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EVALUATION OF BLADDER DOSE IN INTENSITY-MODULATED RADIATION THERAPY OF THE PROSTATE

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Abstract—Day-to-day variation in bladder and rectal filling affects prostate location and positioning accuracy. Systems using ultrasonic localization or gold seed placement are most often used to help correct for these changes. At some institutions, patients are instructed to empty their rectum and fill their bladders prior to treatment in an attempt to standardize the prostate location, displace small bowel out of the radiation field, and move some of the bladder wall away from the high-dose area. Although instructed to come to treatment with a full bladder, it is presumed that there is variability in bladder filling each day of treatment, depending on the amount of fluids consumed and time to treatment. We have reviewed daily bladder volumes on a subset of 5 prostate patients, all of them prescribed to receive 7560 cGy in 42 fractions, and have evaluated the dosimetric consequences of bladder volume changes from full to two-third or one-third filling. All of these patients' positions were verified daily with ultrasonic localization. Those measurements have been used to help analyze the actual treated bladder volumes for comparison with the treatment plan. We find that, in general, maximum filling only occurred on the initial simulation/image acquisition day and was typically smaller on all the following treatment days. Based on our dose-volume model, we estimate that average bladder daily doses were 8–50% higher than predicted by the initial intensity-modulation radiation therapy (IMRT) plan. © 2006 American Association of Medical Dosimetrists.

Key Words: **IMRT, Bladder volume, Prostate cancer, Dosimetry.**

INTRODUCTION

In recent years, prostate cancer has been treated with more conformal forms of therapy than the 2-, 3-, and 4-field approaches traditionally used. Three-dimensional (3D) conformal therapy[1–3] and, more recently, intensity-modulated radiation therapy (IMRT)[4,5] have been employed for both dose escalation and organ-sparing advantages. The RTOG has originated 3D conformal[6] and IMRT[7] trials for prostate treatment. As part of the IMRT protocol, they have recommended dose-volume limits for rectum and bladder, which can be used to guide constraint selection.

Treatment planning is done using computed tomography (CT) and/or magnetic imaging (MR) image sets, which provide, essentially, a snapshot of the internal organ positioning at the time of imaging. The bladder is sometimes artificially filled, using a Foley catheter, and the patient is asked to come to treatment with a full bladder on the subsequent treatment days. Although we are well aware of the problems of prostate motion[8] and the effects of changing rectal filling on rectum doses, we have not addressed the problem of differential bladder filling on the actual doses imparted to the bladder.

In this report, we have attempted to quantify, for a subset of prostate patients receiving 7560 cGy with IMRT (180 cGy/fraction), the actual vs. planned bladder doses. We find that, on average, bladder filling is significantly less on treatment days than on the initial data-taking day. This leads to an underestimate of maximum and average bladder doses by as much as 50% in the planning phase, and could be responsible for unexpected side effects following treatment.

METHODS AND MATERIALS

IMRT planning was done on the Varian Eclipse planning system (V7.2), using the Helios optimization program. Five patients were randomly selected, all of whom had the same stage clinical disease and were treated to 7560 cGy in 42 fractions. The same physician drew the clinical target volumes (CTV), which did not include seminal vesicles, for these patients. A 1.5-cm margin was used to define the planning target volumes (PTV) for each case. The rectum was drawn to the sacro-iliac junction and bladders contoured with the aid of injected contrast. All of these patients were scanned on a Siemens Somatom Plus CT, for which 3-mm slice thicknesses were acquired through the area to be planned. A reference isocenter was selected as a point 6 cm posterior to the pubic symphysis and 3 cm superior to the urethral verge, as visualized on a urethrogram.

The planning technique was the same for each patient, with a 5-field approach used. The gantry angles were 180°, 240°, 315°, 45°, and 100°. Twenty-five–

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Table 1. RTOG dose volume limits

Structure	D_{50} (Gy)	D_{35} (Gy)	D_{25} (Gy)	D_{15} (Gy)
Bladder	65	70	75	80
Rectum	60	65	70	75

megavolt photons were used for these treatments on a Varian 2300cd linear accelerator. This machine utilizes a 40-leaf-pair multileaf collimator (MLC) with leaf widths of 1 cm, projected to the isocenter. Patients are immobilized with a partial body vacuum bag system, conformed from their upper thighs to (and including) their feet. Treatments include an acrylic table insert, for rigidity, which is included in the plan as a 1.5-cm-thick bolus, applied after optimization is complete.

