AbstractID: 3297 Title: A dynamic phantom for 4-dimensional imaging and radiation therapy verification

Purpose: Current research is producing a variety of methods to model breathing motion in the abdomen and thoracic regions. Testing of these methods is hampered by the lack of a reproducible standard that reproduces complex, multidimensional motion. The purpose of this study was to create a 4D phantom that could be used for evaluation of breathing motion.

Method and Materials: A 4-dimensional (4D) stage capable of arbitrary multidimensional motion with speeds up to 10 cm/sec was constructed. The positioning system was developed using stepping motor-actuated linear slides (Velmex Inc.) capable of carrying a 10 kg water-equivalent phantom. A 4 axis motor controller (National Instruments) with onboard PID algorithms was used with an amplifier capable of 4 Amps per axis at 1.7 V (Primatics, Inc). Custom software was written to allow input trajectories as a text file of x, y, and z coordinates spaced 20 ms apart. A 3 Dimensional digitizing arm (Immersion Corporation) was physically connected to the system to monitor stage localization accuracy. The intended position and measured positions were compared over a series of points.

Results: The scanning system produced highly verifiable and reproducible trajectories for a variety of ellipses and modeled tumor trajectories. The system also produced very accurate and precise positioning using simple raster scanning patterns. The average error was 0.1397mm, where the published error for the digitizing arm is 0.3mm. The total cost to construct the phantom was less than $10,000.

Conclusion: The 4D phantom produces accurate positioning throughout the range of motion found in human tumors. It can provide a 'gold standard' for evaluating 4D CT, organ motion, and internal localization systems for both research and clinical applications. Further refinements, such as the addition of encoders for truly closed loop motion control, are ongoing.