MODELING AND OPTIMIZATION OF A TIME-RESOLVED PROTON RADIOGRAPHIC IMAGING SYSTEM FOR PROTON CANCER TREATMENT

by

Bin Han

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Approved by the
Examining Committee:

_____

Dr. X. George Xu, Thesis Adviser

_____

Dr. George TY Chen, Member

_____

Dr. Yaron Danon, Member

_____

Dr. Li Liu, Member

_____

Dr. Jim Napolitano, Member

_____

Dr. Peter F. Caracappa, Member

Rensselaer Polytechnic Institute
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ABSTRACT

This dissertation describes a research project to test the clinical utility of a time-resolved proton radiographic (TRPR) imaging system by performing comprehensive Monte Carlo simulations of a physical device coupled with realistic lung cancer patient anatomy defined by 4DCT for proton therapy. A time-resolved proton radiographic imaging system was modeled through Monte Carlo simulations. A particle-tracking feature was employed to evaluate the performance of the proton imaging system, especially in its ability to visualize and quantify proton range variations during respiration. The Most Likely Path (MLP) algorithm was developed to approximate the multiple Coulomb scattering paths of protons for the purpose of image reconstruction. Spatial resolution of ~ 1 mm and range resolution of 1.3% of the total range were achieved using the MLP algorithm. Time-resolved proton radiographs of five patient cases were reconstructed to track tumor motion and to calculate water equivalent length variations. By comparing with direct 4DCT measurement, the accuracy of tumor tracking was found to be better than 2 mm in five patient cases. Utilizing tumor tracking information to reduce margins to the planning target volume, a gated treatment plan was compared with un-gated treatment plan. The equivalent uniform dose (EUD) and the normal tissue complication probability (NTCP) were used to quantify the gain in the quality of treatments. The EUD of the OARs was found to be reduced up to 11% and the corresponding NTCP of organs at risk (OARs) was found to be reduced up to 16.5%. These results suggest that, with image guidance by proton radiography, dose to OARs can be reduced and the corresponding NTCPs can be significantly reduced. The study concludes that the proton imaging system can accurately track the motion of the tumor and detect the WEL variations, leading to potential gains in using image-guided proton radiography for lung cancer treatments.