AbstractID: 13996 Title: A comparison of protons versus gamma X-rays in producing patient radiographs: a Monte Carlo study

Purpose: To assess the imaging properties of proton radiography against X-ray radiography for both a phantom and an actual patient lung cancer case using Monte Carlo simulations.

Methods and Materials: The GEANT4 Monte Carlo toolkit was used to simulate radiographs with a pure 230-MeV proton beam as well as a pure 100-keV X-ray beam both with similar dose equivalent. For those simulations, a phantom was designed using a water cube in which different tissues (low density lung, high density lung, adipose, soft tissue, muscle, cartilage, bone) were implemented, each within 10 cylinders of different sizes. The simulations were run for different phantom and tissue thicknesses. For each material, spatial resolution, signal-to-noise ratio (SNR), and contrast-to-noise ratio (CNR) were compared for the two modalities. Using an actual CT, a proton radiograph of a lung cancer patient was then simulated and compared to the actual portal X-ray image. The contrast of soft-to-soft tissue (S2S), soft-to-bone tissue (S2B), and bone-to-bone (B2B) were evaluated for both radiographs.

Results: X-ray radiographs present a 1-mm spatial resolution; proton radiographs show a larger 3-mm spatial resolution due to multiple coulomb scattering and halo effect of the proton beam. SNR and CNR of a radiograph using X-rays stay constant versus tissue area size (20*dB*). For a radiograph using protons, both SNR and CNR increase from 2*dB* to 30*dB.* Proton radiographs present much better S2S and B2B contrasts, but poorer S2B contrasts than X-ray radiographs.

Conclusion: Preliminary results show that proton radiography presents lower spatial resolution than X-ray radiography. Conversely, proton radiography is more sensitive to tissue density variations, it offers better soft-to-soft and bone-to-bone tissue contrasts, hence allowing for sharper edge detection and better tumor localization for specific tumor cases such as lung cancer. Furthermore, proton radiography would significantly reduce the dose to the patient.