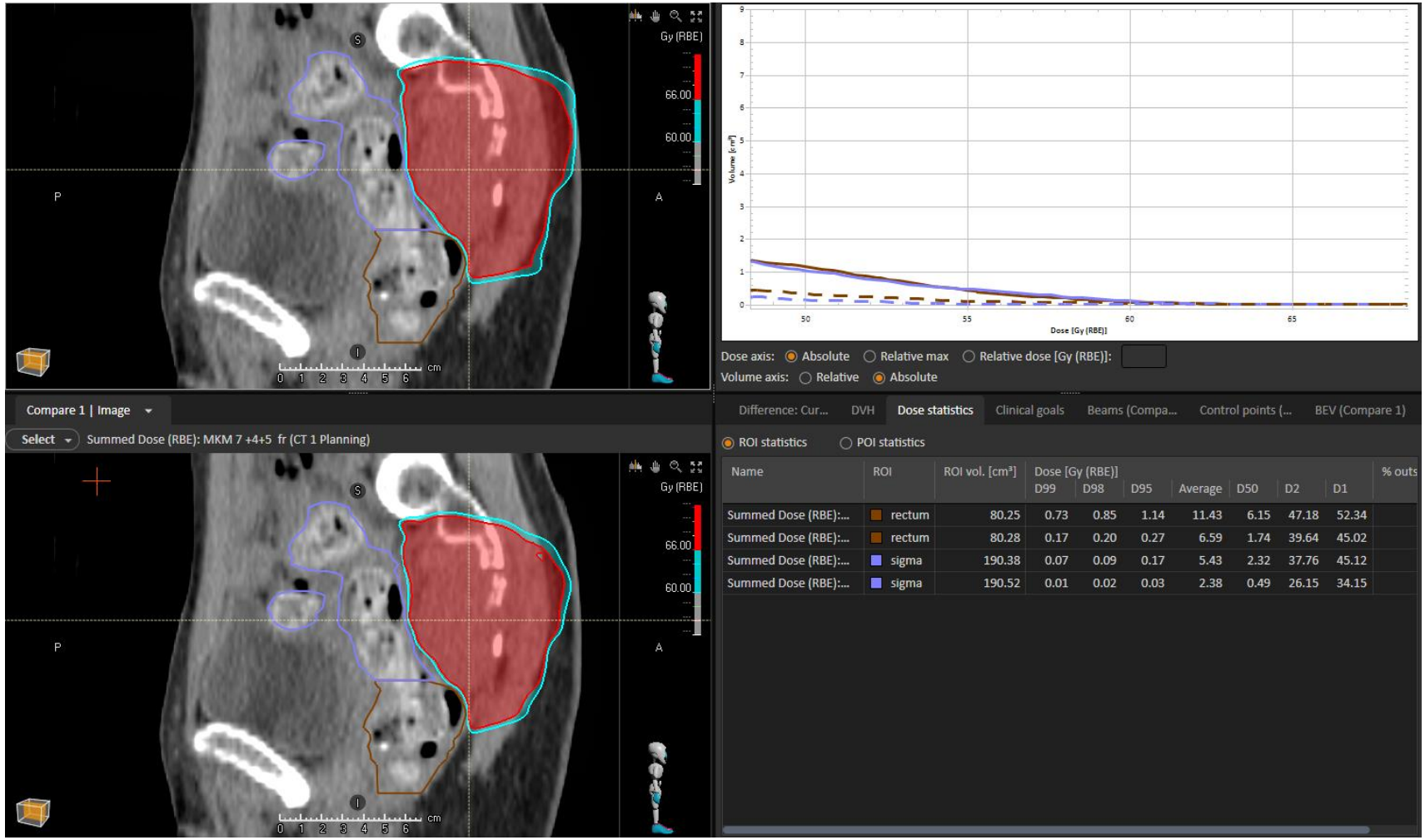
mMKM 67.2 Gy RBE


LEM
R
A
P
0 2 4 6 8 10 12 14
cm
Gy (RBE)
72.13
69.92
66.24
65.86
63.84
60.48
L
MKM
R
A
P
0 2 4 6 8 10 12 14
cm
Gy (RBE)
65.86
63.84
60.48
L

Target coverage: LEM 73.6 Gy RBE, MKM 67.2 Gy RBE

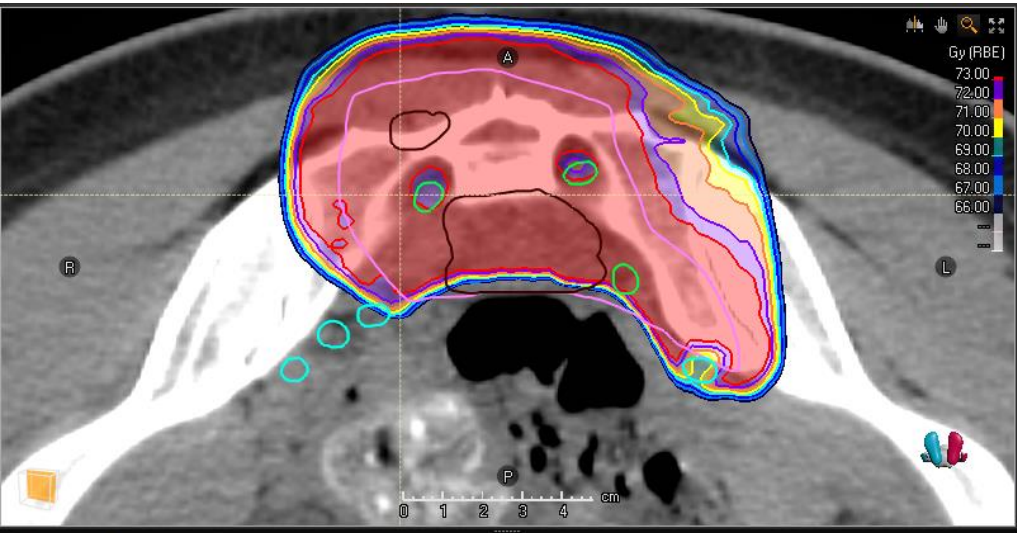


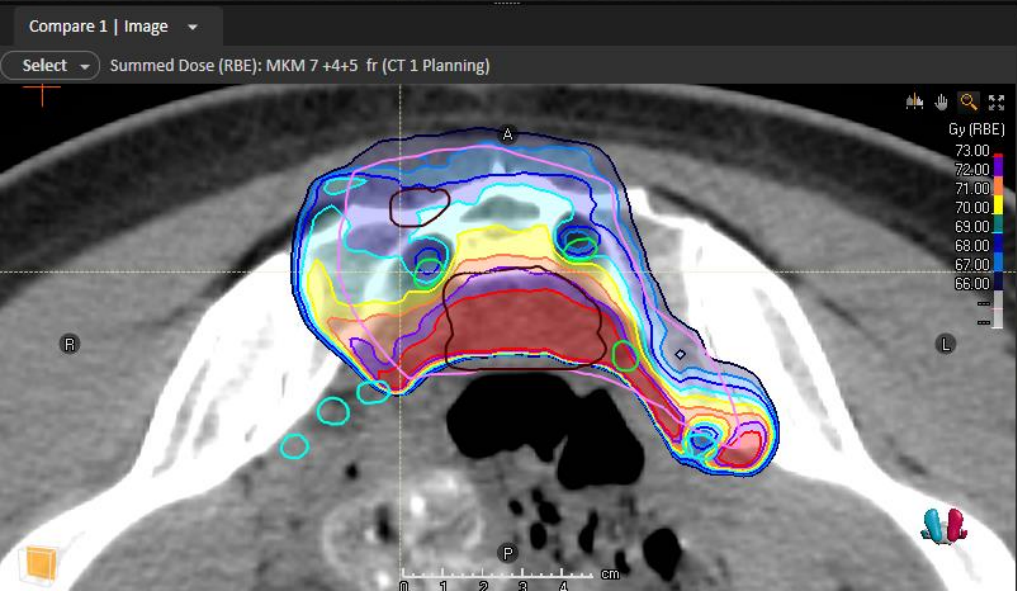
Rectum/sigmoid: LEM D1cc< 66 Gy RBE, MKM D1cc < 60Gy RBE

