Do prostate displacements between 1.5 and 4.4 mm need correction? A randomized study

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Introduction: Radiation therapy always involves a compromise between adequate target coverage and normal tissue sparing. In order make the best use of this compromise, it is important to ensure that the target is properly positioned within the treatment volume as designed in the treatment plan. This can be achieved by taking positioning verification films prior to each treatment fraction and shifting the patient accordingly so that the target is positioned within the treatment volume. However, intrafraction target motion may result in the target being even further from its correct position by the end of treatment than it would be if no pretreatment correction had been made. The goal of this work is to assess the effect of correcting for daily prostate displacements between 1.5 and 4.4 mm during whole-pelvis IMRT.

Methods and Materials: 18 patients with 3 intraprostatic fiducial markers underwent daily online verification according to an in-house protocol. A lateral port film was taken after patient setup. The film magnification factor of the film was measured directly from the image of the radio-opaque marker tray. The AP (Z direction) and SI (Y direction) distances from isocenter (as denoted by the radio-opaque marker tray) were measured for each fiducial and corrected for film magnification. For consistency, the seeds for each patient were numbered from superior to inferior. A sample portal image with the seeds and coordinate directions identified is shown in figure 1. Similarly, the fiducial markers and isocenter were identified in the treatment planning CT.

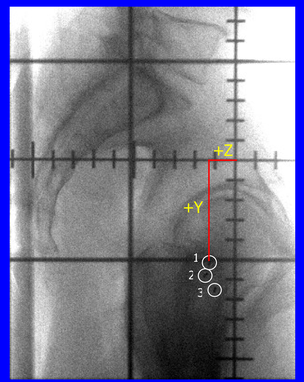
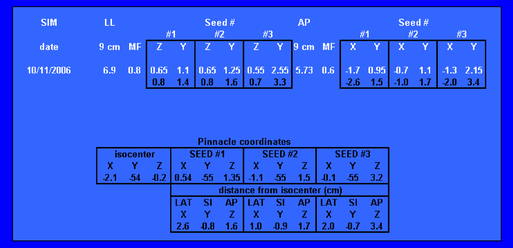


Figure 1. Sample lateral portal image

The centroid of each contoured seed volume was taken to be the location of the seed in the CT coordinate system. The seed Z an Y distances from the planning isocenter were calculated. An Excel spreadsheet, with sample shown in figure 2, was generated to compare the measured and planned seed displacements from isocenter and give the necessary patient shift to position the target as specified in the treatment plan.

If the displacement along either the Z- or Y-axis exceeded 4.4 mm, it was corrected and the session considered not eligible for randomization. Also, if both Z/Y measurements were within 1.5 mm, no action was taken and the session not randomized. Randomization was stratified by patient and resulted into two groups of sessions: corrected (C) and not corrected (NC). After correction/no correction, another lateral port film was taken just before treatment and a third one at completion of treatment.



SIM	LL			Seed #						AP				Seed #					
				#1		#2		#3						#1		#2		#3	
date	9 cm	MF		Z	Y	Z	Y	Z	Y	9 cm	MF			X	Y	X	Y	X	Y
10/11/2006	6.9	0.8		0.65	1.1	0.65	1.25	0.55	2.55	5.73	0.6			-1.7	0.95	-0.7	1.1	-1.3	2.15
				0.8	1.4	0.8	1.6	0.7	3.3					-2.6	1.5	-1.0	1.7	-2.0	3.4

Pinnacle coordinates

isocenter			SEED #1			SEED #2			SEED #3		
X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
-2.1	-54	-0.2	0.54	-55	1.35	-1.1	-55	1.5	-0.1	-55	3.2

distance from isocenter (cm)

LAT	SI	AP	LAT	SI	AP	LAT	SI	AP
X	Y	Z	X	Y	Z	X	Y	Z
2.6	-0.8	1.6	1.0	-0.9	1.7	2.0	-0.7	3.4

		Seed #1		Seed #2		Seed #3		Shift distance (mm)		
								- means table right	-means drop table	- means table out
9 cm	Mag.	Z	Y	Z	Y	Z	Y	X	Y	Z
12.2	1.4	2.0	2.1	2.1	2.7	2.7	5.1	0	8	2
12.4	1.4	1.0	1.8	1.1	2.3	1.6	4.9	-2	1	-1
11.8	1.3	2.05	2.5	2.05	3	2.55	5.5	2	9	6
12.2	1.4	1.1	1.9	1.1	2.4	1.65	5	2	1	1
11.9	1.3	1.3	2.5	1.4	3	1.9	5.5	-3	3	6
12	1.3	0.5	1.7	0.6	2.3	1.2	4.9	1	-3	0
12.5	1.4	1.3	2.2	1.4	2.8	1.95	5.45	-3	3	3
11.9	1.3	1.2	1.8	1.2	2.4	1.7	4.9	-1	2	1
12	1.3	1.1	2.05	1.3	2.65	2.05	5.15	0	3	2
11.8	1.3	0.6	1.4	0.7	2	1.4	4.4	0	-1	-2
11.9	1.3	1.4	2.5	1.55	3	2.05	5.5	-1	4	6
12.1	1.3	0.65	1.6	0.8	2.2	1.3	4.8	-4	-1	-1
12.3	1.4	1.05	2.7	1.1	3.3	1.4	5.8	-4	0	7
12.2	1.4	1.2	1.95	1.25	2.5	1.5	5	-8	1	1
12.7	1.4	1.1	2.55	1.3	3.3	1.9	5.9	-4	-2	6

Figure 2. The top image shows the seed displacements in the CT coordinate system used as the daily standard. The bottom image shows the daily seed displacements and required table shifts.

The time interval (mean ± SD) between the `initial` and `before` treatment films was 9 min. ± 4 min. and 22 min. ± 6 min. between the start and the end of treatment.

The purpose of the study was to compare systematic (Σ) and random errors between the two groups at the three film time points, `initial`, `before` and `after`. Errors were defined per Van Herk and computed using a mixed model, that takes into account within-patient correlation. The difference in the magnitude of errors between the 2 arms was evaluated using an F test.

Results: Of 18 patients, 3 were excluded; 2 because of only one eligible session and 1 because of noncompliance. 239/545 (43.8%) of sessions had prostate displacements between 1.5 and 4.4 mm, and were randomized: 117 (49%) to NC and 122 (51%) to C. The systematic errors (mm) by randomization are reported in Table 1.

	Z			Y		
	NC	C	F Test, p value	NC	C	F Test, p value
Initial	1.10	1.30	1.40, p=0.54	1.84	1.95	1.12, p=0.83
Before	1.35	0.33	16.9, p<0.001	2.11	1.12	3.57, p=0.02
After	1.21	0.43	7.68, p<0.001	1.84	1.12	2.72, p=0.07

Table 1. Analysis of displacements

The correction of errors translated into a significantly smaller pretreatment Σ for both axes. At the end of treatment, the benefit for C over NC remained highly statistically significant along the Z axis and was borderline significant along the Y axis. Regarding the random error, we observed ≈ 15-20% average reduction for C as compared to NC for both Z- and Y-axes when assessed over the entire time period, though the difference was not statistically significant. If the overall treatment course consisted of only the sessions with an error between 1.5 and 4.4 mm, correcting for prostate displacement would translate into a margin reduction of 2-3 mm for C over NC.

Conclusions: The results support taking action to correct prostate displacements between 1.5 and 4.4 mm after set-up to minimize the systematic error. The benefit also holds true after prolonged treatment sessions especially along the Z-axis.