Purpose: Proton beams have finite range and a potential to deliver a more conformal dose to the treatment target while sparing surrounding healthy tissues. To fully take advantage of the dosimetric advantage of proton beams, accurate dose calculation and range determination, especially for heterogeneous tissue and small fields, are important. The purpose of this work is to study the dosimetric effects of tissue density change and small field size in proton therapy plans using Monte Carlo methods.

Methods: Using Monte Carlo code MCNPX 2.5.0, we simulated the proton dose distribution for the following cases: 1) a water phantom with heterogeneity inserts of various densities; 2) a water phantom using various beam sizes from 0.1, 0.25, 0.5, 2.0, 4.0 and 8.0 cm), 3) a phantom of low density (from 0.4 to 0.9 g/cm^3 with 0.1 g/cm^3 density interval) with proton beam energy at 150 MeV and 250 MeV respectively.

Results: Proton penetration range and dose distributions changed significantly with inserts of various densities. Proton Bragg curves degraded when small beam with beam radius at several mm range. Proton Bragg curves degraded also when high energy proton beam irradiated to low density material. For high energy proton beam and small size beam, the Bragg curves degraded more significantly. For high energy proton beam and low density tissue, the Bragg curves degraded more significantly. Comparison of dose distributions between Monte Carlo simulation and treatment planning system calculations is underway.

Conclusion: Accurate proton dose calculations are challenging in proton treatment planning for heterogeneous tissues. For low density tissue and small field size beams, proton Bragg curves degrades significantly and needs to take into account in proton treatment planning. By simulating detailed particle transport and energy deposition, Monte Carlo simulations provide accurate dose calculations in inhomogeneous tissues and for small field size beams.