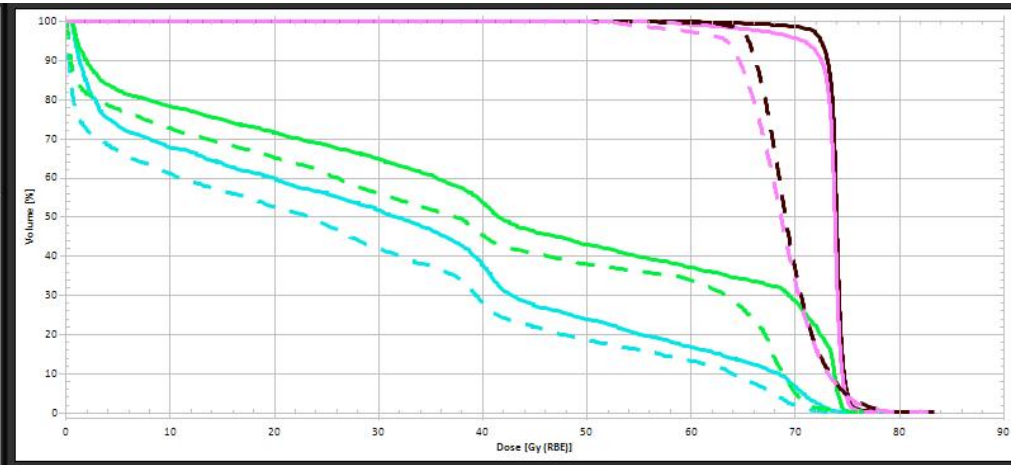


Name	ROI	ROI vol. [cm³]	Dose [Gy (RBE)] D99	D98	D95	Average	D50	D2	D1	% outs
Summed Dose (RBE):...	rectum	80.25	0.73	0.85	1.14	11.43	6.15	47.18	52.34	
Summed Dose (RBE):...	rectum	80.28	0.17	0.20	0.27	6.59	1.74	39.64	45.02	
Summed Dose (RBE):...	sigma	190.38	0.07	0.09	0.17	5.43	2.32	37.76	45.12	
Summed Dose (RBE):...	sigma	190.52	0.01	0.02	0.03	2.38	0.49	26.15	34.15	

Nerve roots: LEM D5%< 73/71 Gy RBE, MKM D5% < 69/66 Gy RBE







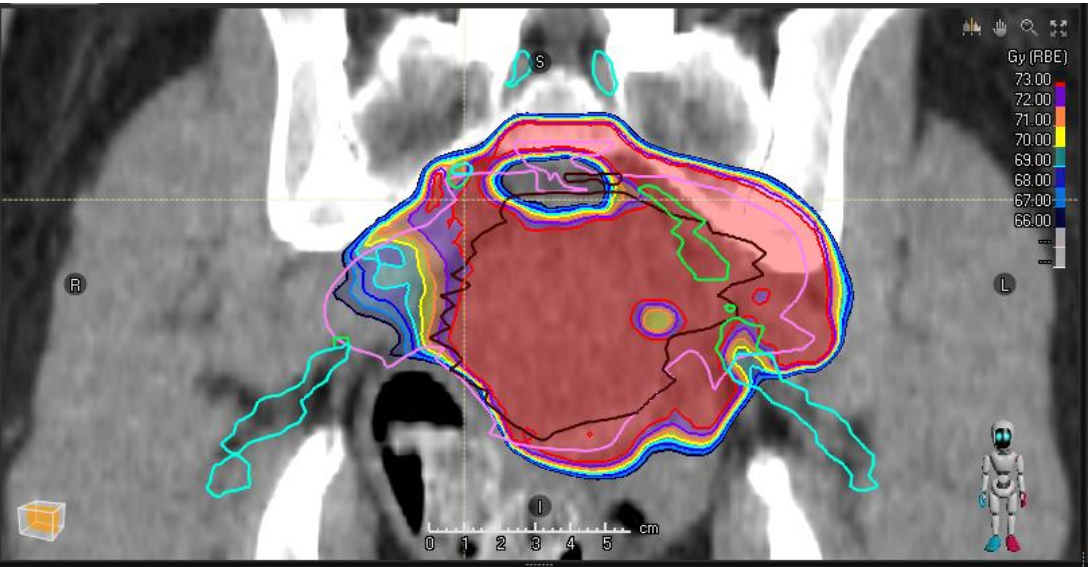
Dose axis: ◉ Absolute ○ Relative max ○ Relative dose [Gy (RBE)]:

Volume axis: ◉ Relative ○ Absolute

Difference: Curre... | DVH | **Dose statistics** | Clinical goals | Beams (Compare... | Control points (C... | BEV (Compare 1)

