Lung Material Phantom for Small Field Monte Carlo Dose Validation

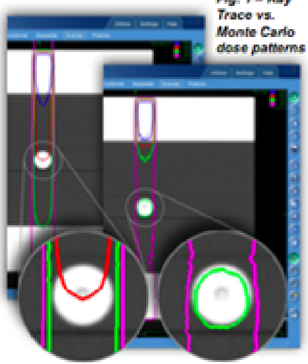
J McKay[1], I Das[2], C Cheng[3], J Xue[4], J Grimm[5], R Berg[1]

(1) Erlanger Medical Center, Chattanooga, TN, (2) Indiana University- School of Medicine, Indianapolis, IN, (3) Indiana University- School of Medicine, Bloomington, IN, (4) Cooper University Hospital, Camden, NJ, (5) Holy Redeemer Hospital, Meadowbrook, PA

Objective

Monte Carlo has the potential to be much more accurate than conventional effective path length algorithms, especially in a highly heterogeneous environment. Commissioning Monte Carlo beam data for clinical use within a treatment planning system (TPS) for Stereotactic Body Radiation Therapy (SBRT) should require validation both in homogeneous and in heterogeneous phantom materials. Compounding this task is the difficulty in accurately measuring small field sizes. This work outlines the use of a proprietary lung material phantom in conjunction with a new scintillation detector designed for small field measurement in order to verify the Monte Carlo dose calculated in the TPS.

Fig. 1 – Ray Trace vs. Monte Carlo dose patterns



The figure in the bottom left shows the 20mm cone calculated with Ray Trace and Monte Carlo. The green isodose line indicates that Monte Carlo appropriately predicts dose within the solid water insert, while Ray Trace appears to treat the entire phantom homogeneously.

Materials/Methods

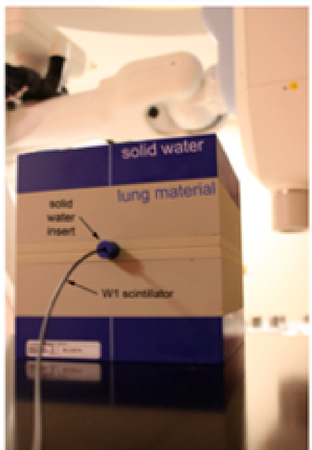


Fig. 2 – components of lung material phantom

The measurements were performed on a CyberKnife VSI. The Stereotactic Dose Verification Phantom (SDVP) from Standard Imaging (SI) was fitted with 12cm of lung material with a physical density of 0.28 g/cc.

The scintillating detector was placed in a 1.5 cm diameter water-equivalent insert, which was then placed in the SDVP lung phantom and CT scanned. Fiducials were embedded in both the lung material and insert for tracking purposes using 45 degree orthogonal kV imagers.

After dose cross-calibration with the SI A19 ion chamber in the basic SDVP water equivalent phantom, measurements were taken with the scintillator for all 12 cones (5mm – 60mm).

The new SI W1 pinpoint scintillator is nearly water equivalent but with careful window/leveling the 1mm diameter by 3mm long scintillating fiber was visible and was contoured in the MultiPlan TPS. The Monte Carlo calculations were executed with an uncertainty value of 0.5%.

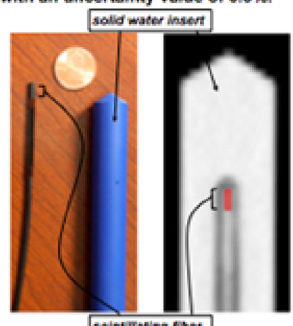
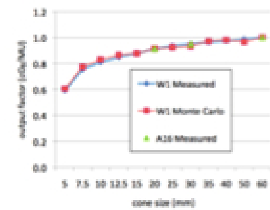


Fig. 3 – point of measurement of physical scintillator (left) and imaged scintillator within solid water insert (right)

Results

For cross-calibration to known larger field equilibrium conditions, the SI A16 ion chamber was used to re-measure the 20, 30, and 60mm cones, and the measured dose matched the Monte Carlo dose within 2% for the three collimator sizes. All 12 cones measured with the W1 scintillator matched the calculated Monte Carlo dose to within 3%.

Fig. 4 – measured vs. Monte Carlo output factors



Conclusions

The SDVP lung material inserts provide an acceptably heterogeneous environment that is well suited to testing the accuracy of Monte Carlo calculations. The W1 scintillator has an appropriately small sensitive area capable of measuring field sizes down to 5mm in diameter. The combined utilization of both pieces of equipment results in a clinically acceptable correlation of measured dose to the Monte Carlo dose calculated in the TPS for all cone sizes.