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Depth – dose volume – target volume in IOeRT

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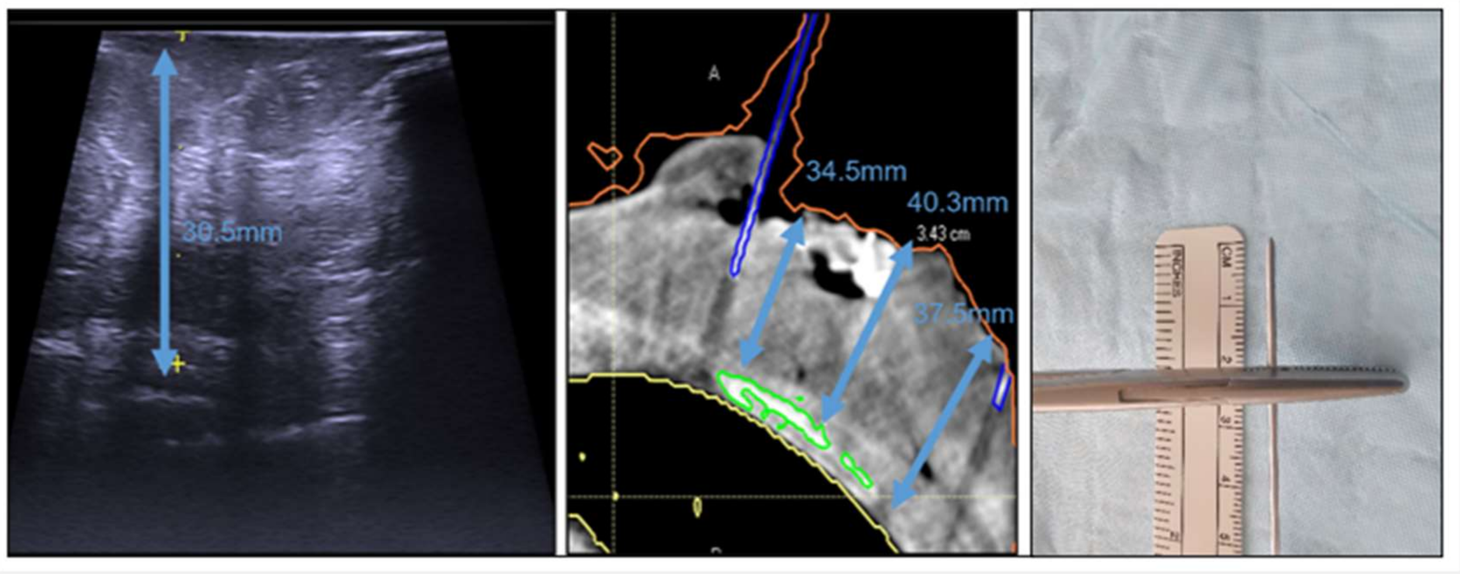
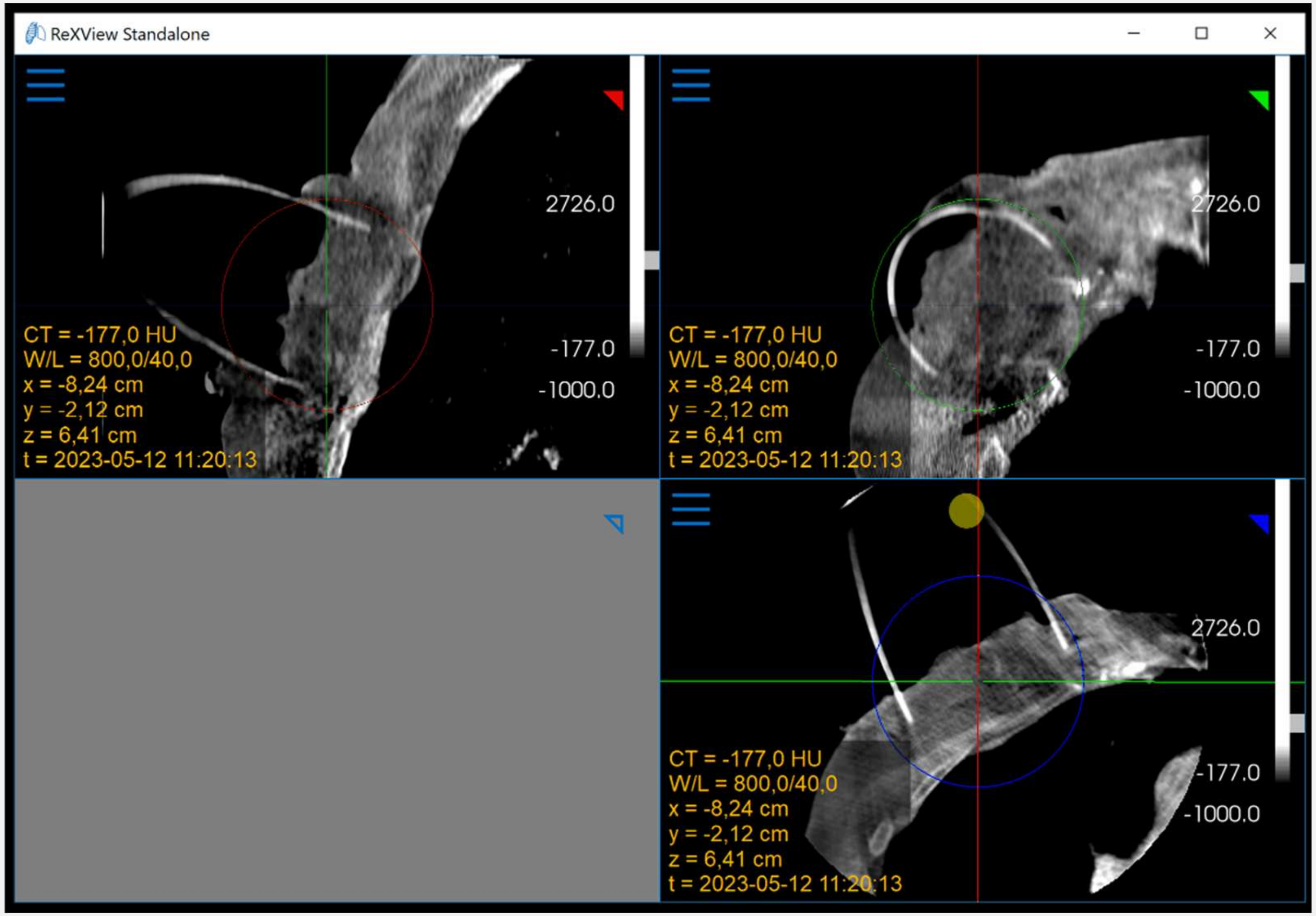
Overview