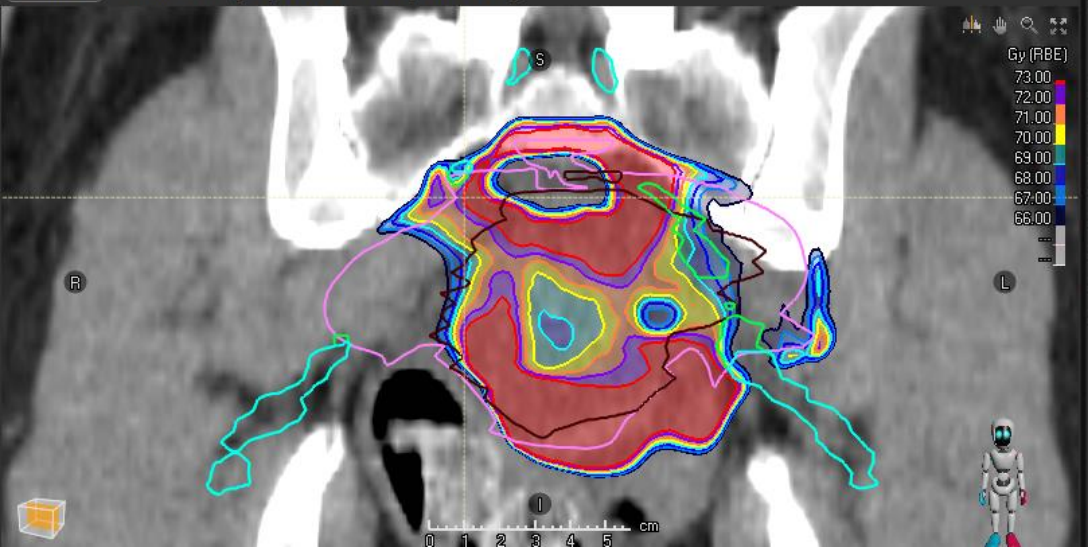
◉ ROI statistics ○ POI statistics

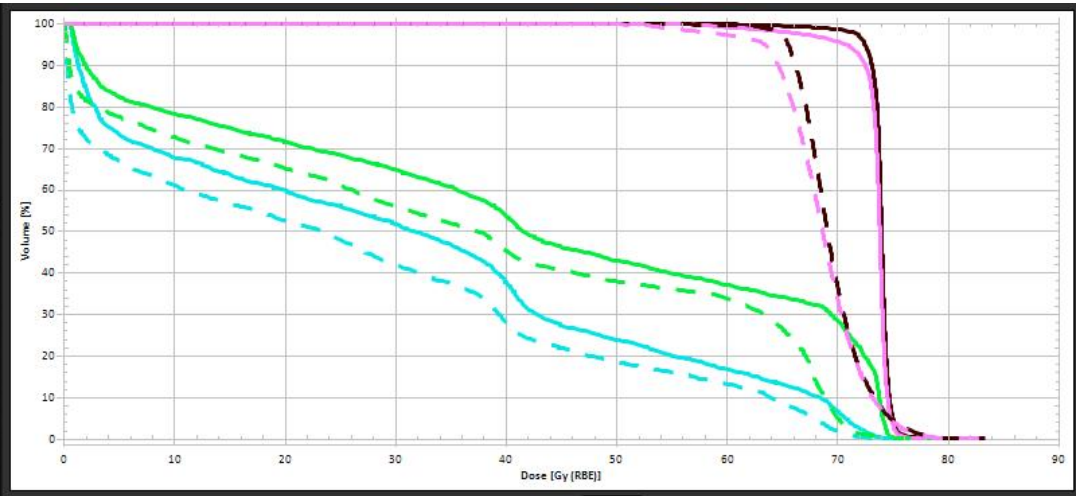
	ROI	ROI vol. [cm³]	Dose [Gy (RBE)] D99	D98	D95	Average	D50	D2	D1	% outside grid
ose (RBE):...	CTV2	512.38	60.16	64.95	70.64	73.38	73.85	75.22	75.53	0 %
ose (RBE):...	CTV2	512.32	54.05	57.44	63.35	68.60	68.68	76.33	77.35	0 %
ose (RBE):...	GTV1	274.53	67.79	71.20	72.49	73.86	74.02	75.40	75.82	0 %
ose (RBE):...	GTV1	274.52	63.24	64.64	65.56	69.42	69.10	76.65	77.72	0 %
ose (RBE):...	nerveroots_AN	34.95	0.73	0.83	1.13	41.74	41.56	74.48	74.65	0 %
ose (RBE):...	nerveroots_AN	34.91	0.18	0.21	0.29	36.14	37.42	71.18	72.39	0 %
ose (RBE):...	nervestospare_AN	22.82	0.69	0.77	0.93	30.55	31.52	72.43	73.13	0 %
ose (RBE):...	nervestospare_AN	22.77	0.17	0.18	0.24	25.66	23.43	69.81	71.21	0 %



Compare 1 | Image

Select — Summed Dose (RBE): MKM 7 +4+5 fr (CT 1 Planning)





Dose axis: (•) Absolute ( ) Relative max ( ) Relative dose [Gy (RBE)]:

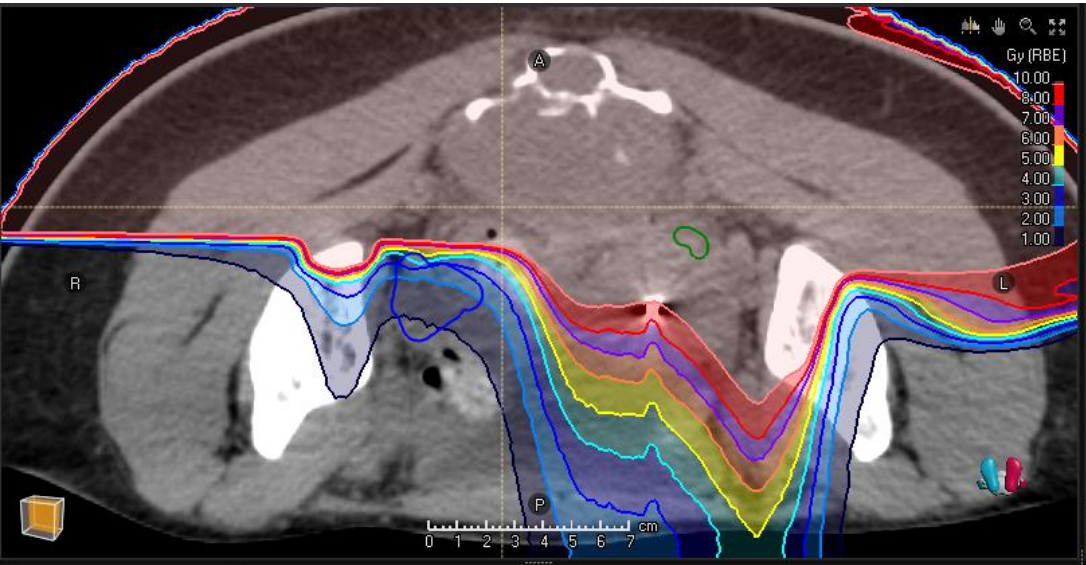
Volume axis: (•) Relative ( ) Absolute

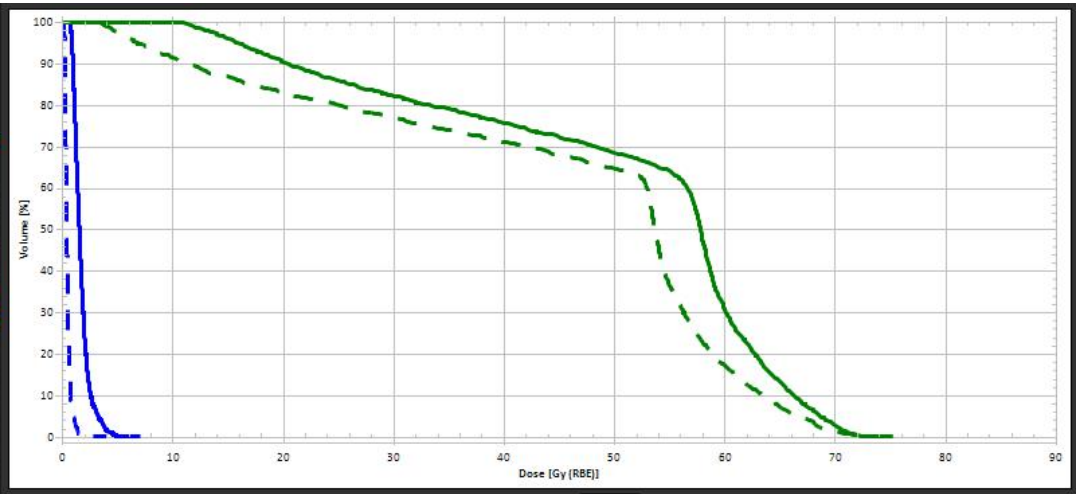
Difference: Curre... | DVH | **Dose statistics** | Clinical goals | Beams (Compare... | Control points (C... | BEV (Compare 1)

(•) ROI statistics ( ) POI statistics

	ROI	ROI vol. [cm³]	Dose [Gy (RBE)] D99	D98	D95	Average	D50	D2	D1	% outside grid
ose (RBE):...	CTV2	512.38	60.16	64.95	70.64	73.38	73.85	75.22	75.53	0 %
ose (RBE):...	CTV2	512.32	54.05	57.44	63.35	68.60	68.68	76.33	77.35	0 %
ose (RBE):...	GTV1	274.53	67.79	71.20	72.49	73.86	74.02	75.40	75.82	0 %
ose (RBE):...	GTV1	274.52	63.24	64.64	65.56	69.42	69.10	76.65	77.72	0 %
ose (RBE):...	nerveroots_AN	34.95	0.73	0.83	1.13	41.74	41.56	74.48	74.65	0 %
ose (RBE):...	nerveroots_AN	34.91	0.18	0.21	0.29	36.14	37.42	71.18	72.39	0 %
ose (RBE):...	nervestospare_AN	22.82	0.69	0.77	0.93	30.55	31.52	72.43	73.13	0 %
ose (RBE):...	nervestospare_AN	22.77	0.17	0.18	0.24	25.66	23.43	69.81	71.21	0 %

Ovaries



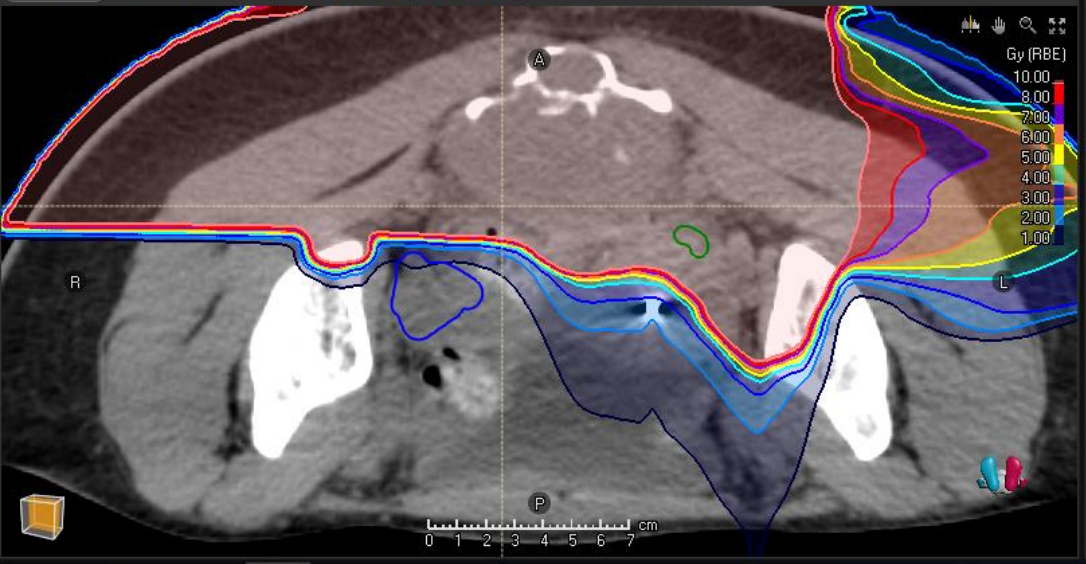


Dose axis: ◉ Absolute ○ Relative max ○ Relative dose [Gy (RBE)]:

Volume axis: ◉ Relative ○ Absolute

Compare 1 | Image

Select Summed Dose (RBE): MKM 7 +4+5 fr (CT 1 Planning)



Difference: Curre... | DVH | **Dose statistics** | Clinical goals | Beams (Compare... | Control points (C... | BEV (Compare 1)

◉ ROI statistics ○ POI statistics

Name	ROI	ROI vol. [cm³]	Dose [Gy (RBE)] D99	D98	D95	Average	D50	D2	D1	% ou
Summed Dose (RBE):...	left Ovary	12.06	0.77	0.81	0.89	1.72	1.57	3.90	4.34	
Summed Dose (RBE):...	left Ovary	12.03	0.20	0.21	0.23	0.49	0.43	1.31	1.52	
Summed Dose (RBE):...	right ovary	9.86	11.97	13.00	15.79	50.62	57.86	70.44	71.25	
Summed Dose (RBE):...	right ovary	9.85	4.03	4.72	6.86	45.49	53.70	68.93	70.46	

Which risks ?

Might happen:

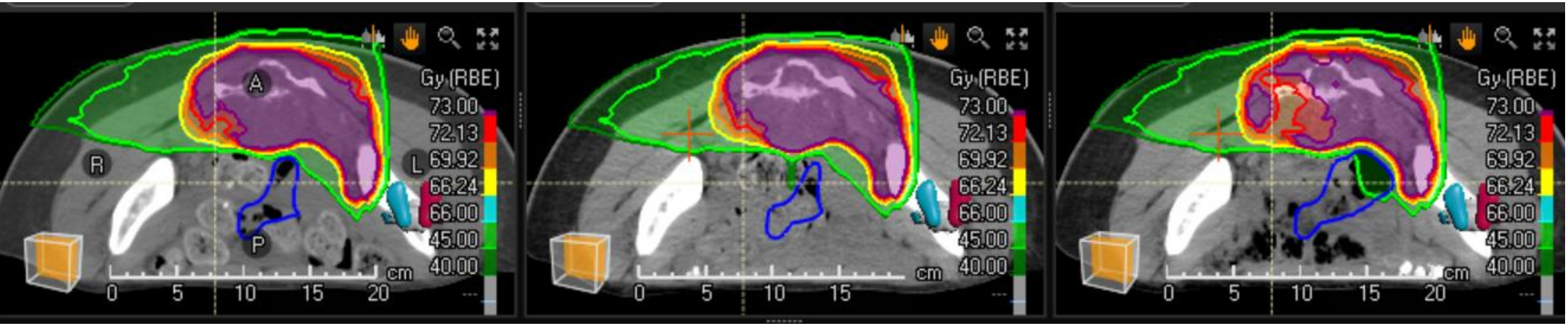
Neuropathy

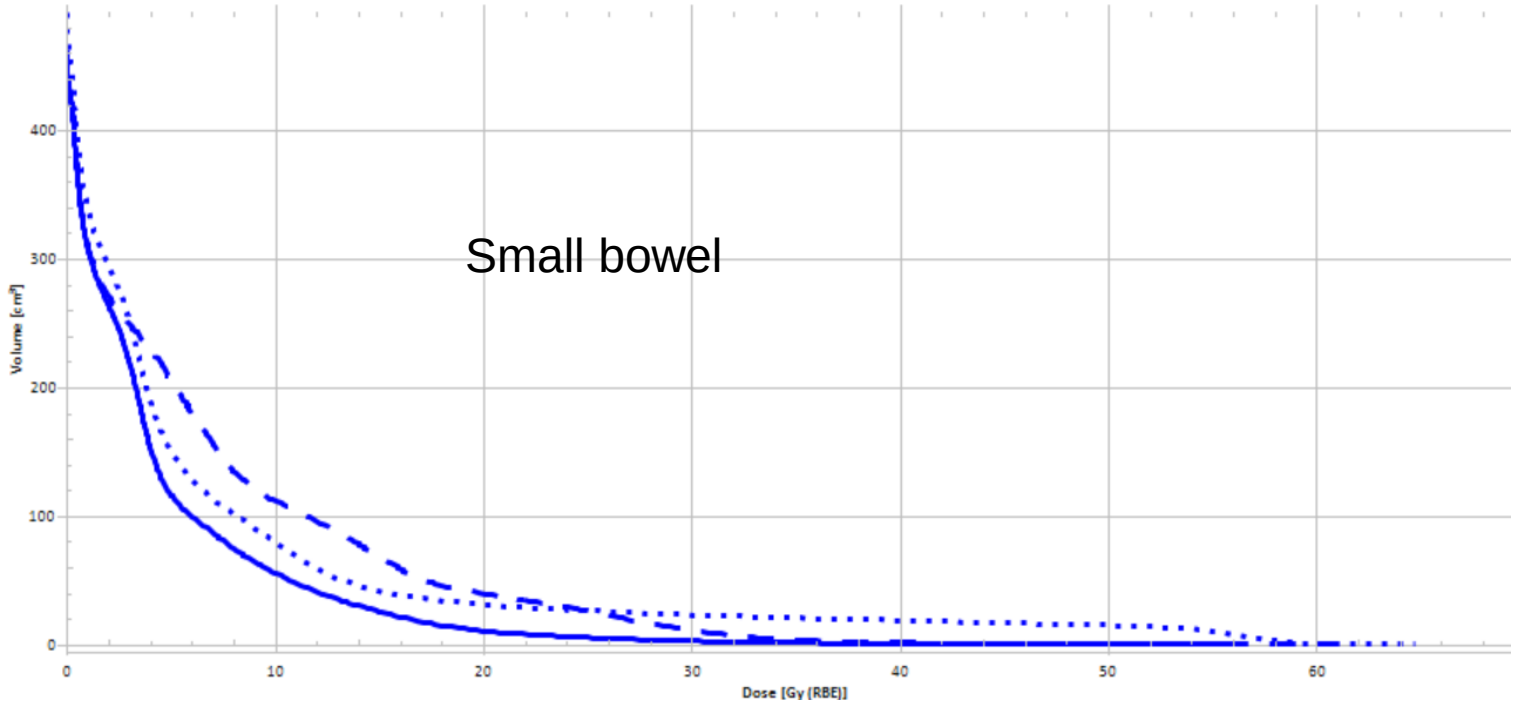
Bone fracture

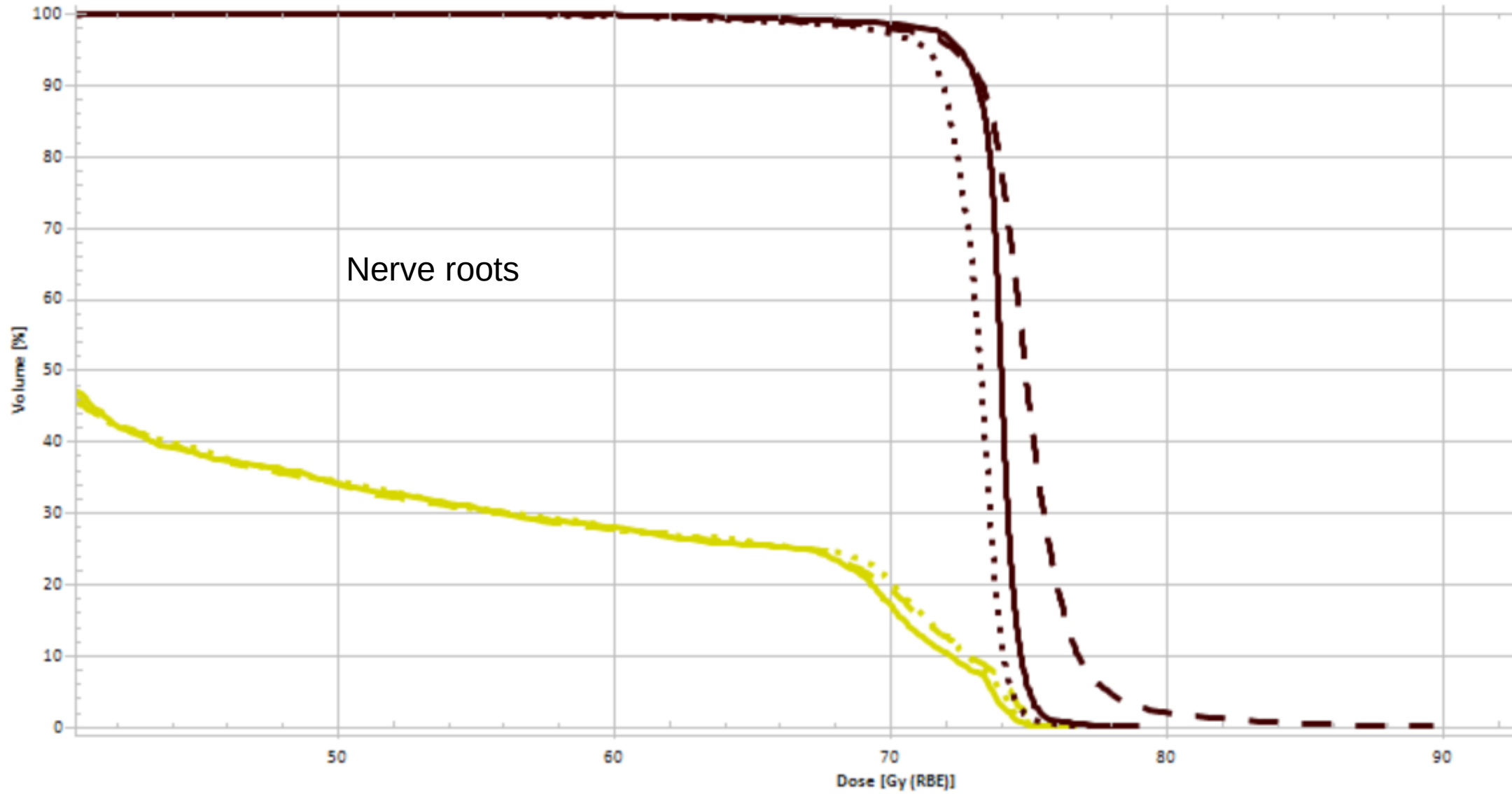
Will not happen:

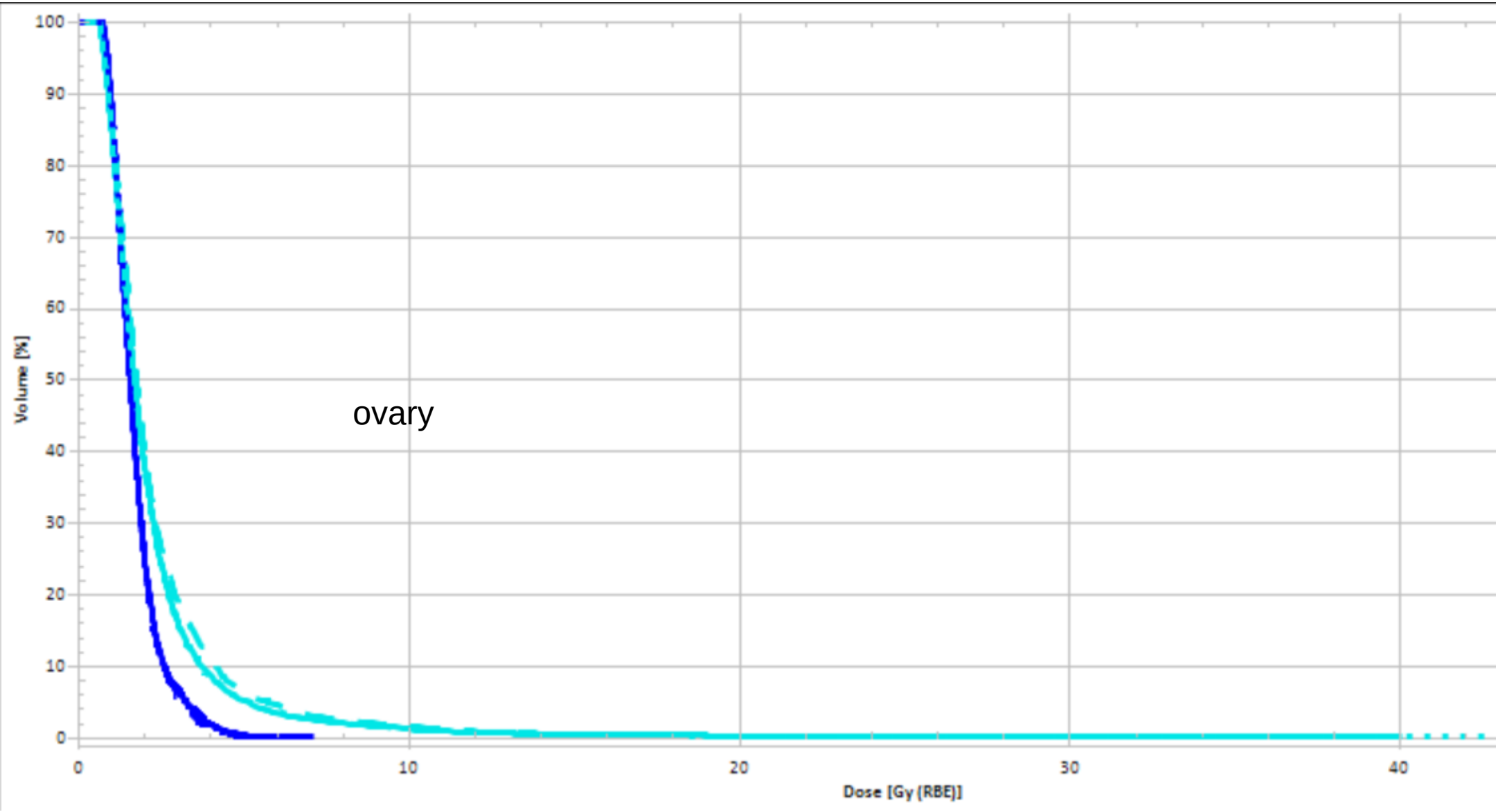
Rectal toxicity

Fertility?

