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

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Objectives: Synchrony was historically tested with a static head phantom placed on the couch, with the couch only moving in the anterior/posterior direction. With the CIRS Dynamic Phantom, lung tumors can also move 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 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. A dose volume of the lesion is acquired during delivery using Gafchromic film set orthogonally in a mini ball cube phantom insert. The mini ball cube phantom fulfills the requirements for the end-to-end QA test, calculating the total targeting error of the Synchrony system.

Methods: The CIRS dynamic phantom, which contains four fiducials, was scanned with 1.0 mm slices on a GE HiSpeed 4 slice helical CT scanner. Two separate treatment plans were constructed and four treatments were delivered to the phantom using Synchrony with these plans. All treatments delivered 30 Gy to the 42 cc ball lesion in the phantom in three fractions. The first two treatments delivered 30 Gy to the 70% isodose line with 69 nonzero beams. The average treatment time was 94 minutes. The last two treatments delivered 30 Gy to the 80% isodose line with only 34 nonzero beams and an average treatment time of 73.5 minutes. Approximately 12 hours after treatment, the Gafchromic film was analyzed to determine the total targeting error with the use of end-to-end testing software.

Results: The total targeting error reported by the software accounts for any error associated with imaging, treatment planning, the robot and/or linear accelerator, and the safety subsystem. The total targeting errors for the first two treatments were 0.58mm and 0.45mm and 0.744mm and 0.76mm for the second set of treatments. Rotations were disabled during all treatments.

Conclusion: Because CyberKnife radiosurgery can provide such tight margins around the tumor, very accurate QA methods must be applied to ensure that a moving tumor is contained within the treatment margins. Since the CIRS dynamic phantom allows for nonlinear motion, it is a more realistic method than using the traditional method with couch movements to test the positional accuracy of the Synchrony system.