Effect of Film Orientation on Proton Beam Dosimetry

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Purpose

The mission of the Radiological Physics Center (RPC) is to assure the NCI and the Cooperative Groups that institutions participating in clinical trials deliver prescribed radiation doses that are comparable and consistent. A major component of this quality assurance program is the use of mailable heterogeneous phantoms to evaluate radiation treatment procedures. The RPC is currenty evaluating an anthropomorphic phantom for auditing proton therapy procedures. The phantom was originally designed for testing IMRT procedures. The phantom was first scanned on a CT scanner, a treatment plan was created based on the structures inside the phantom and a dose prescription of 6 Gy to the prostate and the phantom was treated. Two inserts are used for the phantom: an imaging insert containing internal anatomy used for the treatment plan and a dosimetry insert which contains radiochromic film and TLD for treatment delivery. *The passing criterion for the measured and calculated dose is to show agreement within 5%/3mm.*

Materials/Methods

One concern with the dosimetry insert for the pelvis phantom was having one piece of the Gafchromic© EBT film parallel to the lateral beams irradiating the phantom. This is illustrated in Figure 3 where the light blue rectangles represent the film being held within the phantom insert. With the protons traveling along the film, there is a slight difference of densities and relative stopping powers between the HI Polystyrene insert and the film. The differences in materials might allow for the protons to stream further down the film then intended by the treatment plan. To test this theory, the dosimetry insert was modified to allow it to be held in place with a 10º rotation from the beam axis as seen in Figure 4. By rotating the film 10º, the protons are no longer parallel to the film and any "streaming" effect should be eliminated.

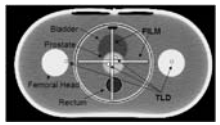

Figure 1: *(left) The RPC Pelvis phantom with imaging insert and dosimetry insert. The dosimetry insert has been dismantled to show the film.*

Figure 2: *(above) An axial CT slice of pelvis phantom with imaging inset. Locations of the film and TLD have been overlayed*

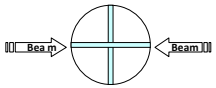

Figure 3: *Film Orientation with a 0º Rotation*

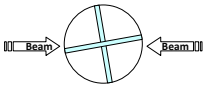

Figure 4: *Film Orientation with a 10º Rotation*

CT simulation of the phantom was performed and the Hounsfield Units were converted to the measured stopping power for each material to correct for the phantom materials not being proton equivalent.

The phantom was irradiated using a treatment plan (Plan 1) with lateral fields along with the appropriate apertures and compensators for both film orientations. This process was performed three times per film orientation. The TLD dose was used as the absolute dose and the film dose was scaled relative the TLD. Dose profiles were taken across the film and compared to the corresponding axis from the treatment plan.

A second plan was created with contours surrounding materials in the phantom which are not normally contoured for IMRT treatments (including acrylic surrounding the inserts) and this plan was treated once for each film position.

Results

Figure 5 shows the film results plotted along with the treatment plan for a film which was parallel to the beam direction. 4 profiles were taken for each phantom irradiation and the right-left profile on the coronal plane was the only profile to exceed the 3 mm limit. The displacement between the measured (shown in blue) calculated (shown in pink) dose profiles were -8 mm on the left side and 4 mm on the right side. This irradiation was performed 3 consecutive times with similar results.

Figure 6 shows the film results plotted with the treatment plan for a film rotated 10º off the beam axis (see Figure 4). The displacement after rotating the film was -5 mm on the left side and 2 mm on the right side.

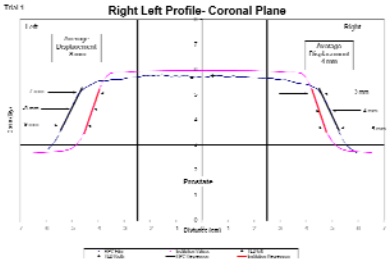

Figure 5: *Film Orientation at 0º for Plan 1*

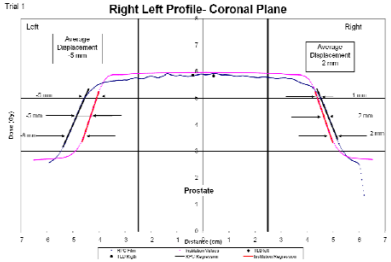

Figure 6: *Film Orientation at 10º for Plan 1*

The second treatment plan (Plan 2) contoured not only the anatomical structures in the phantom, but also the acrylic which surrounded the inserts in an effort to reduce the margins to 3 mm and was delivered by a second institution.

Figure 7 displays the right-left profile in the coronal plane for Plan 2 with the film oriented at 0°. The displacements were -3 mm on the left and 4 mm on the right. Rotating the film by 10° reduced the margins to -2 mm on the left and 2 mm on the right as seen in Figure 8.

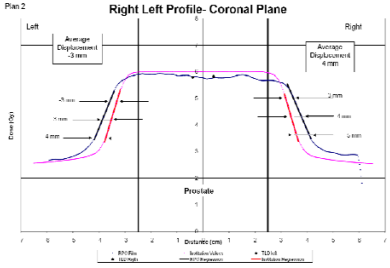

Figure 7: *Film Orientation at 0º for Plan 2*

Results continued

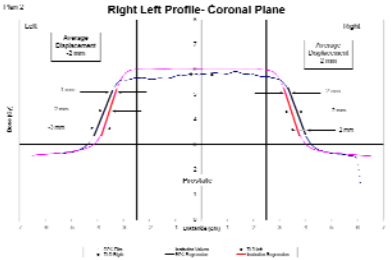

Figure 8: *Film Orientation at 10º for Plan 2*

	Plan 1		Plan 2	
	Left	Right	Left	Right
Film 0	-8 mm	4 mm	-3 mm	4 mm
Film 10	-5 mm	2 mm	-2 mm	2 mm
Total Difference	**3 mm**	**2 mm**	**1 mm**	**2 mm**

Discussion

The measured and calculated dose profiles had an improved agreement between 1 and 3 mm with the film rotated 10º from the central beam axes. This suggests that differences in relative stopping power between the film and the phantom material might be causing discrepancies as the planning system did not account for the relative stopping power of the film and underestimated the range of the protons.

A second insert might be created allowing for only a 1° rotation as opposed to the current 10° rotation. The current rotation is large enough to show changes in the calculated profiles. A smaller angle has the potential to allow for a comparison of the film profile to the calculated profile along the path of the beam given the difference on the calculated profile at 0° and 1° does not change substantially.

References

[1] Zhao, L. and Das, I. J. "Gafchromic EBT film dosimetry in proton beams." Phys Med Biol **55**(10): N291-301

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