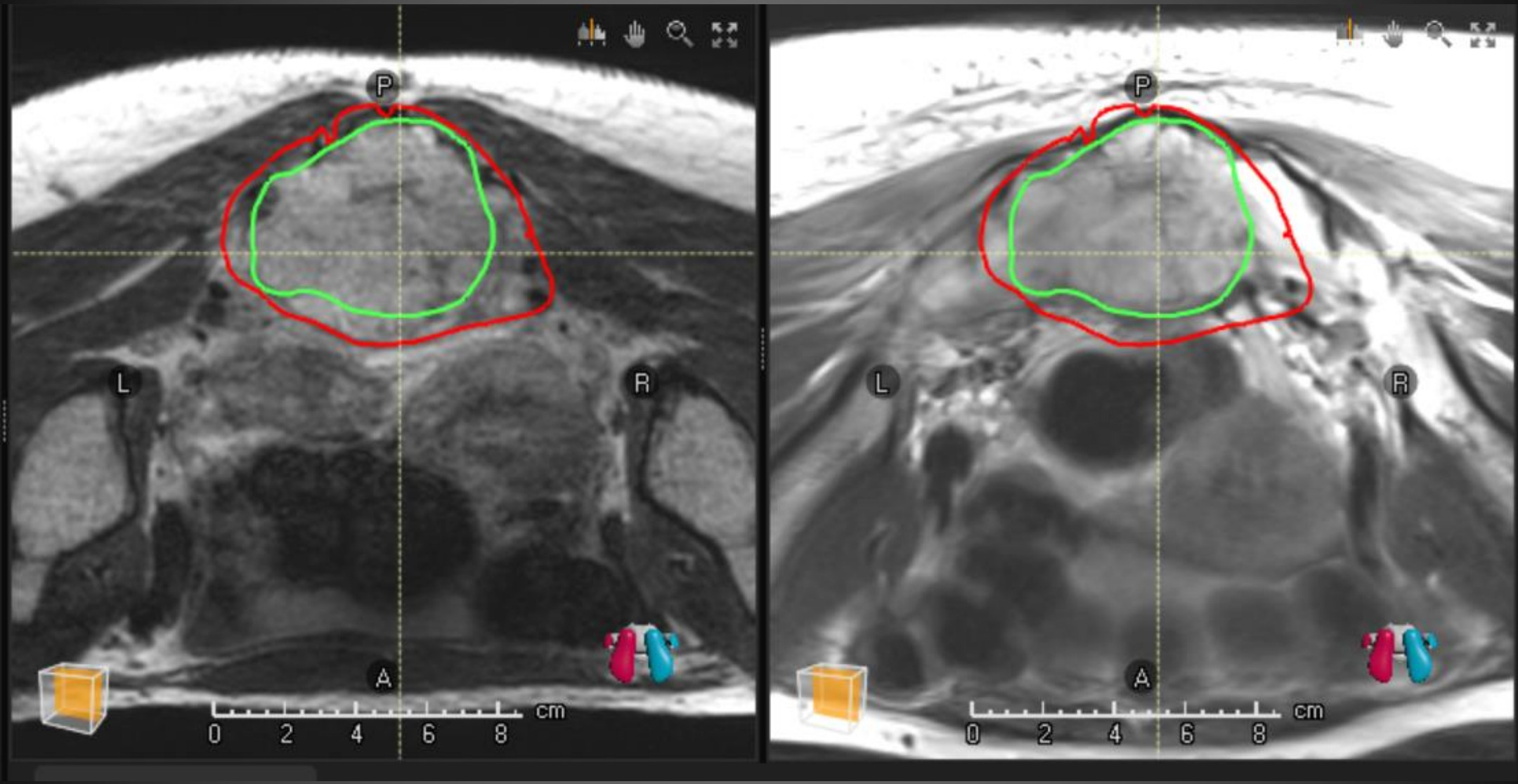

A
R
L
P
Gy (RBE)
73.00
72.13
69.92
66.24
66.00
45.00
40.00
cm
0
5
10
15
20


Small bowel
Volume [cm³]
400
300
200
100
0
0
10
20
30
40
50
60
Dose [Gy (RBE)]

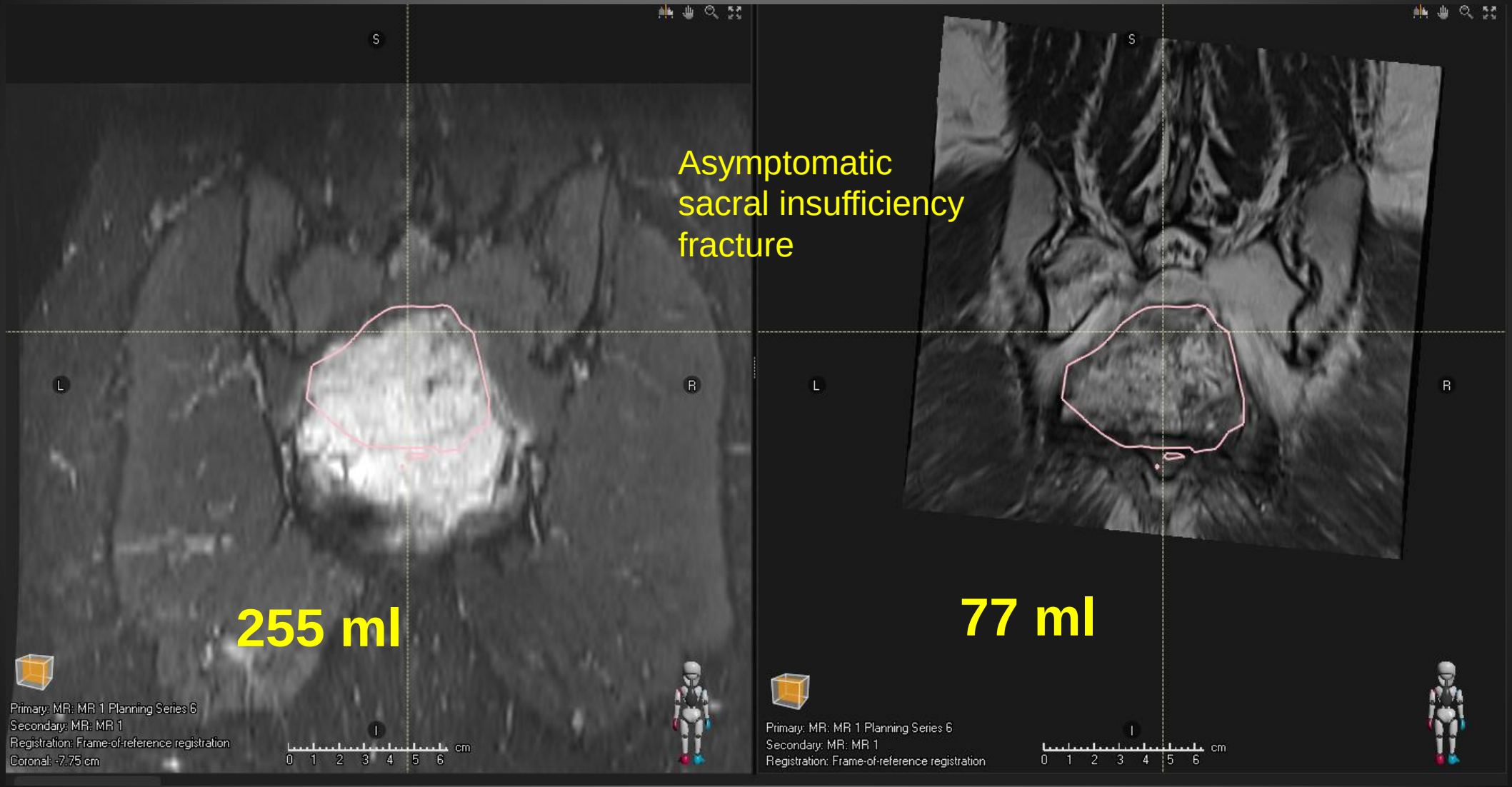

Nerve roots
Volume [%]
100
90
80
70
60
50
40
30
20
10
0
50
60
70
80
90
Dose [Gy (RBE)]


ovary
Volume [%]
Dose [Gy (RBE)]
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40

