AbstractID: 13229 Title: Characterization of Cubic Spline Path Estimate for Quantitative Proton Stopping Power Reconstruction and Bragg Peak Location Prediction

Purpose: To characterize the cubic spline path (CSP) estimate for quantitative reconstruction of proton computed tomography (pCT) image, compared with those using the most-likely path (MLP) estimate and the real path.

Method and Materials: Monte Carlo simulation of proton projections onto a Shepp-Logan phantom was performed using the GEANT4 simulation toolkit. The real proton paths were recorded during the simulation. Entrance and exit information of each proton were stored and used for CSP and MLP estimation. A Bayesian inference-based probability map was generated to evaluate the relative probability of CSP and real path, which are compared with that of MLP. Inter-path distance between CSP and the real path was evaluated at different depths. Proton stopping power images were reconstructed using CSP, MLP, and the real path, respectively. The quantitative accuracy of the reconstructed images was evaluated. Integral depth dose and Bragg peak were predicted on the stopping power image reconstructed using CSP.

Results: CSP performs almost identically to the real path in terms of its relative probability. Specifically, probabilities of more than 80% of all CSP pixels fall within 90% of the MLP probability. 75% of the CSP pixels at maximum inter-distance to MLP are within 90% of MLP probability. The direct comparison between CSP and the simulated real path shows that 95% of the CSP pixels are within one pixel of the simulated real path. Reconstruction using the path estimates or the real path shows no significant difference in average stopping power or noise. Bragg peak location as predicted on images reconstructed using CSP agrees with that from simulation within 1 mm accuracy.

Conclusion: As verified from relative path probability distribution, inter-path distance distribution, and Bragg peak prediction, CSP as a proton path estimate is sufficient for quantitative pCT reconstruction at even very low imaging dose levels.