Evaluation of Positional Accuracy in Moving Tumors Using a CIRS Dynamic Phantom

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PURPOSE/OBJECTIVES

With the CIRS Dynamic Phantom (Computerized Imaging Reference Systems, Inc, Norfolk, VA), a lung target moves in the inferior/superior and left/right directions. In addition to the internal motion of the tumor mimicked by the CIRS phantom, a chest plate on the phantom (Fig. 2) simulates the anterior/posterior motion of a patient’s chest wall. These are used to establish the motion tracking model for Synchrony. The tumor and the chest plate move in concert along a predetermined sinusoidal pattern. To allow for a closer inspection of the previously mentioned features.

MATERIALS AND METHODS

The CIRS dynamic phantom, model 008, was scanned with 1.0mm slices on a GE HiSpeed 4 slice helical CT scanner. The dynamic phantom includes a thorax phantom, cylindrical moving rod with target insert (ball cube phantom), motion actuator, tracking device (chest plate), and control box (Fig. 1 and Fig. 2). The phantom is 15 cm in length, but was modified for this experiment; an additional 5 cm slab was appended to the cranial end of the phantom. The target insert is a 3 x 3 cm ball cube phantom with a 4.2 cc acrylic sphere (Fig. 3). The phantom, target, and rod are tissue equivalent, and the cube is lung equivalent (air). The phantom is a perfect patient, allowing for a closer inspection of the previously mentioned features.

Features tested with the use of this phantom include reliance of imaging for accuracy, X-ray techniques, varying image parameters, and effect of rotation with limited number of fiducial markers. Because the phantom is a perfect patient, external patient movements (i.e. leg movements, patient coughing, etc.) and fiducial migrations can be extracted from system errors commonly associated with treatment. This allows for a closer inspection of the previously mentioned features.

RESULTS

The results from the delivered treatments are shown in Table 1 in the last column. All the results show sub-millimeter accuracy except for treatment 7. Treatment 7 showed poor correlation errors (>1.0 mm) during the first half of treatment, and then an error resulted in the plan being aborted. After the plan was recovered, the correlation error was once again below 1.0 mm.

CONCLUSIONS

The CIRS Dynamic Phantom can mimic patient respiration with the use of a chest plate, and tumor motion with the use of the moving rod. In the past, Synchrony was tested using AP movement of the couch, but with the dynamic phantom, SI and LR movement of the tumor and A/P movement of the chest wall can determine positional accuracy that more closely reflects patient respiratory models. It was found that Accuray had commissioned the Cyberknife unit in San Antonio. Further experiments into the effect of variables (e.g., physical positioning alterations, dosimetry changes) on the treatment plan and delivery need to be done to determine the positional consistency of tracking with Synchrony.

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Table 1. Plan Summaries and Results

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<th>IDL</th>
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<th># nonzero beams</th>
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<th>Avg. Tx. Time (min)</th>
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Fig. 1. CIRS Dynamic Phantom setup

Fig. 2. Close up of Dynamic Phantom with fiducials

Fig. 3 Ball cube phantom with fiducials

Fig. 4 Respiratory model of Dynamic Phantom during treatment

Fig. 5 Respiratory model of patient during treatment