- Measuring tissue depth
- Calculating the isodose volume
- Calculating the size of the target volume
- What did we learn?

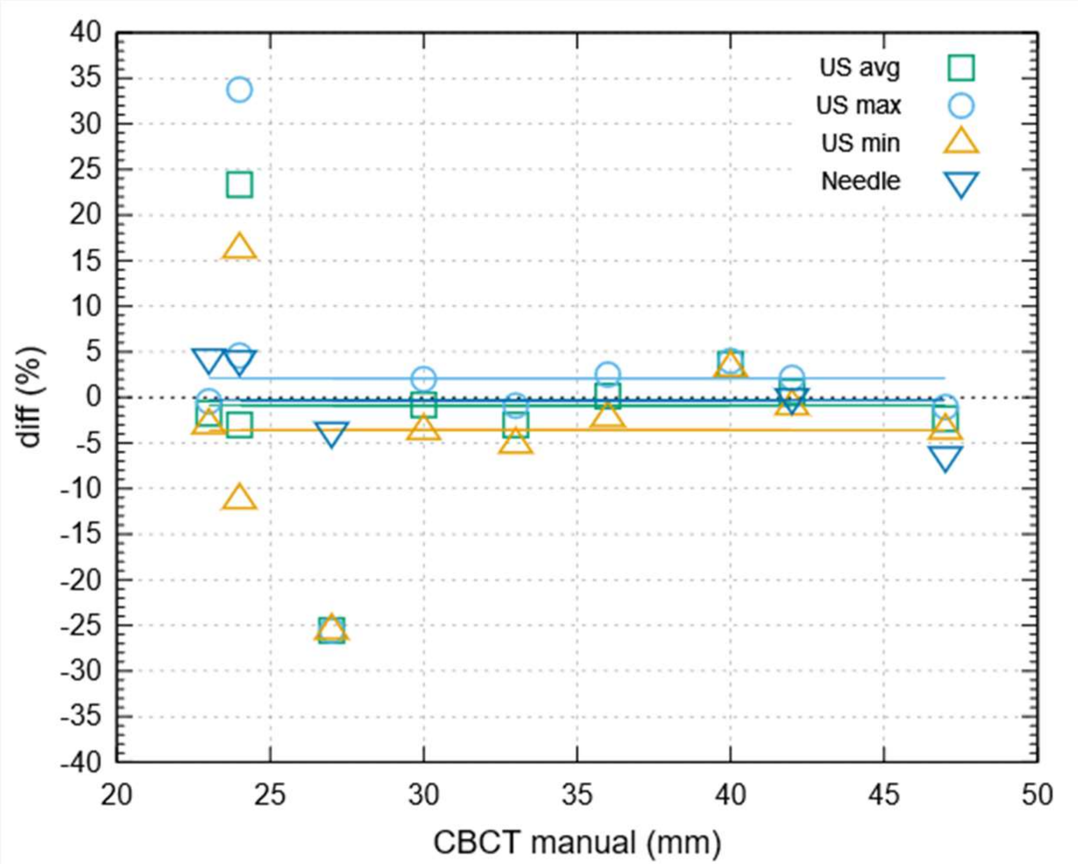
Different methods to measure tissue thickness



