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Dosimetry

Dosimetric evaluation of prostate rotations and their correction by couch rotations

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Abstract

***Purpose*: To investigate the dosimetric effect of prostate rotations and limited on-line corrections by couch rotations ($\leqslant 3°$) for prostate, seminal vesicles and organs at risk.**

***Methods*: For 5 patients IMRT plans were made, treating the prostate plus base of the seminal vesicles. Realistic and idealised dose distributions were considered, the latter demonstrating extreme effects for rotations and their corrections. Translation errors were assumed to be corrected on-line.**

For each patient 20 treatments with different rotation errors were simulated: 20 systematic errors were generated and 20 times 35 random deviations were superimposed to simulate day-to-day variations. Using a research module of PLATO-RTS treatments with rotation errors, with and without on-line corrections, were simulated.

***Results*: The largest dosimetric effect of rotation errors and corrections was found for the seminal vesicles with idealised dose distribution: coverage improved from 92.6% (range 89.9—96.0%) to 95.9% (94.7—98.1%). The gain for the idealised prostate was less: 95.9% (94.4—97.0%) to 97.5% (95.5—98.4%). For the femoral heads the dose increase could be as large as 12.2% (6.2—19.3%).**

***Conclusions*: On-line correction of rotations can improve target coverage slightly. For organs at risk at a large distance from the isocentre the result can be a significant increase in dose.**

Keywords: Prostate; Rotation; Correction; Treatment couch; Radiotherapy dose planning

Modern image-guided radiotherapy (IGRT) enables detection of target shifts compared to the treatment plan using fiducial markers or otherwise [1—5].

For prostate irradiation it has been demonstrated that the prostate moves during the whole treatment, both intra-fractional and inter-fractional [6—11]. Its movement can be described by translations along the orthogonal directions (lateral, longitudinal, vertical), and rotations around the three main axes. The standard way to account for this movement is to use margins. Due to these margins extra healthy tissue is irradiated, hence many strategies to reduce these margins are nowadays pursued. The use of position verification protocols for translations can reduce these margins [12—15]. However, even if translational errors are completely compensated for, margins are still required for rotational errors.

When IGRT is done just prior to treatment it is possible to correct target translations and rotations on-line, before each fraction. The correction for translations is easily achieved using a couch shift. For correcting rotations there are two possibilities. First, by changing treatment parameters such as multi-leaf positions, gantry, collimator and couch angle [16—18] for each beam, it is possible to correct almost every rotation. Secondly, using recently developed robotic couches it is possible to rotate the tabletop in all three directions [19,20]. In this study, we focussed on the latter option. Before considering clinical implementation of any of these procedures, the efficacy of rotational corrections for prostate patients should be established [21].

The purpose of this simulation study is twofold: first to determine the maximum dosimetric effect of prostate rotations and secondly to determine the maximum beneficial effect of rotation corrections using a robotic couch. To quantify the effect of rotations only, it is assumed that all translation errors are fully compensated for. Both target and organs at risk are considered.

Materials and methods

Patient data

CT-scans of 5 consecutive patients with prostate cancer were selected. The prostate, the base of the seminal vesicles, rectum, bladder and femoral heads were contoured

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according to our clinical protocol. The base of the seminal vesicles was defined as the first 2 cm of the seminal vesicles from the base of the prostate in the sagittal view. The clinical target volume (CTV) contained the prostate and the base of the seminal vesicles. No-margin was added in order to explore the maximum effect of rotations of the target. In this simulation study, it was assumed that translation errors were corrected on-line and that this was done perfectly, i.e. no residual translation errors remained. Other assumptions are that there were no intra-fractional movements of the prostate or delineation errors.

To investigate the situation that is most sensitive to rotations, we took the 95% isodose (73.2 Gy) for prostate as a new target (prostate_95, see Fig. 1). For the seminal vesicles we took the 95% isodose of the whole CTV (66.5 Gy) as a new target (seminal_vesicles_95). This new structure was only allowed to expand to the posterior direction to avoid including the prostate. No regions with a dose higher than 73.2 Gy outside the prostate_95 structure are present. In this way the given dose distribution is the idealised but still realistic dose distribution for the newly created organs.

