Potential Clinical Impact of Dosimetric Uncertainties in Proton Therapy

Innovation/Impact: The analytical, pencil beam algorithms are used widely for proton treatment planning in today’s clinical practice. The aim of this study is the assessment of potential clinical impact of dosimetric uncertainties in highly heterogeneous areas of the thorax.

Introduction: The accuracy of dose computation within the lungs depends strongly on the performance of the calculation algorithm in regions of strong tissue inhomogeneities with large density variations. Lung cancers are surrounded by a low density aerated pulmonary parenchyma and bony anatomy of the thorax resulting in very high heterogeneities in the particle beam path used for treatment. The additional scattering caused by these heterogeneities is not modeled adequately by most treatment planning systems (TPS) used in clinical practice. In this study we use a detailed Monte Carlo model of the passive scattering proton therapy (PSPT) beam line together with a computed tomography (CT) based model of the patient anatomy to investigate the heterogeneity induced dosimetric uncertainties in PSPT treatment planning and correlate the regions of underdosed target with the location of tumor recurrence in 8 patients treated for lung cancer.

Methods: A cohort of 8 patients with local (in field) recurrences, originally treated for lung cancer at our institution, was selected for this study. CT scans and treatment plans were used to assemble the input files for the Monte Carlo (MC) code MCNPX. The MC results were compared to the dose computed by the clinical treatment planning system (TPS). The area of the recurrence was contoured on the follow-up PET/CT study for each of the patients and registered to the planning CT.

Results and Discussion: While there is acceptable agreement between the TPS and the Monte Carlo dose in homogeneous regions, there are noticeable differences caused by heterogeneities. The regions of largest differences are the points around and beyond the distal edge and points around the lateral penumbra and in several patients the target has received lower then the prescribed dose (see DVH in Figure 1). The area of the recurrence correlates well with the MC predicted underdosed area of the target.

Figure 1. A dose volume histogram (DVH) comparison between Eclipse (squares) and MCNPX (triangles) for the PTV (cyan), esophagus (green), total lung T30 (blue), heart (purple), and spinal cord (red). The distal edge degradation in Monte Carlo doses results in 5% less dose to the patient treatment volume.