



Establishing margins from clinical to planning target volume for low-risk prostate cancer radiotherapy: a multi institutional study

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1. Purpose

The aim of this multi institutional study was to determine the appropriate margins from clinical target volume (CTV) to planning target volume (PTV) in low risk prostate cancer irradiation, in relation to the image guided radiotherapy (IGRT) protocol used, derived from data from three radiotherapy (RT) centers.

2. Methods

Twenty patients with localized low risk prostate cancer were selected from each RT center for retrospective review. Prescribed dose of 78Gy in 39 fractions was delivered with volumetric modulated arc therapy (VMAT) in supine position. Localized low-risk prostate cancer^{1,2} includes patients with TNM stage T1-T2a disease, PSA ≤10 ng/ml or Gleason score ≤6. Pretreatment preparation was applied in accordance with Affidea's institutional protocol (full bladder-empty rectum). CTV included prostate only (Figure 1).



Figure 1. Contours of CTV and organs at risk.

Cone beam computed tomography (CBCT) was daily co-registered with planning Computed Tomography (CT), using two registration protocols: bone match and soft tissue (prostate) match (Figure 2). Based on this data, set up errors and inter-fraction prostate motion were calculated in all three RT centers.

Literature data for delineation errors and intra-fraction motion³ were used to determine CTV-PTV margins for different imaging protocols (online 2D/2D bone match and online CBCT match).

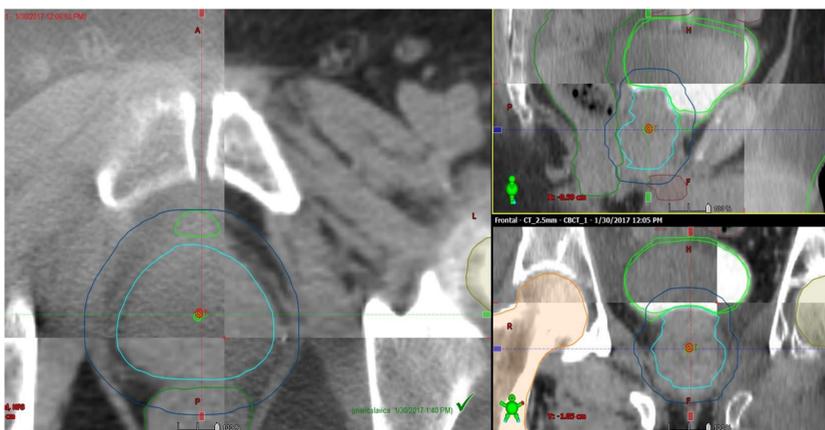


Figure 2. Matching a CBCT with the patients planning CT.

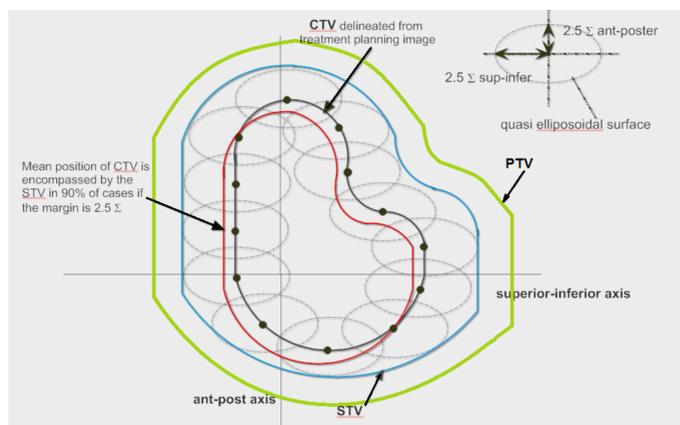


Figure 3. CTV to PTV margin.

To ensure the minimum dose to the CTV of 95% for 90% of the patients, margin between CTV and PTV (Figure 3) is defined as:

$$PTV \text{ margin} = 2.5\Sigma + 0.7\sigma$$

where Σ is the quadratic sum of the standard deviation (SD) of all systematic errors (STV) and σ is the quadratic sum of SD of all random errors³ (Figure 4).

