INVESTIGATION OF GEOMETRIC UNCERTAINTY INTRODUCED DOSIMETRIC VARIATION IN INTENSITY MODULATED PROTON THERAPY (IMPT) AND ITS INTERVENTION

Miao Zhang

Under the supervision of Professor Thomas Rock Mackie

At the University of Wisconsin-Madison

The intensity modulated proton therapy (IMPT) can generate plans with reduced normal tissue toxicity and increased target dose conformity. However, geometric uncertainty associated with the treatment process could introduce large dose variations between the delivered dose distribution and the planned. There are three common types of geometric uncertainty: setup uncertainty, inter-, and intra-fractional organ motion. This thesis work will investigate setup uncertainty and inter-fractional organ motion introduced dose variation and find solutions to minimize such variations.

A proton treatment planning system was developed by using Geant4 Monte Carlo toolbox as the dose calculation engine. The setup uncertainty was studied on the head and neck cancer site. Plan delivery simulation shown large dose variation occurred even with small amount of setup uncertainty. Two intervention strategies were investigated: (i) different proton pencil beam sizes, and (ii) the energy margin. By varying proton pencil beam size, we found the larger the beam size the less the dose variation, nevertheless the higher normal tissue dose. The energy margin is a planning strategy incorporating the possible motion effect into the planning stage by assigning proton pencil beams an energy value large enough to guarantee protons will travel to where they are planned. The energy margin solution was tested to be effective to minimize the dose variation in the distal edge tracking (DET) based IMPT.

The inter-fractional motion was studied by looking at the daily prostate shift in the prostate cancer treatment. Delivery simulation for prostate cancer IMPT shown large dose variation would result even if the image guidance (IG) technique was used to realign the prostate back to its original location on the planning CT. A novel on-line adaptive image guided IMPT (A-IG-IMPT) technique was proposed to minimize the dose variation. By updating the energy value for individual proton pencil beam from the on-line image, without re-optimization the planned dose distribution can be restored for the DET-based IMPT. But the improvement in the spot scanning based IMPT plans is not significant.