DOSIMETRIC EFFECT OF A HIP PROSTHESIS WHEN DELIVERING INTENSITY MODULATED RADIATION THERAPY (IMRT): A PHANTOM STUDY

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Introduction

The American Association of Physicists in Medicine Task Group 63 survey found 1-4% of patients treated had a prosthetic device, and with an aging patient population, it can be expected that the number of patients with prostheses is likely to increase. Unfortunately, precision in dosimetry for radiation beams that pass through a prosthetic device is difficult to accomplish, as there is a significant dose perturbation when x-rays interact with materials whose atomic number (Z) is more than five times the Z of the surrounding medium. This is often the case for radiotherapy patients who have treatment fields that pass through a prosthesis, e.g. extremity prosthetics, rods, stents, or fillings. Radiation dosimetry studies have measured dose attenuation medial to various hip prostheses, which ranged from 5 to 50%, depending on the energy used and the physical characteristics of the prostheses.[1,2,3,4] In a previous treatment planning study we investigated the ability of intensity modulated radiation therapy to minimize the effect of a prosthesis, while meeting dose constraints to surrounding normal tissue.[5] The results of that work indicated treating through the prosthesis was an excellent dosimetric option, if the planning system properly modeled photon transport through the prosthesis. The purpose of this study was to experimentally quantify our inverse treatment planning system's ability to accurately calculate the radiation dose distribution for treating the prostate for patients with a hip prosthesis.