Orientation of CBCT slices for depth measurement



Comparison w. manual CBCT measurement



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Depth – Master thesis by Klarissa Ellmauer

Assessing the Benefits of 3D Imaging for Intraoperative Electron Radiotherapy (IOERT): A Quantitative Comparison of Geometrical Information in Breast Cancer Treatment

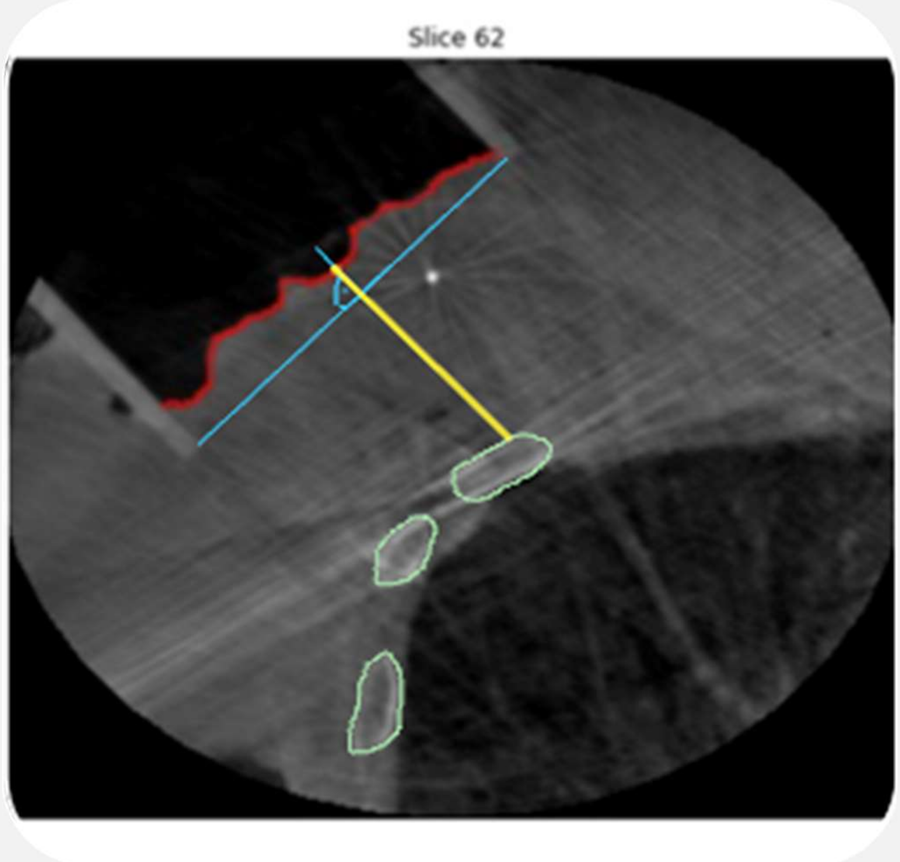
Submitted by: **Klarissa Ellmauer BSc**

at **Master´s Programme MedTech: Functional Imaging, Conventional and Ion Radiotherapy**