Determination of CTV-PTV margins for NO SETUP corrections protocol Low Risk Prostate Cancer Treatment

mm	systematic errors		random errors	
delineation	2.0	4.0	0.0	0.0
organ motion/interfractional	1.3	1.7	2.0	4.0
setup error	2.7	7.0	2.9	8.0
intrafraction motion			1.0	1.0
total error	3.6	13.1	3.6	13.0
Total error margin	11.6			

CTV-PTV margins		
Long	9.9	mm
Lat	10.0	mm
Vert	11.6	mm

Figure 4. Practical calculation of CTV-PTV margins for No SetUp corrections protocol.

3. Results

Systematic, random, setup and inter fraction-organ motion errors (Σ_{setup} , $\Sigma_{\text{organmotion}}$, σ_{setup} and $\sigma_{\text{organmotion}}$), calculated data for all three RT centers is presented in Table 1.

Table 1. Calculated data for all three RT centers: Σ_{setup} , $\Sigma_{\text{organmotion}}$, σ_{setup} and $\sigma_{\text{organmotion}}$.

		RT Centre 1	RT Centre 2	RT Centre 3
Systematic SetUp error (Σ_{setup})	Long (mm)	1.6	2.0	1.6
	Lat (mm)	2.5	3.0	1.6
	Vert (mm)	2.7	3.0	2.9
Random SetUp error (σ_{setup})	Long (mm)	2.8	2.4	1.8
	Lat (mm)	3.0	2.9	2.4
	Vert (mm)	2.9	2.8	2.6
Systematic Inter-fraction Organ Motion ($\Sigma_{\text{organmotion}}$)	Long (mm)	0.8	0.7	1.8
	Lat (mm)	0.3	0.4	0.4
	Vert (mm)	1.3	0.5	1.7
Random Inter-fraction Organ Motion ($\sigma_{\text{organmotion}}$)	Long (mm)	0.9	1.5	2.4
	Lat (mm)	0.8	1.6	1.6
	Vert (mm)	2.0	1.5	2.3

Depending on the IGRT protocol, the calculated CTV-PTV margins of longitudinal (Long), lateral (Lat) and vertical (Vert) directions are presented in Table 2.

Table 2. Calculated CTV-PTV margins for different IGRT modalities.

		RT Centre 1	RT Centre 2	RT Centre 3
NO SetUp Correction Protocol	Long (mm)	10	10	11
	Lat (mm)	10	11	8
	Vert (mm)	12	11	12
IGRT online: 2D/2D bone match	Long (mm)	8	8	10
	Lat (mm)	5	6	6
	Vert (mm)	8	6	8
IGRT online: CBCT soft tissue match	Long (mm)	7	7	7
	Lat (mm)	5	5	5
	Vert (mm)	6	6	6

4. Conclusion

If no setup correction protocol is used, CTV-PTV margins less than 10mm cannot be used due to increased risk of missing the CTV.

Treating patients for low risk prostate cancer with daily online IGRT protocol allows smaller PTV-CTV margins (5-7mm) to be used and may lead to better local control and lower toxicity rates.

Calculated margins exclude rotational errors and shape deviations and therefore should be considered when defining the PTV³.

5. References

- (1) American Urological Association. Clinically Localized Prostate Cancer: AUA/ASTRO/SUO Guideline Very Low-/Low-Risk Disease, 2017
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- (3) Marcel van Herk, Peter Remeijer, Coen Rasch, et al. The probability of correct target dosage: dose-population histograms for deriving treatment margins in radiotherapy Int. J. Radiation Oncology Biol. Phys., Vol. 47, No. 4, pp. 1121–1135, 2000
- (4) Alan McKenzie, Mary Coffey, Tony Greener, et al. Technical overview of geometric uncertainties in radiotherapy, Geometric Uncertainties in Radiotherapy, British Institute of Radiology, pp. 11-27, 2003