IROC Houston QA Center's anthropomorphic proton phantom program

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Purpose:

To describe the proton phantoms that IROC Houston uses to approve and credential institutions to participate in NCI-sponsored clinical trials.

Methods and Materials:

Photon phantoms cannot necessarily be used for proton measurements because protons react differently than photons in some plastics. As such plastics that are tissue equivalent for protons were identified and tested to assure, relative stopping power (RSP) and HU values were tissue equivalent. Proton-equivalent plastics/materials used for the development of the new phantoms include RMI solid water, Techtron HPV, blue water, RANDO soft tissue material, balsa wood, compressed cork and polyethylene. Results of the HU values, are shown in Figure 1.

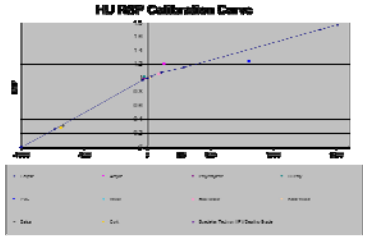

Figure 1. HU relative stopping power calibration curve

In addition to altering the plastics, alteration of our phantoms were required to ensure that the film dosimeters contained no air gap to avoid proton streaming.

When institutions are interested in any proton protocol, they can go to the IROC Houston website (http://irochouston.mdanderson.org) and request either the head, spine, prostate, liver, or lung phantom. Upon receipt the institution will image the phantom and develop a treatment plan according to instructions.

Methods and Materials (continued):

Upon receipt the institution will image the phantom and develop a treatment plan according to instructions. For a few phantom materials RSP values are provided in case an override is necessary. The treatment is then delivered and the phantom is returned. The measured dose distributions are compared to the institution's electronically submitted treatment plan dosimetry data.

Images of all phantom types are shown in Figure 2. The head phantom has both a imaging and dosimetric insert. The water fillable imaging insert contains the GTV (tumor target). While the dosimetric insert contains TLD at 2 locations and perpendicular sheets of film in order to evaluate the dose to target. The total dose to the phantom is 6 Gy(RBE).

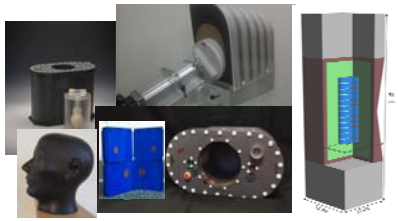

Figure 2. Images of all IROC Houston proton phantom types

The spine phantom consists of three parts: spinous processes in the posterior portion, the patient's right contains the right transverse process, and left which is patient's left. The phantom is simulated supine. When planning, two fields are used and the fields must match in the middle of the phantom, at the 6th vertebral body. This phantom is made of solid water while the processes are made of bone equivalent material. CT images shown on Figure 2. A biologically weighted dose of 6.00 Gy (RBE) at each isocenter must be delivered.

Methods and Materials (continued):

The liver phantom insert is made of blue water and two GTV's (tumor targets) made of solid water. This phantom has motion capabilities if needed, to replicate in-house treatment protocols for motion management. In this phantom a list of measured relative stopping powers of each material are given. Though you may need to override the structures if your planning system predicts a stopping power different from those given.

The proton lung phantom was designed to simulate a heterogeneous thorax and is made up of primarily solid water and cork. The dosimetry insert is made of balsa wood incasing a solid water tumor. Anatomical structures such as the heart and ribs are also included and are made up of blue water and Techtron HPV, respectively. This phantom includes a motion apparatus to simulate breathing, but unlike most of our phantoms, the insert moves independently from the rest of the phantom.

The proton prostate phantom is very similar to the liver phantom in design. Unlike the liver, the prostate phantom has an imaging insert that includes the structures (prostate, bladder, and rectum). Once the phantom has been imaged and planned using the imaging insert, the imaging insert is removed and replaced with the dosimetry insert for treatment. The dosimetry insert is made entirely of polyethylene, and does not include any structures, but contains dosimeters for measurement. Other structures included in the body of the phantom are the left and right femoral heads.

Results:

IROC Houston has developed an extensive proton phantom approval/credentialing program consisting of five different phantoms designs: head, spine, prostate/pelvic, liver and lung. The phantoms are made with proton equivalent plastics that have proton equivalent HU and relative stopping powers similar (within 5%) of human tissues. They also and have imageable targets, avoidance structures, and heterogeneities. TLD and radiochromic film are contained in the target structures. There have been 13 head, 33 prostate, 18 lung, 2 liver and 16 spine irradiations with either passive scatter, or scanned proton beams. The pass rates have been: 100%, 69.7%, 72.2%, 50%, and 81.3%, respectively.

	Prostate	Spine	Lung	Head	Liver	TOTAL
Number of Irradiations	35	16	20	16	4	91
Passed	25	13	15	16	2	71
Pass Rate [%]	71.4	81.3	75.0	100.0	50.0	78.0

Table 1. Pass rate of all IROC Houston proton phantoms till 3-1-2015.

Conclusions:

As new proton institutions are constructed and continue to enroll in NCI-sponsored clinical trials, IROC Houston will continue to construct and develop new phantoms to meet this demand.

Support:

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