Treatment plan

For every patient, a five-beam IMRT plan (10 MV) was made with PLATO-ITP (Nucletron, Veenendaal, The Netherlands). The five-beam directions were 180°, 100°, 40°, 320° and 260°. A dose of 70 Gy in 35 fractions was prescribed to the whole CTV with a concomitant boost up to 77 Gy to the prostate only. This CTV was planned to receive at least 95% of the prescribed dose. Dose limits for rectum were a maximum of 65 Gy to 50% of the rectum volume (V_{65} < 50%) and less than 5% of the rectum volume should receive 76 Gy ($D_{5\%}$ < 76 Gy). For the bladder the dose constraint was a maximum of 70 Gy to 50% of the bladder volume (V_{70} < 50%).

Rotations and corrections

For each patient-plan 20 systematic rotation errors were generated assuming a Gaussian distribution. For each *systematic* rotation error, 35 *random* rotation errors were superimposed independently. In this way, 20 different treatments given in 35 fractions were simulated per patient. The standard deviations for both systematic and random errors were based on the literature values [22] and are listed in Table 1. Rotations were quantified with respect to the bony structures. The CTV was rotated around the centre of the prostate and it was assumed that the rectum and bladder rotate with the prostate.

Table 1
Standard deviations of systematic (Σ) and random (σ) rotations of the prostate used in the simulations

	Left–right axis	Anterior–posterior axis	Cranial–caudal axis
Σ (°)	6.2	2.6	3.0
σ (°)	3.1	1.7	1.9
Range (°)	−17.8; 18.5	−9.1; 8.6	−9.8; 11.1

The third row indicates the range of the combined systematic and random rotations used in the simulations. The CTV was rotated around the centre of the prostate.

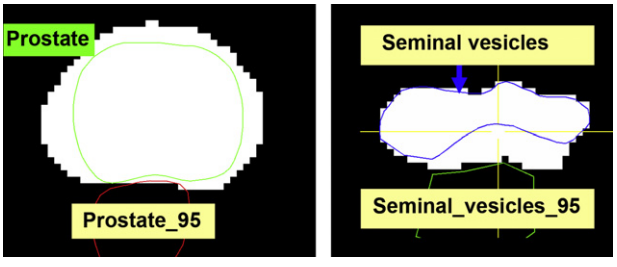

Fig. 1. In the left picture, the prostate (green line) and the 95% isodose for the prostate defining the prostate_95 (white region) are indicated. In the right picture, the same definitions are shown for the seminal vesicles: seminal vesicles (blue line) and seminal_vesicles_95 (white region).

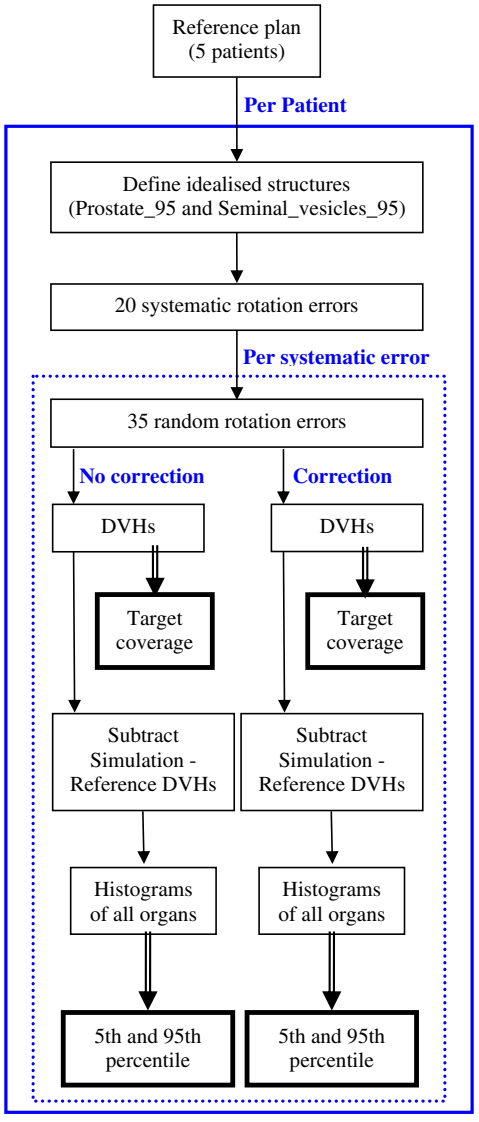

Fig. 2. Flowchart of the simulations and analyses performed in this study. Results are presented in the bold frames.