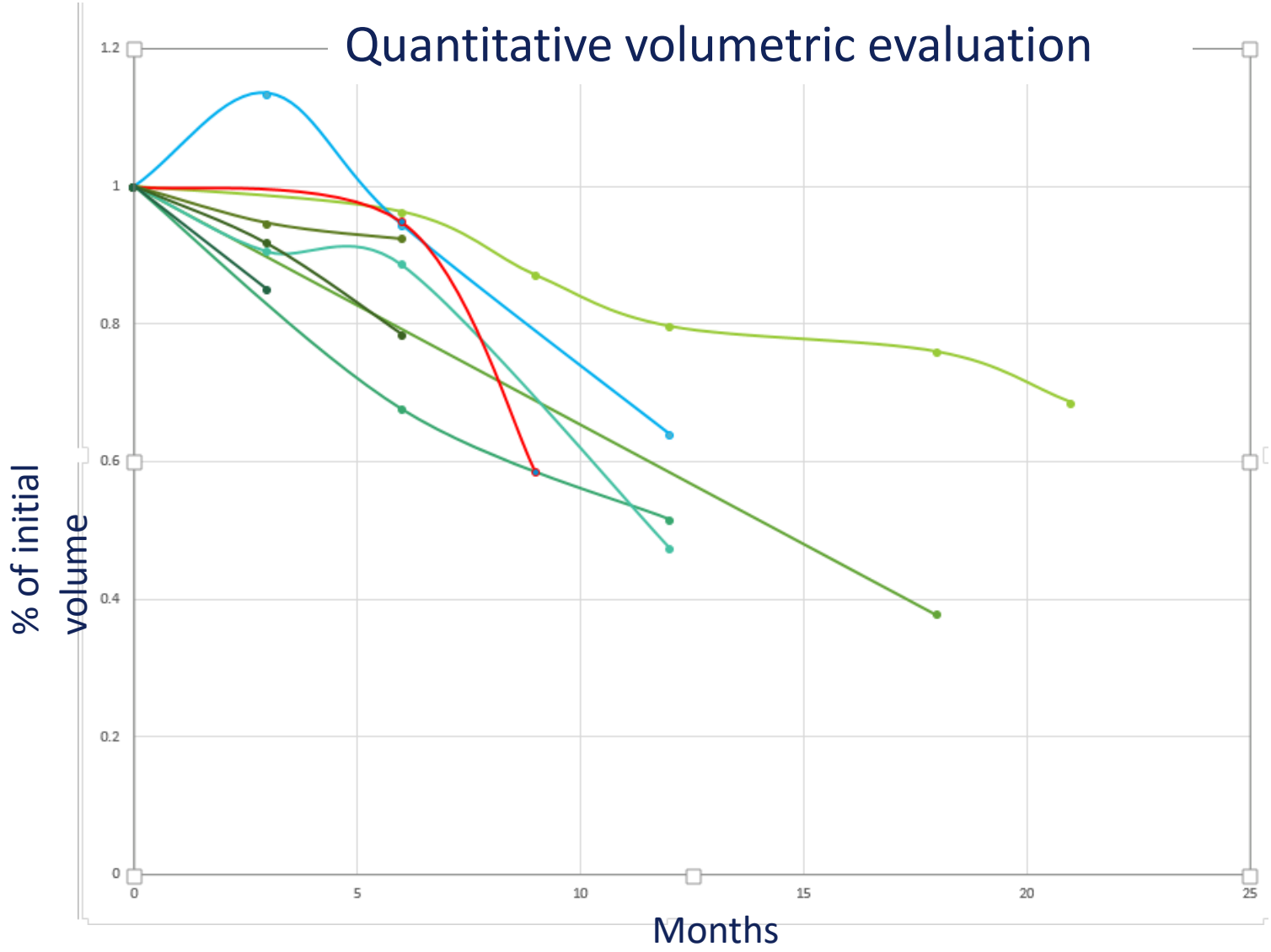
9 Months

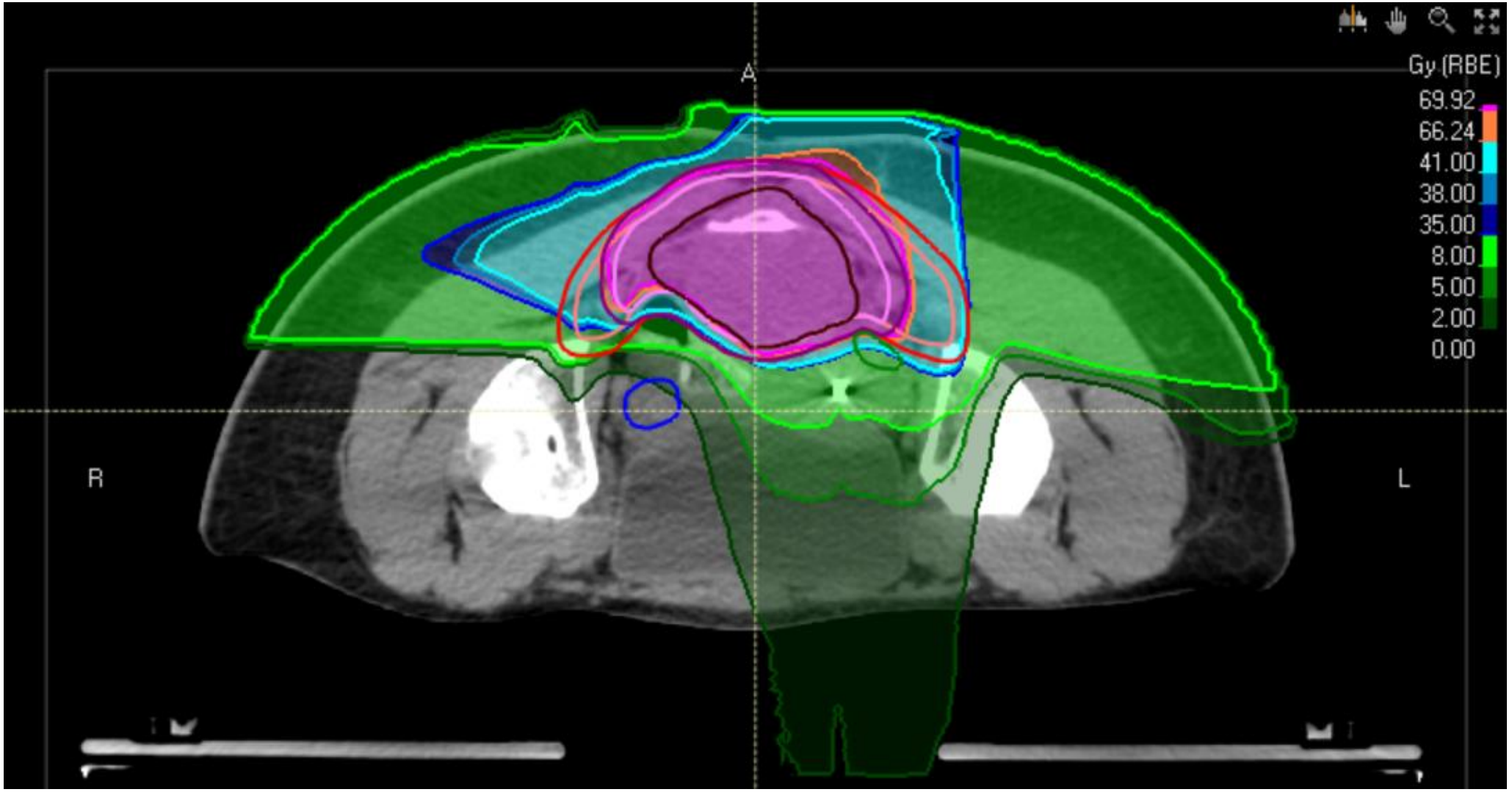


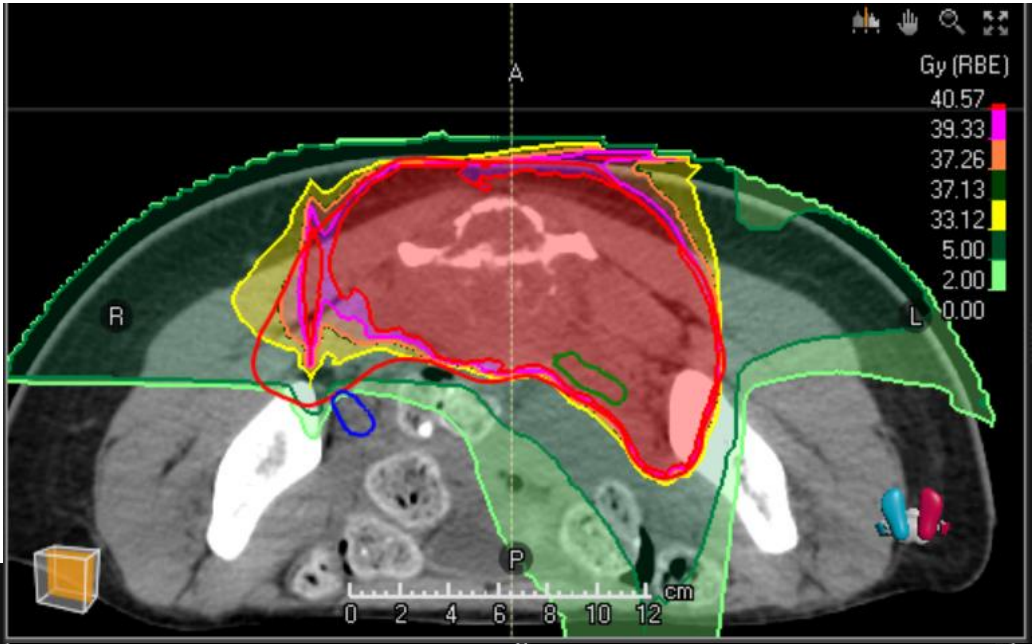
21 Months

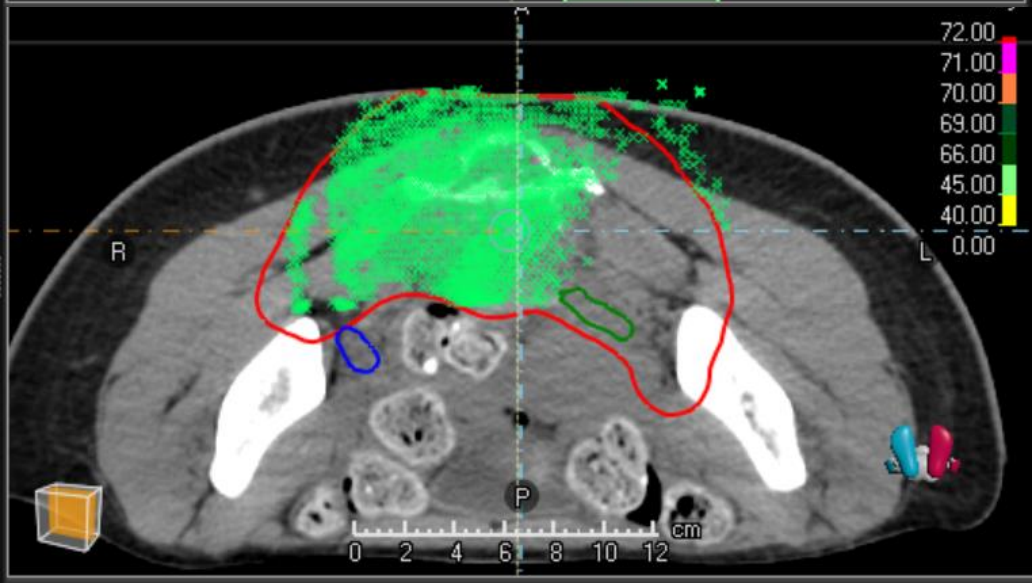

S
L
R
I
Primary: MR: MR 1 Planning Series 6
Secondary: MR: MR 1
Registration: Frame-of-reference registration
Coronal: -7.75 cm
0 1 2 3 4 5 6
cm
255 ml
Asymptomatic sacral insufficiency fracture
77 ml

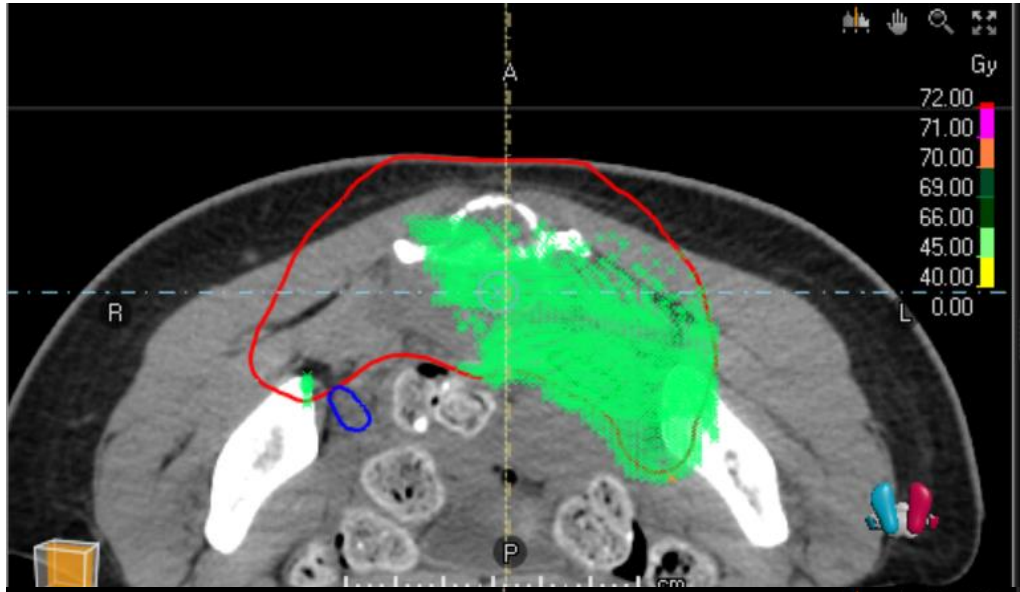