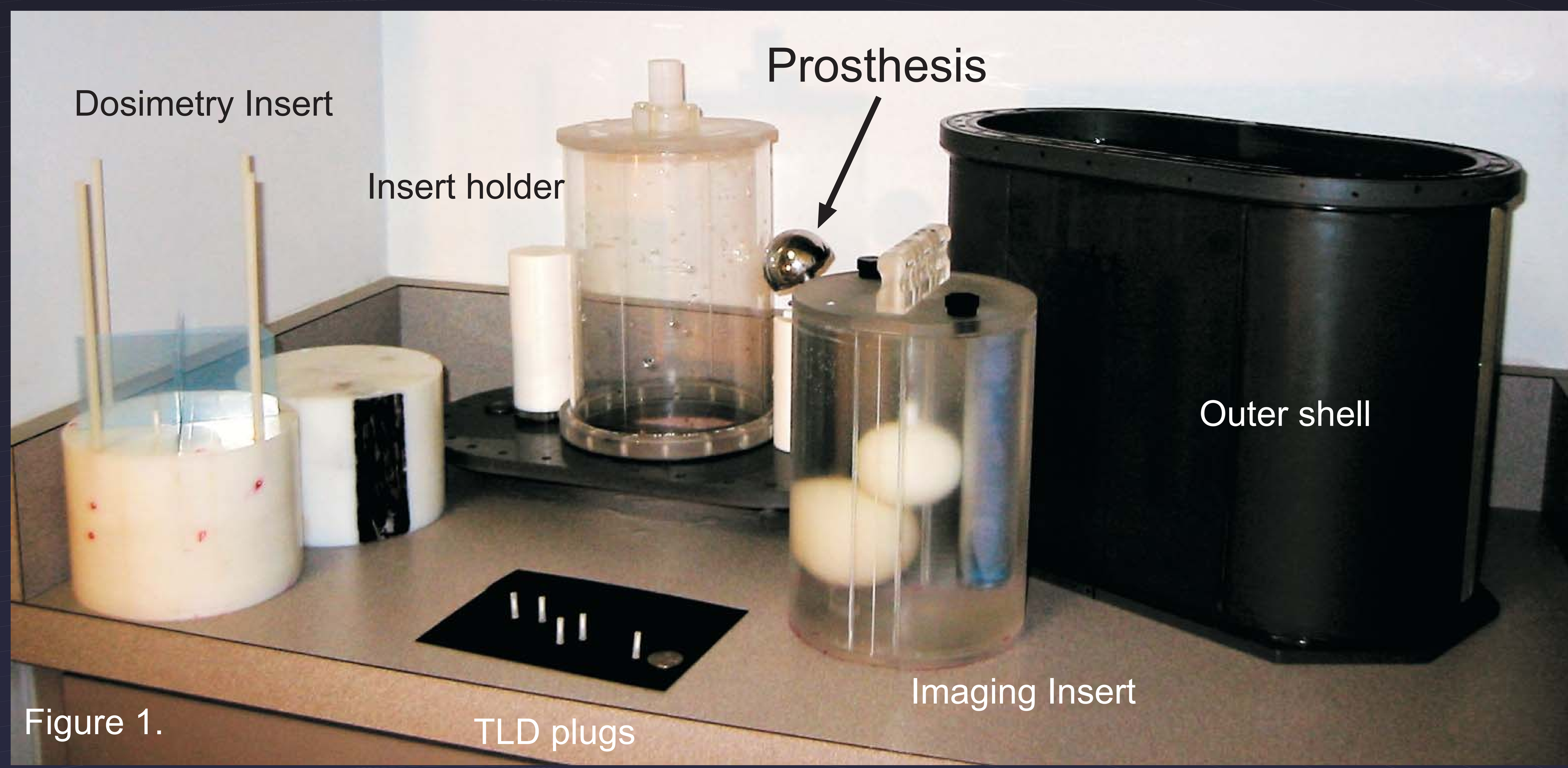

Figure 1.

Materials and Methods

An anthropomorphic pelvic phantom designed at the Radiological Physics Center of The M.D. Anderson Cancer Center was modified to hold a cobalt-chromium hip prosthesis (6.84 g/cm3), which is shown in Figure 1. The phantom holds one of two central inserts: for planning (1) an anatomic insert containing a prostate, bladder, and rectum, and for delivery (2) a dosimetry insert which holds two TLDs near isocenter (5mm superior, 5 mm inferior), 1 TLD in the femur contra-lateral to the prosthesis, and gaphchromic film in the sagital and coronal planes. Treatment plans were created using 8 non-opposed co-planar 6 MV x-ray beams (see figure 2), with one beam (100°) passing directly through the prosthesis. In order to best use the dosimeters, the prescription dose was set to 25 Gy to at least 95% of the planning target volume designed around the prostate. Dose and dose-volume objectives were set for the bladder and rectum, proportional to the values set forth in RTOG protocol P0126. Four different treatment planning techniques were considered:

1) assume uniform density for optimization and dose calculation,
2) assume uniform density for optimization but assign densities for dose calculation,
3) same as 2, but minimizing scanning artifacts by setting the density of all non-ROI voxels to unit density,
4) assign artifact-corrected densities for both optimization and dose calculation