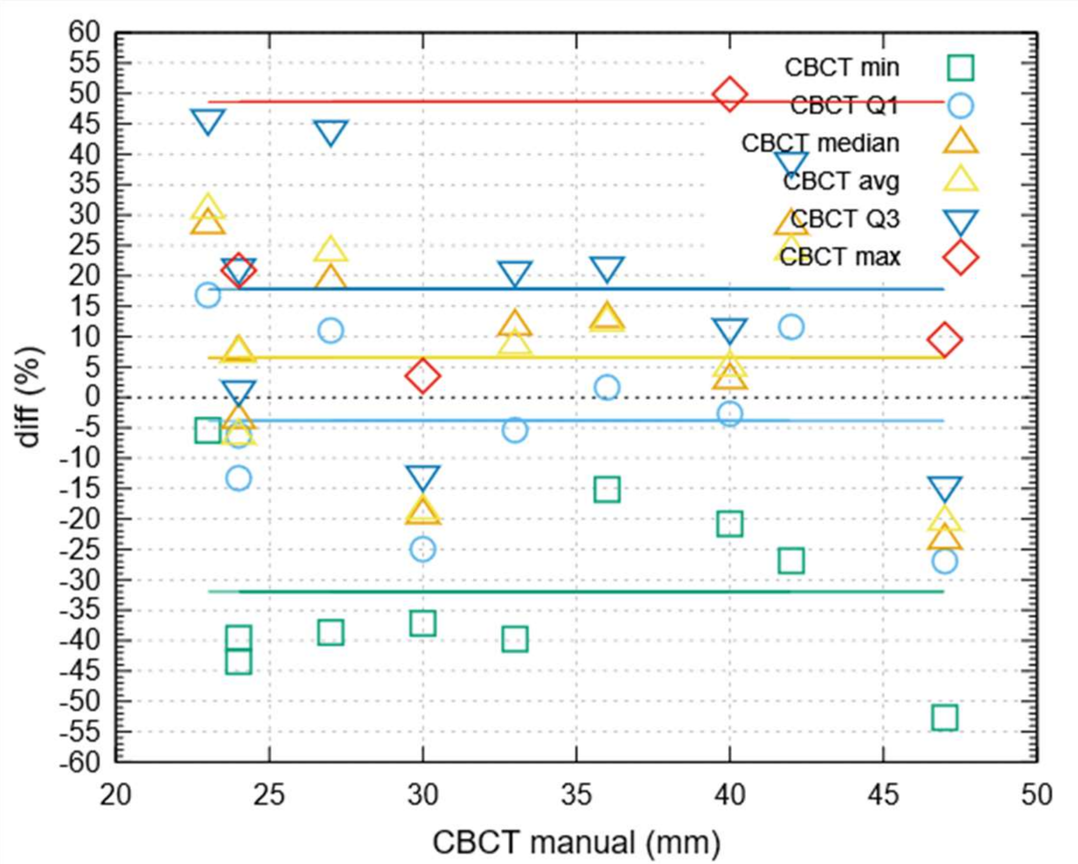
Wiener Neustadt, August 23th 2024

Supervisor: **Markus Stana**

How the program works



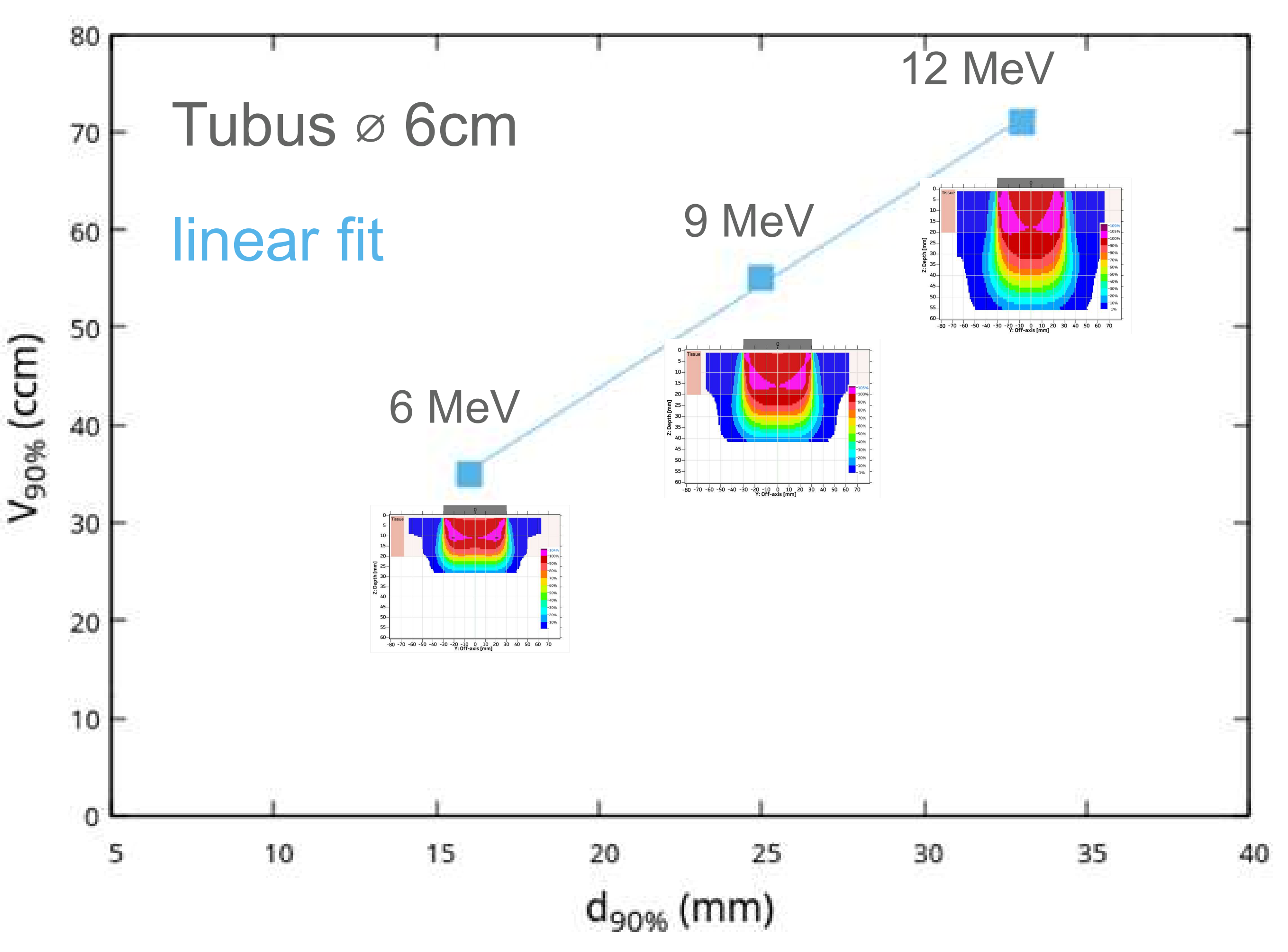
Comparison w. manual CBCT measurement



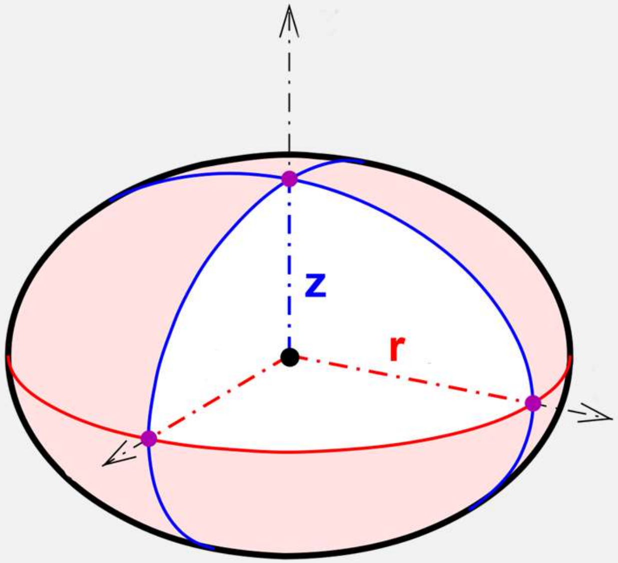
Calculating the size of the isodose volume

- Method 1: body of rotation from measured isodoses in water
- Method 2: volume of a spheroid
- Method 3: isodose volume from 3D voxel data patient model

Method 1: body of rotation from isodoses measured in water



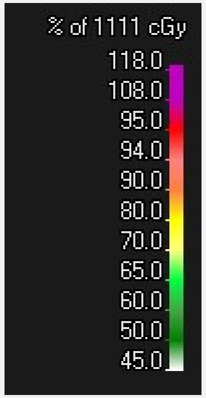
Method 2: volume of a spheroid



$$V = \frac{4}{3}\pi r^2 z$$

r … radius of tube
z … half of tissue depth

Method 3: isodose volume from CBCT



Comparison of methods for $V_{90\%}$ calculation

Energy (MeV)	**$V_{90\%}$ (ml)**		
	Spheroid	measured profiles	Radiance in water
Tube 4cm			
6	2.4	9.0	5.2
9	5.1	19.0	11.0
12	7.2	27.0	23.0
Tube 6cm			
6	9.6	35.0	21.0
9	15.0	55.0	43.0
12	19.8	71.0	62.0
Tube 8cm			
6	17.1	64.0	49.0
9	26.7	109.0	94.0
12	35.2	136.0	123.0

