Evaluation of An Anthropomorphic Pelvis Phantom for Proton Therapy

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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. Currently, the RPC has a need for a heterogeneous phantom to evaluate the quality of proton therapy at institutions participating clinical trials. This phantom will audit the accuracy of the CT simulation, challenge the treatment planning system and provide dose measurements for treatment delivery. The criterion for passing are proposed to be agreement between the measured dose the calculated dose within 5%/3mm.

Materials/Methods

The RPC has several pelvis phantoms intended for use in independent audits of photon IMRT treatments. This design was retrofitted for use in proton beams.

The relative stopping power of each material used to construct the phantom was measured to determine the tissue equivalence of the materials. This measurement was done following the method outlined by Schaffner and Pedroni[1]. A slab of material to be tested was placed in a water phantom in the path of the beam as a PDD scan was performed. The shift between this scan and a reference scan with only water in the path of the beam was measured. The relative stopping power was calculated as:

$$\text{Rel. SP} = 1 + \frac{\Delta x}{\text{Material Width}}$$

where Δx is the displacement between the two scans. This procedure was repeated for each phantom material.

The phantom was scanned with a clinical CT scanner and the HU of each material was measured in the treatment planning system. Each relative stopping power was then compared to the CT scanner's calibration curve.

All of the structures within the phantom were contoured so a treatment plan could be devised. The stopping powers assigned by the TPS were not altered. Two lateral beams were used to deliver a prescription of 6 Gy to the prostate. Custom apertures and compensators were built in the machine shop to replicate a patient treatment.

The phantom was loaded with 4 TLD capsules and 2 pieces of Gafchromic® film. 2 TLD capsules were placed in the prostate and 2 more were placed in the femur. The films were placed in the coronal and sagittal planes through the center of the prostate.

The phantom was aligned by the laser system in the treatment room and the plan was delivered 3 separate times.

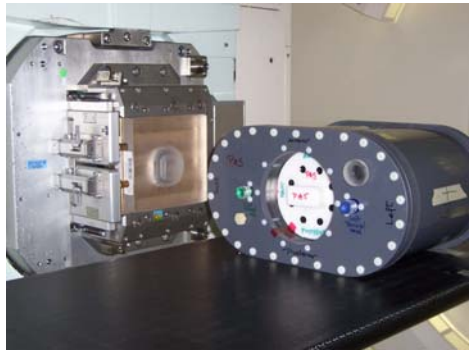

Figure 1: The pelvis phantom is aligned on the table in preparation for a right lateral field. The white insert in the center of the phantom contains the film and the target TLD.

Materials/Methods continued

After the treatment, the TLD and film were both analyzed and registered to the treatment plan. The TLD was read 10 days post irradiation and registered through CERR[3] using previously defined points. The film was scanned with a CCD microdensitometer and also registered to the treatment plan in CERR. The film dose was scaled relative to the TLD dose. Two profiles in each plane of film were exported to Excel along with the corresponding profiles from the treatment plan. The average displacement between the measured dose and the calculated dose was measured for each plane.

Results

The measured stopping powers differed by as much as 10% from the values used in the treatment planning system as seen in Figure 2.

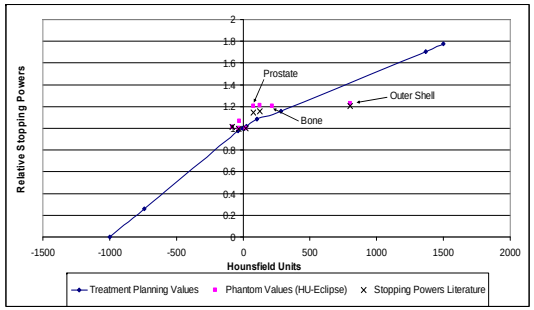

Figure 2: Each phantom material is plotted along with the calibration curve for the clinical CT scanner used to image the phantom. Also shown are available literature values for some of the materials to compare with the measured values. [2]

Most of the stopping powers were comparable to those stored in the TPS with 3 notable exceptions; the prostate, femoral heads and outer shell material. The stopping powers were not changed for the first set of irradiations to see the effect these differences would have on dose comparison.

The TLD results are shown in Table 1. The dose to the target was within 2% of the planned dose and the dose to the femoral heads was within 3%. These values were well within our goal of 5%/3mm.

	PTV Right	PTV Left	Femur Right	Femur Left
Institution Predicted Dose (cGy)	600.2	600.2	247.3	243.8
TLD Measured Dose (cGy)	589.8	595.1	242.1	240.4
Measured / Predicted Dose	0.983	0.992	0.979	0.986

Table 1: The TLD results for one trial are shown above. Across the 3 trials the PTV values stayed within 2% and the femoral head values stayed with 3% agreement.

The film results for one profile in each plane are shown in Figures 3 and 4. Both profiles showed excellent agreement within range of our criterion.

Results continued

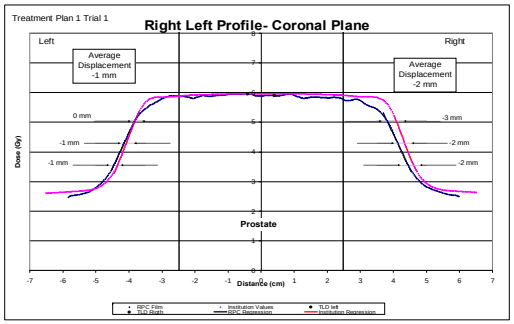

Figure 3: The right-left profile was taken along the central axes of the beams so the average displacement was measured on both sides. The average is taken at the specific points noted on the plot.

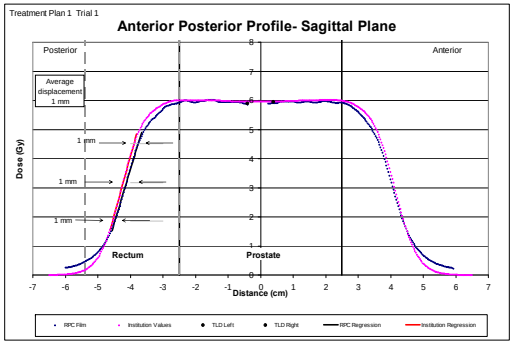

Figure 4: The sagittal plane also showed good agreement with a 1 mm displacement.

Conclusion

Initial studies suggest the RPC's current anthropomorphic pelvis phantom is suitable to audit proton therapy treatment procedures for institutions participating in clinical trials.

Further studies are being conducted to quantify the stopping power differences found between the phantom materials and the TPS assigned values.

References

1. B. Schaffner and E. Pedroni, "The precision of proton range calculations in proton radiotherapy treatment planning: experimental verification of the relation between CT-HU and proton stopping power," Phys Med Biol 43, 1579-1592 (1998).
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3. J. O. Deasy, A. I. Blanco and V. H. Clark, "CERR: a computational environment for radiotherapy research," Med Phys 30, 979-985 (2003).

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