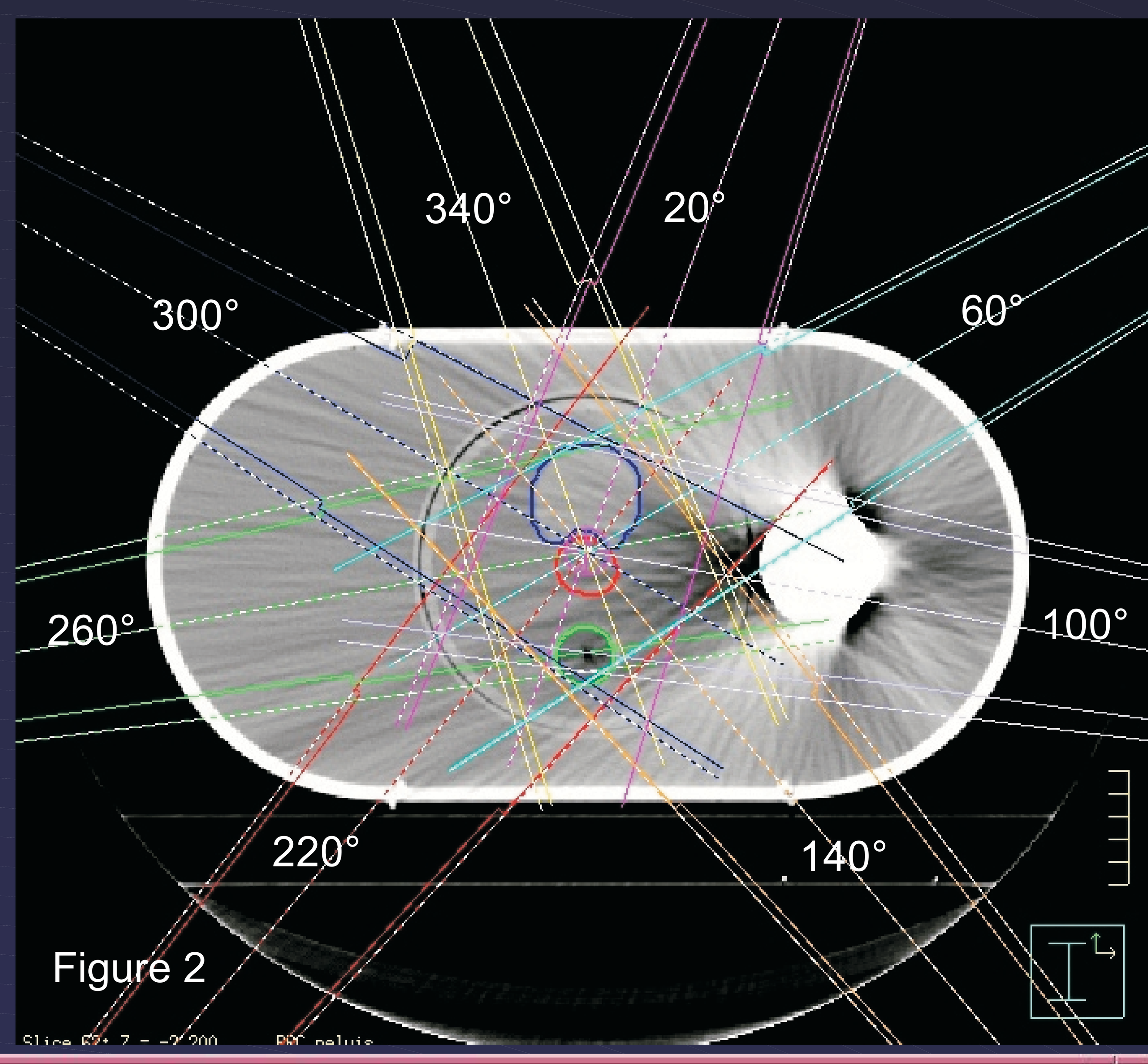

Figure 2

The resultant plan from each technique was delivered to the phantom 3 times. Absolute doses were obtained with TLD, relative dose profiles through isocenter acquired from gaphchromic film. Both were compared calculated values.

Results

Figures 3 and 4 show the dose distributions computed for planning techniques 1 and 2, where the presence of the prosthesis is indicated by the difference observed. The accuracy in which the planning system is able to predict this effect was measured using TLD and is shown in Table I. The following dose differences (100%x(calc-meas)/meas) were found for the TLDs superior and inferior to isocenter and in the contra-lateral femur: technique 1 (-0.7, -1.9, -7.4 %), technique 2 (-8.2, -3.3, -8.9 %), technique 3 (-6.6, -2.1, -7.1 %), and technique 4 (-0.9, -1.6, -7.2%). The standard deviations of the TLD measurements were all within 1.5%. Measured dose profiles in the superior/inferior direction revealed ignoring the presence of the prosthesis results in an 8% reduction in dose through the thickest aspect of the prosthesis. The treatment planning system calculated the dose reduction in this region to be 6%.

Without the prosthesis (technique 1) or when fully accounted for (technique 4) and treating through it, the PTV TLDs were within 2% of the calculated values. This was not the case for techniques 2 and 3, where scanning artifacts remained.

Figure 3.

Figure 4.

Conclusions

Both TPS and measured results demonstrate the presence of a hip prosthesis should not be ignored when planning IMRT. When assigning the known density of the prosthesis, the TPS was able to account for and calculate dose through the prosthesis to within 2%. However, the treatment planning system overestimated the effect of the prosthesis when scanning artifacts were allowed to remain in either the optimization or final dose calculation. Dose accuracy within the precision of our experiment was observed when scanning artifacts created by the prosthesis were removed prior to optimization.

IMRT Prosthesis Phantom Study Pinnacle			Doses (Gy) Calculated			Doses (Gy) Measured			Doses (Gy) % Difference		
			(Patient Left of iso, anterior to coronal iso)	(Patient Right of iso, posterior of coronal film)	(iso plane)	(Patient Left of iso, anterior to coronal iso)	(Patient Right of iso, posterior of coronal film)	(iso plane)	(Patient Left of iso, anterior to coronal iso)	(Patient Right of iso, posterior of coronal film)	(iso plane)
Case	Treatment Planning	Treatment Delivery	Sup PTV	Inf TLD	Femur TLD	Sup PTV	Inf TLD	Femur TLD	Sup PTV	Inf TLD	Femur TLD
1	Prosthesis excluded (unit density)	Prosthesis excluded	25.6	25.5	7.7	25.8	26.0	8.3	-0.7	-1.9	-7.4
2	Superimpose plan from case 1 on CT that includes prosthesis for optimization, but recompute with heterogeniety (scanning artifacts not corrected)	Include prosthesis. Utilize the deliver sequence for case 1	23.7	24.9	7.5	25.8	25.7	8.2	-8.2	-3.3	-8.9
3	Superimpose plan from case 1 on CT that includes prosthesis for optimization, but recompute with heterogeniety and remove scanning artifacts	Utilize measurements from case 2	24.1	25.2	7.6	25.8	25.7	8.2	-6.6	-2.1	-7.1
4	Include prosthesis, correct for scanning artifacts, and allow the system to treat through the prosthesis	Include prosthesis	25.8	26.3	8.3	26.0	26.7	9.0	-0.9	-1.6	-7.2

Table I.

References

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