Range modulated proton radiographic imaging using pencil beams from the spot scanning MEVION proton therapy system

Chaz Pelas*, Nesreen Alsbou+, Salahuddin Ahmad*, Imad Ali*

*Department of Radiation Oncology, University of Oklahoma Health Sciences Center, Oklahoma City, OK

+Department of Engineering and Physics, University of Central Oklahoma, Edmond, OK

Introduction: On board imaging with kV photon beams have become a vital tool for patient setup and tumor localization using image guided radiation therapy for the treatment of cancer patients. However, this is achieved often by mounting kV photon sources and imaging detectors in the treatment vaults or on the photon and proton radiation therapy machines. Particularly with bulky proton machines, this may be hindered by the lack of space, difficulties in integrations with the gantry, collisions risks. Furthermore, photon radiographic or CT images provide limited image quality with large uncertainties associated with patient setup and tumor localization in image guided proton therapy. The intensity or CT-number values for photon images represent electron densities and thus they do not provide accurate material density, z-composition and proton range values. The goal of this study it to evaluate proton radiographic imaging using the spot scanning MEVION proton therapy system and investigate the use of proton on-board imaging as an alternative for on-board kV photon imaging systems.

Methods: Radiographic proton images of different phantoms were acquired using pencil beams from the spot scanning MEVION proton therapy machine. A high energy of nearly 230 MeV single layer proton 18x18 cm^2 beams with 3.5 mm diameter spots and 2.5mm spot spacing were used to irradiate the phantoms that included different patters to evaluate noise, uniformity, linearity, contrast and position resolutions of the proton radiographs. The proton radiographs were acquired with high sensitivity and spatial resolution phosphorous detector plates used in computed radiography. The detectors were inserted at the bottom of solid water phantoms with different thicknesses were ranging from 0-35cm. The image quality of the proton radiographs was evaluated using different proton dose levels (0.1-2.0MU), ranges (1-32cm) and modulation (2-25cm).

Results: The CR plates provided a detector for proton radiographic imaging with high sensitivity and signal to noise (Fig.1). The range modulation of one energy layer spot scanning proton beam provided higher contrast images by setting the detector at high dose gradient of the Bragg peak (Fig.1a). Proton radiographic with good image quality were obtained with low imaging dose level of sub mGy using 0.2 MU per spot of the pencil proton beam (Fig.1b). Lower imaging dose was achieved by using proton beams with the highest proton energy of nearly 230 MeV that crossed through the phantom and locating the Bragg peak on the level of the detector. The noise and contrast resolution of proton radiograph improved with increasing dose (Fig.1c). The image quality improved with increasing depth of the quality assurance phantom because of shorter scatter range between the imaging objects and the detector. The increased separation between the imaging object and the detector decrease image quality because of increased scatter thickness of the proton beam before detection by the CR plates (Fig.1d).

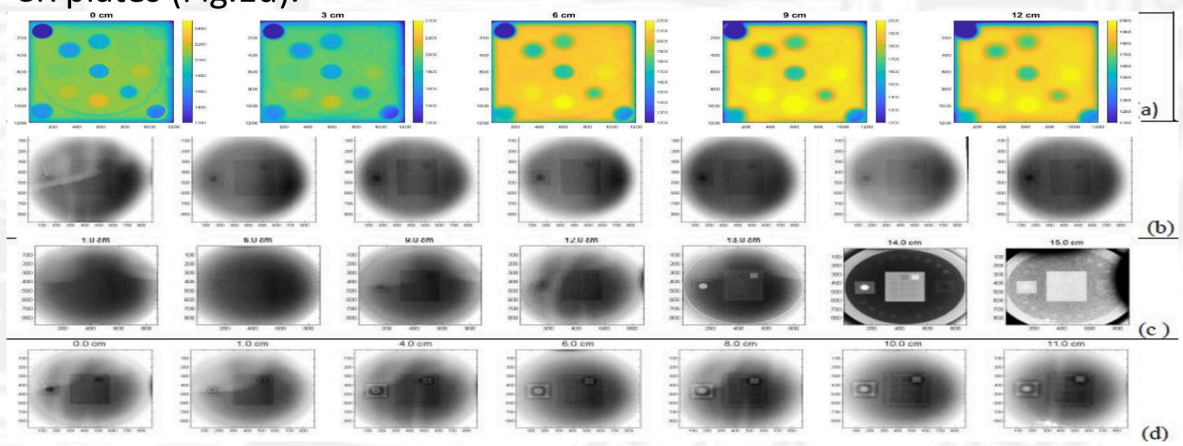

Figure 1: (a) Proton radiograph of CIRS material phantom at different depths in phantom, (b) Proton radiographic images of the Leeds phantom for different MUS, (c) at different depths in phantom (d) different separation between the Leeds phantom and CR-plate

Conclusion: The use of range modulated proton pencil beams produced superior soft-tissue radiographic images with lower imaging doses in comparison with photon radiographic images. This method of proton radiographic imaging using direct therapeutic beams from proton radiotherapy machines may provide an alternative to on-board imaging with photon beams.

E-Mail: imad-ali@ouhsc.edu

The University of Oklahoma HEALTH SCIENCES CENTER

Peggy and Charles STEPHENSON CANCER CENTER at The University of Oklahoma