Purpose: To evaluate the feasibility of image guided proton radiotherapy (IGPT) using direct or indirect tumor tracking (tumor itself or fiducial markers) with on-line proton radiography imaging using Monte Carlo simulations.

Methods and Materials: This study considered two lung cancer patients and one liver cancer patient. For each patient, 230- and 330-MeV proton pencil beams were simulated through each of the ten CT phases of their breathing cycle using the GEANT4 Monte Carlo toolkit. Energy, position and direction cosines of each particle were recorded in front and behind the patient, and proton radiographs were reconstructed using a novel algorithm. These radiographs correspond to on-line images that could be acquired during treatment by quickly changing the proton beam energy. Image sequences were finally generated using the proton radiographs in order to reproduce the breathing cycle of each patient.

Results: Lung tumor radiographs, with high spatial resolution (~1.2-1.6mm), show great contrast-to-noise ratio between the tumor and its surrounding tissues, thence allowing for clear visualization of the tumor edges. Conversely, the liver tumor's density is very similar to its background, and is therefore hard to discern; only the high Z fiducial markers are visible. For both lung cancer patients, direct tumor motion is clearly observed, and comparable to 4DCT data (~0.5-1cm), hence allowing for on-line tumor tracking during proton radiotherapy. The results also show that indirect tumor tracking using the fiducial markers would be a viable technique for other tumor cases such as liver cancer.

Conclusion: It was shown that IGPT using tumor tracking would be feasible using proton radiography by quickly changing the proton beam energy during treatment. The implementation of such technology could further lead to adaptive proton radiotherapy, and further improve irradiation treatments. Due to their intrinsic better imaging properties, carbon ion beam are also under investigation.