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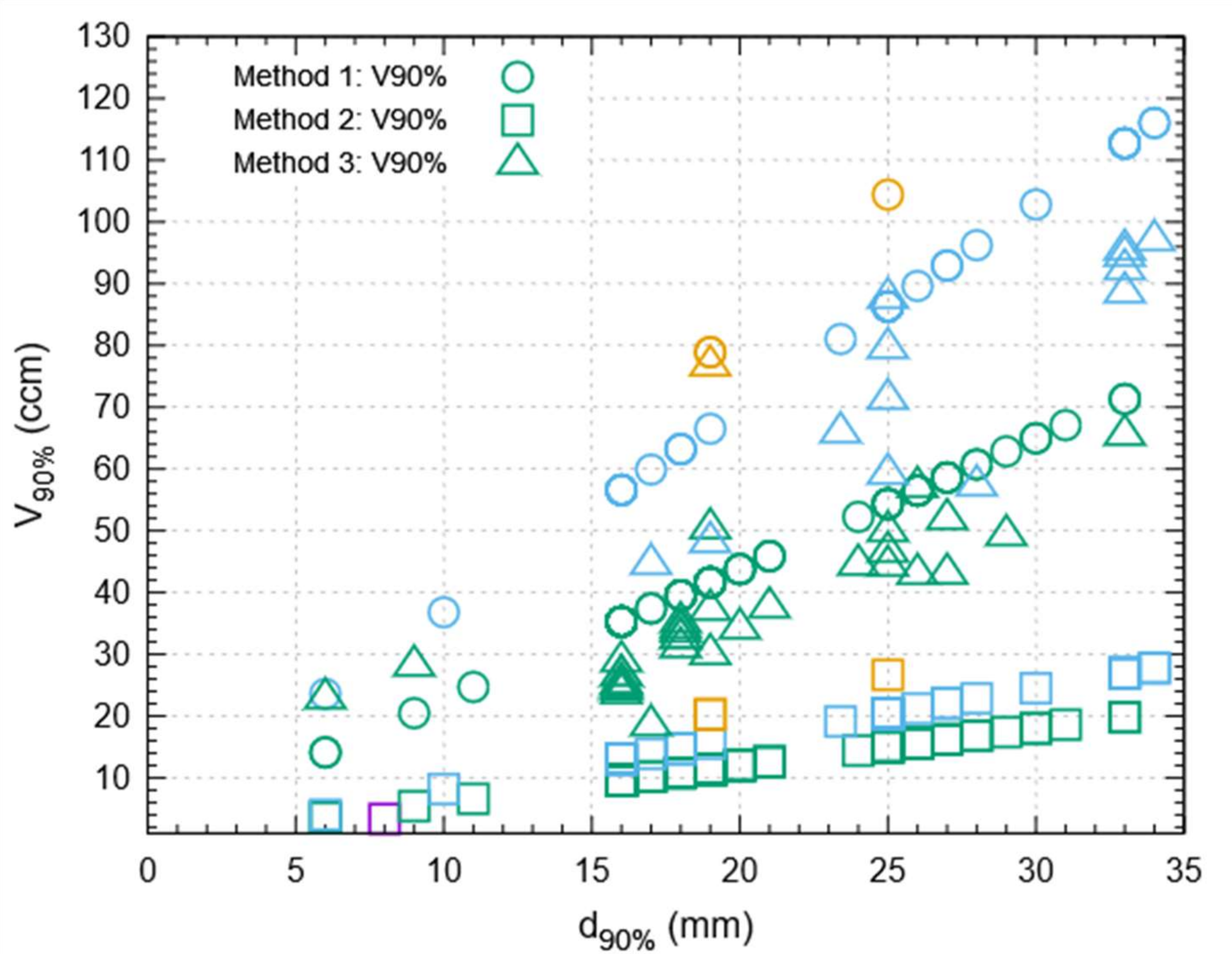
Comparison of calculated $V_{90\%}$ isodose volumes for 110 patients



Tubus:

- ⌀ 5cm
- ⌀ 6cm
- ⌀ 7cm
- ⌀ 8cm

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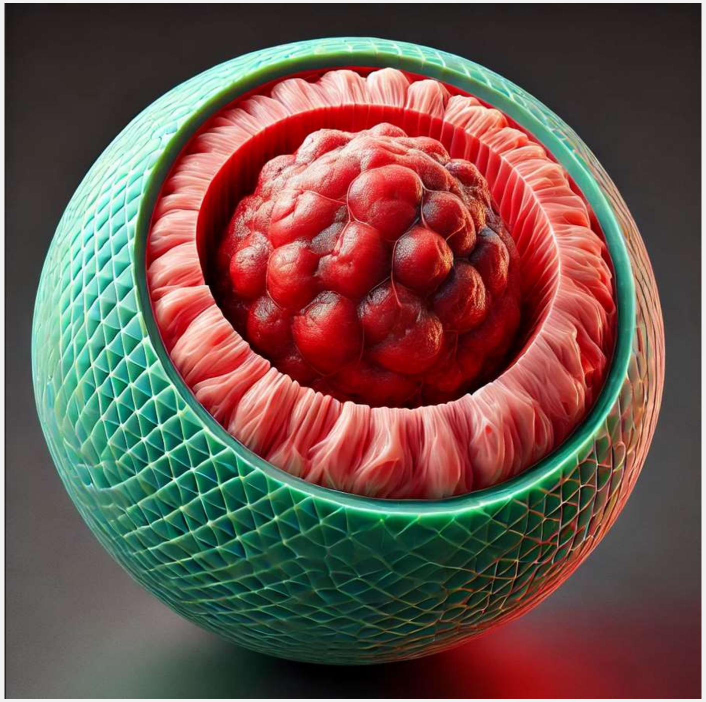
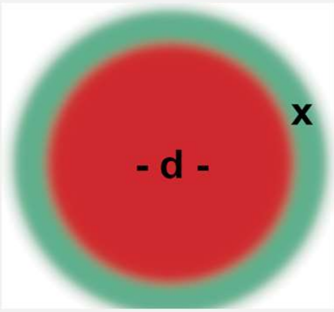
Target volume best case scenario: spherical tumor

The smallest possible tumor bed volume is given in case of a spherical tumor, as the surface to volume ratio is minimized in a sphere



Size of target volume

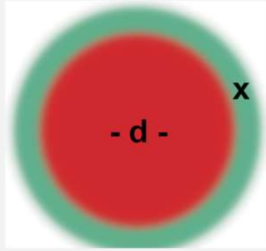
$$V_{TV} = \left(\frac{4}{3}\pi\left(\frac{d}{2}+x\right)^3\right) - \left(\frac{4}{3}\pi\left(\frac{d}{2}\right)^3\right)$$



d … diameter of tumor

x … irradiation margin

Calculated Target Volumes for different tumor sizes



diameter of tumor *d* (mm)	tumor volume (ml)	target volume (ml) for different irradiation margins			
		x = 5 mm	x = 10 mm	x = 15 mm	x = 20 mm
5	0.07	1.70	8.12	22.38	47.65
10	0.52	3.67	13.61	32.99	64.93
15	1.77	6.41	20.68	45.95	85.35
20	4.19	9.95	29.32	61.26	108.91
25	8.18	14.27	39.53	78.93	135.61
30	14.14	19.37	51.31	98.96	165.46
35	22.45	25.26	64.66	121.34	198.44
40	33.51	31.94	79.59	146.08	234.57

$V_{90\%}$ vs. Target Volume for Tubus with **4cm diameter**

6 MeV	9 MeV	12 MeV
9 ml	19 ml	27 ml

Diameter of Tumor (mm)	tumor volume (ml)	target volume (ml) and coverage for different irradiation margins			
		x = 5 mm	x = 10 mm	x = 15 mm	x = 20 mm
5	0.07	1.70	8.12	22.38	47.65
10	0.52	3.67	13.61	32.99	64.93
15	1.77	6.41	20.68	45.95	85.35
20	4.19	9.95	29.32	61.26	108.91
25	8.18	14.27	39.53	78.93	135.61
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$V_{90\%}$ vs. Target Volume for Tubus with **5cm diameter**

6 MeV	9 MeV	12 MeV
21 ml	33 ml	46 ml

Diameter of Tumor (mm)	tumor volume (ml)	target volume (ml) and coverage for different irradiation margins			
		x = 5 mm	x = 10 mm	x = 15 mm	x = 20 mm
5	0.07	1.70	8.12	22.38	47.65
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$V_{90\%}$ vs. Target Volume for Tubus with **6cm diameter**

6 MeV	9 MeV	12 MeV
35 ml	55 ml	71 ml

Diameter of Tumor (mm)	tumor volume (ml)	target volume (ml) and coverage for different irradiation margins			
		x = 5 mm	x = 10 mm	x = 15 mm	x = 20 mm
5	0.07	1.70	8.12	22.38	47.65
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$V_{90\%}$ vs. Target Volume for Tubus with **7cm diameter**

