

Purpose: To determine whether the dose perturbations caused by implanted markers in or near the mobile tumors have significant impact on the dose distributions, particularly by creating hot or cold spots behind the markers.

Method and Materials: A preliminary dose-depth distribution measurement with 200 MeV protons has been performed at the Proton Medical Research Center of the University of Tsukuba. The effective-source size was approximately 4 cm, the source-to-surface distance (SSD) was 250 cm and the Spread Out Bragg Peak (SOBP) modulation range was 5 cm, between 15 cm and 20 cm depths. A cylindrical Gold marker with 0.3 cm length and 0.12 cm radius has been placed, both in horizontal mount and vertical mount, at 14 cm and 17 cm inside the water tank. The doses have been measured using a novel imaging plate technique. Analytical SOBP dose calculations have been performed in the $y = 0$ plane, using z depth integration steps of 0.04 cm and x cross-field lateral steps of 0.01 cm.

Results: Analytical calculations showed that the presence of the markers modify quite significantly the Central Axis (CAX) dose distributions of single Bragg peaks. However, this dose perturbation is washed out almost entirely when employing the SOBP technique using multiple modulated Bragg peaks. In such case, the CAX dose increases behind the markers by less than 1% and decreases by less than 3% at the distal end of the SOBP plateau. The experimental measurement of the CAX dose distribution did not observe a significant effect, which confirms the theoretical prediction.

Conclusions: This work indicates that it should be safe to use small Gold markers in the proton therapy of mobile tumors employing SOBP techniques. The investigation will be continued using various marker sizes and materials of clinical interest, different proton energies and an ionization chamber.