Cone Beam CT Acquisition Simultaneous with VMAT Delivery to Monitor Intrafraction Motion during SBRT of Lung Cancer Patients

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Purpose/Objective(s): Even with image guidance, intra-fraction baseline shifts can lead to geometrical misses, especially in hypofractionated regimes. Marker-based methods allow high speed monitoring, marker implantation in lung is, however, not without risk. The purpose of this study was therefore to devise and apply a method for marker-less intrafraction monitoring of the respiratory tumor trajectory during rotational SBRT (VMAT) by kV imaging simultaneous with MV delivery.

Materials/Methods: A modified Elekta Synergy system (XVI4.6) was used that allows simultaneous 3D and 4D cone beam CT acquisition during VMAT. Recently, the hardware was further modified to allow alternating image acquisition with the kV panel with and without X-ray exposure. This method of image acquisition allows accurate estimation and correction ofMV scatter onto the kV panel. Intrafraction monitoring method was used since September 2010 for 37 early stage lung cancer treated with 3 fractions of 18 Gy, typically using two 200 degree arcs (140 s delivery time each). Individualized treatments margins were used. Cone beam CT scans were acquired during both VMAT arcs. The first scan was used to monitor and correct potential intra-fraction motion. The second scan serves as continuous quality assurance step of our SBRT procedure which uses limited immobilization. The latter scan replaces our previously used post-treatment scan. The obtained 4D scans were analyzed by means of local image registration of the tumor region.

Results: Scattered MV radiation onto the kV panel caused severe reduction of image contrast, affecting the reliability of bone registration, as well as additive noise. However, the contrast between lung and tumor and lung and diaphragm remained adequate for automatic verification of the tumor position as well as 4D scan reconstruction. The novel scatter correction method fully recovered the scan contrast without introducing extra noise. The respiratory motion pattern analyzed from the 4D-CBCT scans was stable during treatment. Observed baseline shifts during delivery were generally small. However, in 5 of 37 patients, baseline shifts exceeding 4 mm vector length were observed in at least one fraction during the first arc, which were subsequently corrected for the second arc. In the second arc, the mean vector length of baseline shifts was mostly less than 2 mm. However, in two fractions the shift in the second arc was close to the typical margin of 7 mm. This finding suggests that it remains useful to develop more real-time monitoring, e.g., by analyzing individual projection images rather than reconstructed 4D-CBCT scans.

Conclusions: Intrafraction kV cone beam CT allows efficient detection of baseline shifts in the tumor trajectory.