6 MeV	9 MeV	12 MeV
48 ml	81 ml	104 ml

Diameter of Tumor (mm)	**tumor volume (ml)**	**target volume (ml) and coverage for different irradiation margins**			
		x = 5 mm	x = 10 mm	x = 15 mm	x = 20 mm
5	0.07	1.70	8.12	22.38	47.65
10	0.52	3.67	13.61	32.99	64.93
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35	22.45	25.26	64.66	121.34	198.44
40	33.51	31.94	79.59	146.08	234.57

$V_{90\%}$ vs. Target Volume for Tubus with **8cm diameter**

6 MeV	9 MeV	12 MeV
64 ml	109 ml	136 ml

Diameter of Tumor (mm)	tumor volume (ml)	target volume (ml) and coverage for different irradiation margins			
		x = 5 mm	x = 10 mm	x = 15 mm	x = 20 mm
5	0.07	1.70	8.12	22.38	47.65
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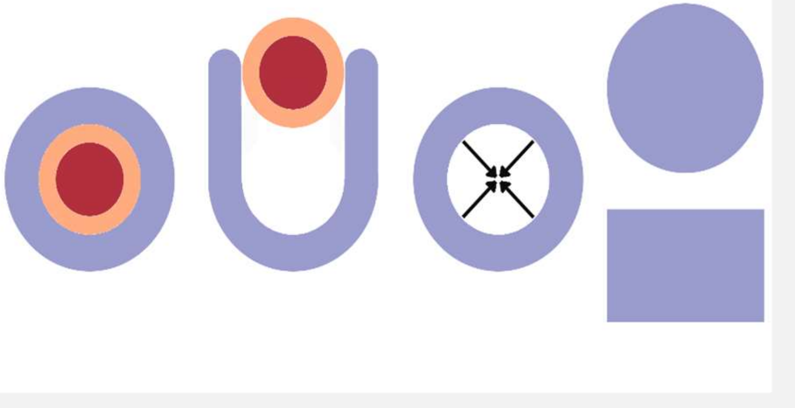
Size of target volume considering resection margin

$$V_{TV} = \left(\frac{4}{3}\pi\left(\frac{d}{2}+r+x\right)^3\right) - \left(\frac{4}{3}\pi\left(\frac{d}{2}+r\right)^3\right)$$

d … diameter of tumor

r … resection margin

x … irradiation margin



Target Volumes for different tumor sizes and *r* = **5mm resection margin**

Diameter of Tumor *d* (mm)	tumor volume (ml)	target volume (ml) for different irradiation margins			
			x = 5 mm	x = 10 mm	x = 15 mm
5	0.07		6.41	20.68	45.95
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25	8.18		25.26	64.66	121.34
30	14.14		31.94	79.59	146.08
35	22.45		39.40	96.08	173.18
40	33.51		47.65	114.14	202.63

$V_{90\%}$ vs. TV for **5mm resection margin** and a **4cm** Tubus

6 MeV	9 MeV	12 MeV
9 ml	19 ml	27 ml

Diameter of Tumor *d* (mm)	tumor volume (ml)	target volume (ml) and coverage for different irradiation margins			
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$V_{90\%}$ vs. TV for **5mm resection margin** and a **7cm** Tubus

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Target Volumes for different tumor sizes and *r* = **10mm resection margin**

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$V_{90\%}$ vs. TV for **10mm resection margin** and a **4cm** Tubus

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Diameter of Tumor *d* (mm)	**tumor volume (ml)**	**target volume (ml) and coverage for different irradiation margins**			
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$V_{90\%}$ vs. TV for **10mm resection margin** and a **7cm** Tubus

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35	22.45			56.68	133.78
40	33.51			66.50	154.99

$V_{90\%}$ vs. TV for **10mm resection margin** and a **8cm Tubus**

6 MeV	9 MeV	12 MeV
64 ml	109 ml	136 ml

Diameter of Tumor *d* (mm)	tumor volume (ml)	target volume (ml) and coverage for different irradiation margins			
				x = 5 mm	x = 10 mm
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15	1.77			25.26	64.66
20	4.19			31.94	79.59
25	8.18			39.40	96.08
30	14.14			47.65	114.14
35	22.45			56.68	133.78
40	33.51			66.50	154.99

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What we (I) have learned

- Maximizing the size of the irradiated volume is probably a good idea
- Therefore the distance to the nearest organ at risk has to be measured exactly
- Knowing the size of the target volume and comparing it with the irradiated volume (a certain isodose volume) should be considered as a plan optimization parameter