Accuracy of Fiducial Marker Localization Using Axial and Helical CT, Cone-Beam CT and kV Imaging

Introduction: Image-guided radiotherapy based on CT imaging has become a vital tool for patient positioning and tumor localization. Patient setup with image guidance using seed markers is considered one of the interesting approaches where the markers have superior visibility in CT and kV on-board imaging techniques. The purpose of this study was to determine localization errors of fiducial markers using axial (ACT) and helical CT (HCT), cone beam CT (CBCT) and kV imaging.

Methods: A thorax phantom containing markers of various sizes (2.5, 5, 10, 20mm) was imaged using ACT, HCT, CBCT and kV imaging. The phantom was imaged with and without motion (15mm amplitude, 15 cycles/min). CT images were reconstructed at 0.625, 1.25, 2.5 and 5mm thickness. Marker location and length were measured using axial and coronal imaging.

Results: The measured marker size increased almost linearly with increased slice thickness used in CT reconstruction with ACT for the stationary phantom (Fig. 1a). In HCT, the marker size varied non-linearly with increase in slice thickness (Fig. 1a). Motion of the phantom induced further blurring and shifts of the center of the marker with different sizes. The 10 mm marker was elongated up to 13.5 mm and 16.2 mm in the ACT and HCT, respectively. The markers were elongated up to nearly 26 mm using axial and helical scanning modes by phantom motion (Fig. 1a). The displacement of maker center was more prominent in the HCT with a shift up to 2 mm due to slice thickness for stationary phantom (Fig. 1b). The marker center was displaced by up to 18 and 22 mm using ACT and HCT, respectively, which was even higher than 15 mm motion amplitude (Fig. 1b). KV imaging produced the sharpest marker image with the least difference between actual and measured marker sizes.

Conclusion: Increase in slice thickness enlarged the apparent marker size and displaced the maker center in ACT and HCT. Motion led to further enlargement in the marker size and displacement of maker center that depended on the motion amplitude. These effects should be considered in CT-based image-guided radiation therapy to ensure accurate tumor localization and patient positioning with implanted markers.

Figure 1: (a) Variation of marker size with slice thickness for various scanning modes. (b) Marker position with slice thickness for different scanning modes.