Phantom based evaluation of CT to CBCT image registration for proton therapy dose recalculation.

Abstract:

The ability to perform dose recalculation on the anatomy of the day is important in the context of adaptive proton therapy. The objective of this study was to investigate the use of deformable image registration (DIR) and cone beam CT (CBCT) imaging to generate the daily stopping power distribution of the patient. We investigated the deformation of the planning CT scan (pCT) onto daily CBCT images to generate a virtual CT (vCT) using a deformable phantom designed for the head and neck (H&N) region. The phantom was imaged at a planning CT scanner in planning configuration, yielding a pCT and in deformed, treatment day configuration, yielding a reference CT (refCT). The treatment day configuration was additionally scanned at a CBCT scanner. A Morphons DIR algorithm was used to generate a vCT. The accuracy of the vCT was evaluated by comparison to the refCT in terms of corresponding features as identified by an adaptive scale invariant feature transform (aSIFT) algorithm. Additionally, the vCT CT numbers were compared to those of the refCT using both profiles and regions of interest and the volumes and overlap (DICE coefficients) of various phantom structures were compared. The water equivalent thickness (WET) of the
vCT, refCT and pCT were also compared to evaluate proton range differences. Proton dose distributions from the same initial fluence were calculated on the refCT, vCT and pCT and compared in terms of proton range. The method was tested on a clinical dataset using a replanning CT scan acquired close in time to a CBCT scan as reference using the WET evaluation. Results from the aSIFT investigation suggest a deformation accuracy of 2-3 mm. The use of the Morphon algorithm did not distort CT number intensity in uniform regions and WET differences between vCT and refCT were of the order of 2% of the proton range. This result was confirmed by proton dose calculations. The patient results were consistent with phantom observations. In conclusion, our phantom study suggests the vCT approach is adequate for proton dose recalculation on the basis of CBCT imaging.