Quantitative volumetric evaluation

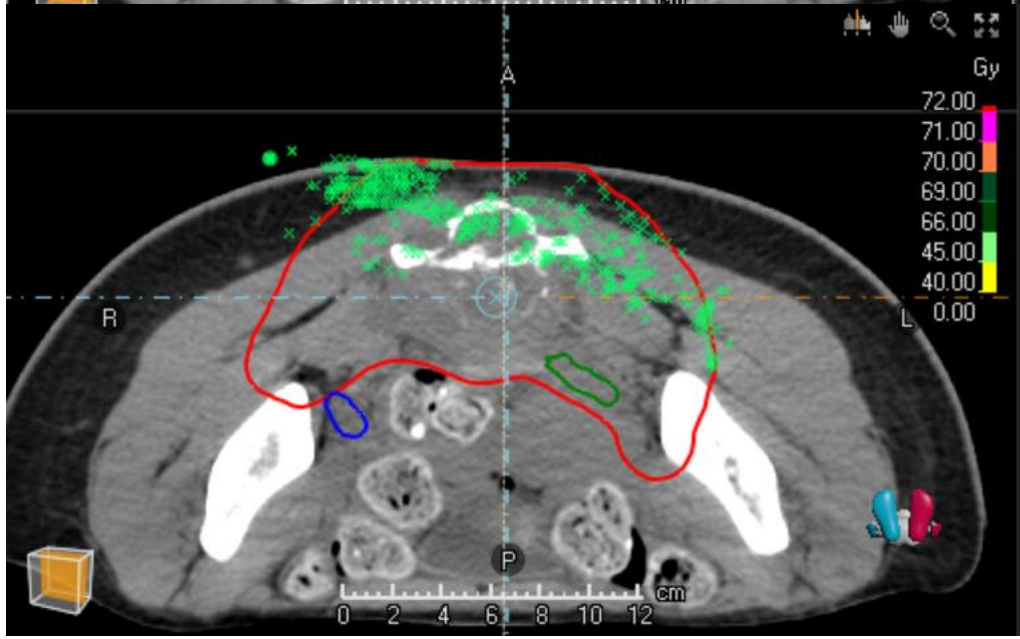



A
R
L
Gy (RBE)
69.92
66.24
41.00
38.00
35.00
8.00
5.00
2.00
0.00


A
Gy (RBE)
40.57
39.33
37.26
37.13
33.12
5.00
2.00
0.00
R
L
P
cm
0 2 4 6 8 10 12


72.00
71.00
70.00
69.00
66.00
45.00
40.00
0.00
R
L
P
cm
0 2 4 6 8 10 12


A
Gy
72.00
71.00
70.00
69.00
66.00
45.00
40.00
0.00
R
L
P


A
Gy
72.00
71.00
70.00
69.00
66.00
45.00
40.00
0.00
R
L
P
cm
0 2 4 6 8 10 12