In Table 1, we list the recommended dose-volume constraint levels proposed in a recent protocol from the RTOG.[7] In practice, we found that for those cases in which IMRT was used for the whole treatment, it was not necessary to specify a bladder constraint in the optimization program. Instead, only rectal limits were set (typically as a dose-volume constraint line extended from 100% volume at 0 dose to 0% volume at 100% dose). The constraint weight is usually set to 80%. The PTV constraints were set as a dose window of ± 20 cGy bounding the prescription dose (with 90% weight). This simple combination generally provided rapid convergence to acceptable dose-volume distributions and homogeneous target coverage in a range of 95–105%. We have tended to avoid using bladder constraints, wherever possible, because they can result in "bow-tie"-like dose distributions around the PTV, which we feel can increase the risk of geometric miss.

To simulate degrees of bladder filling in the planning system, we created 2 additional bladder contours for each patient, representing two-third and one-third

Table 2. Sample relative bladder measurements*

Treatment Day	Relative Volume	Dose/Fraction (cGy)	Mean Total Dose (cGy)
1	0.83	73.8	3099
2	0.96	63.8	2679
3	0.97	63.0	2644
4	1.08	54.9	2304
5	0.89	69.1	2902
6	0.74	80.2	3368
7	0.81	75.4	3168
8	0.95	64.2	2697
9	0.58	98.8	4148
15	0.64	90.4	3798
17	0.70	83.4	3504
18	1.00	61.0	2561
19	0.75	79.9	3356
20	0.77	78.0	3277
21	0.34	136.5	5733
23	0.87	70.8	2972
24	0.84	72.5	3047
25	0.81	74.9	3147
27	0.55	103.2	4336
28	1.00	60.3	2533
29	0.99	61.4	2578
32	0.74	80.5	3380
33	0.64	90.5	3800
34	0.83	73.8	3099
35	0.77	78.1	3281
36	0.71	82.9	3482
37	0.55	104.7	4399
38	0.59	97.7	4103

*Patient no. 1.

filling. Based on our observance of the daily ultrasound measurements, we estimated the direction of bladder collapse to be inward and posterior (due to gravity). Therefore, we maintained the posterior aspect of the bladder and tapered the new contours symmetrically inward. These assumptions were applied to all test cases. Figure 1 provides example drawings of a full bladder and partial bladder estimates on axial and sagittal CT images.

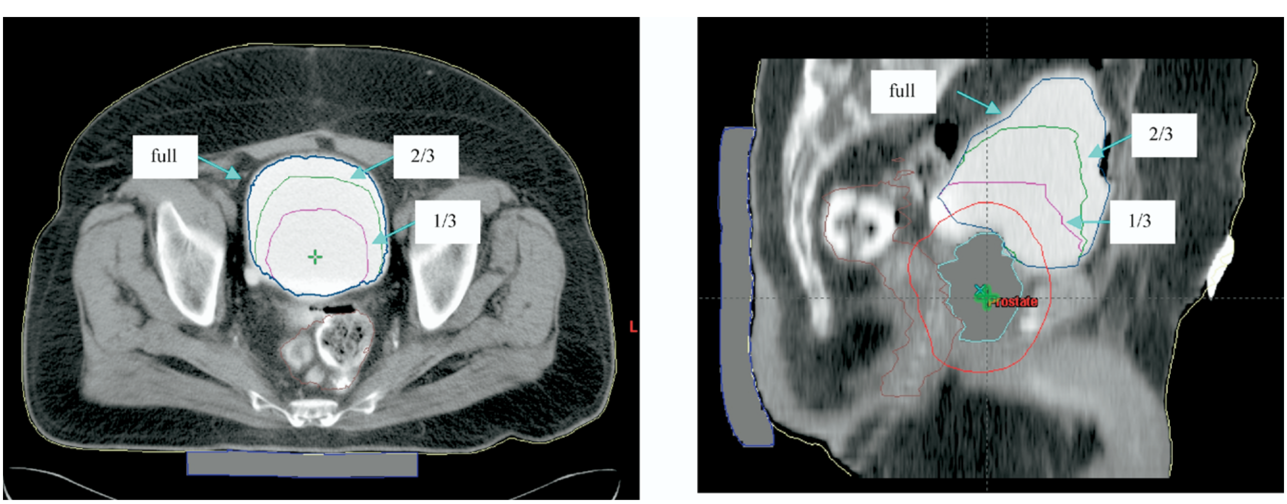

Fig. 1. Anterior (a) and lateral (b) views of the originally scanned bladder volume and estimated one-third and two-third filled bladders for patient no. 1.