

Purpose:To quantify radiological pathlength variations to fiducials in proton beam treatment of liver tumors.

Methods:Serial 4DCT scans of 10 patients with primary liver tumors were analyzed. The water equivalent pathlength (WEL) was quantified from entrance surface to radio-opaque clips 1) for different respiratory phases 2) for serial 4DCT scans 3) for each treatment angle (typically AP or PA and a single lateral field) 4) for different immobilization methods. WEL measurements to fiducials is well defined, Vs range to the distal surface of a deformably registered target, but results in fewer measurements (typically 3 clips). A statistical analysis of the mean range variations and spread is performed.

Results:AP range at T50 to clips is reproducible from day to day with a mean variation of 1.8mm, SD 1.3mm. Lateral field range variations from day to day at T50 were 1.3mm SD 2.6mm. Range variations at inhale were more variable, with AP T00 mean WEL variation of 3.5mm SD 4.4mm and lateral mean variations of 3.2mm SD 1.7mm. An 8mm lateral range variation was observed in one patient. Range variation during respiration was also studied. The mean AP and lateral range variation was 3mm SD 2.4 and 4.1 mm SD 2.1mm. A 13mm variation was observed in one patient, and attributed to clip motion during respiration without significant change in the entrance surface.

Conclusions:Several sources of range uncertainty are routinely included in treatment range determination for proton therapy. These include uncertainties in CT HU numbers, relative stopping powers of tissues, compensator misalignment, etc. Organ motion is explicitly taken into account in the aperture plane, but not in the beam direction. This study elucidates the magnitude and causes of range variations to well defined points. Inclusion of this uncertainty should be considered in determining treatment range.