Does mid-treatment CBCT-guided patient repositioning during lung VMAT impact target coverage?

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ABSTRACT

Purpose: The objectives of this study are to (1) quantify intrafraction motion (IFM) during lung volumetric-modulated arc therapy (VMAT) and (2) evaluate the impact of mid-treatment patient repositioning after cone beam computed tomography (CBCT) acquisition upon target coverage.

Method: This analysis included lung tumors treated with VMAT between April 2012 and June 2015 with 50-60 Gy in 3-5 fractions. Treatment planning consisted of a four-dimensional (4D) CT scan from which an internal target volume (ITV) delineation was performed. A 5 mm margin was added in all directions to obtain the final planning target volume (PTV). Treatment sessions were performed in supine position with a customized dual vacuum immobilization device (BodyFIX, Elekta, Stockholm, Sweden). All patients underwent pre and mid-treatment CBCTs to ensure proper repositioning. Following each CBCT, a two-step rigid registration was performed by an experienced radiation oncologist according to the planning CT, taking into account organs at risk (OARs). Bone shift was first assessed with a registration of the vertebrae adjacent to the lesion. Then, tumor shift was isolated with a soft tissue registration by aligning targets. IFM, combining bone and tumor shifts, was defined as the target displacement from pre to mid-treatment CBCT.
acquisition and was quantified in terms of anterior-posterior (AP), cranio-caudal (CC) and medio-lateral (ML) amplitudes as well as three-dimensional (3D) vector. For patients with IFM ≥ 5 mm, a post hoc dose calculation analysis was performed to assess target coverage impacts of mid-treatment CBCT-guided repositioning.

**Results:** Ninety-seven patients, totalizing 367 fractions, were included. Mean (±SD) overall treatment time was 53:02 ± 13:08 min. Mean time from pre to mid-treatment CBCT acquisition was 22:58 ± 5:33 min. Mean time to perform mid-treatment CBCT scan acquisition, registrations and couch repositioning was 15:49 ± 4:14 min. Mean IFM amplitudes were 0.9 ± 1.2 mm, 0.6 ± 1.0 mm and 0.6 ± 0.8 mm in the AP, CC and ML respectively. IFM was < 3 mm and < 5 mm in all directions in respectively 315/367 (86%) and 358/367 (98%) fractions. Mean 3D IFM vector was 1.5 ± 1.4 mm (max = 8.1 mm) and was < 5 mm in 354/367 (96%). Among the 13 fractions with IFM vector ≥ 5 mm, 11/13 (85%) were dominantly induced by a tumor shift. For all these fractions, dose calculation analysis of worst-case scenario indicates that ITV coverage would have remained ≥ 95% without mid-treatment CBCT-guided patient repositioning.

**Conclusion:** For 96% of fractions in patients immobilized with a customized BodyFIX dual vacuum bag, the IFM vector was within the 5 mm PTV margin used. Mid-treatment CBCT-guided couch repositioning did not significantly impact ITV coverage and prolonged treatment duration. Mid-treatment imaging may remain pertinent for selected patients with strict OAR dose constraints.

**Keywords:** volumetric-modulated arc therapy, intrafraction motion, tumor shift, bone shift, target coverage, cone beam computed tomography