Reconstructed Volume Loss on Cone-beam Computed Tomography Images of Moving Targets

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Abstract

The accurate volumetric estimation of structures during organ motion forms the prerequisite basis of using cone-beam computed tomography (CBCT) images for future re-planning purposes. This study evaluated the difference in the reconstructed volume of moving phantoms between cone-beam computed tomography (CBCT) on linear accelerator and fan-beam CT (FBCT) from simulator, under different moving frequencies and amplitudes. Phantom images were separately acquired by FBCT and CBCT. Three acrylic ball phantoms with diameters of 5.1 cm, 9.9 cm, and 12.2 cm, respectively, were used for static and moving experiments. CBCT and FBCT images were imported to a treatment planning system to compare the reconstructed volumes. The imaging adjustment program of CBCT was done to modify CT numbers by transforming the functions to relative electron density. To simulate respiratory movement, the phantoms were moved longitudinally with amplitudes of 12.5, 15, and 17.5 mm, and frequencies of 8, 10, and 12 oscillations per minute, respectively. With auto-contouring technique and imaging adjustment program, the differences in reconstructed volume of 3 static phantoms (small, medium, large) between FBCT and CBCT were –6.20%, –2.47%, and –2.19%, respectively. The average volume losses of different-sized moving phantoms were significantly different, at 56.6±7.5%, 29.0±3.7%, 19.3±2.5%, respectively (all $p < 0.05$). With large phantom, the average volume losses under different frequencies significantly increased as the amplitude became larger, with 16.5±0.8% for 12.5 mm, 19.4±0.7% for 15 mm, and 22.1±0.6% for 17.5 mm (all $p < 0.05$). In contrast, the average volume losses did not differ between the 3 frequencies, with 19.7±2.7%, 19.8±2.9%, and 18.5±2.9%, respectively (all $p > 0.05$). The similar significant impact of amplitude but not frequency on volume loss was also shown in medium and small phantoms. Moving phantoms were associated with the reconstructed volume losses on CBCT, with more losses for the smaller phantom. The increased amplitude, but not frequency, was associated with greater volume losses.

Keywords: Fan-beam computed tomography (FBCT), Cone-beam computed tomography (CBCT), Volume, Moving, Phantom

1. Introduction

With advanced technology such as three-dimensional conformal radiotherapy (3DCRT) and intensity-modulated radiation therapy (IMRT), the dose escalation and conformity have been improved to enhance tumor control and to reduce normal tissue toxicity. The better dose conformity demands more accurate treatment delivery. Kilo-voltage cone-beam computed tomography (CBCT), integrated into the linear accelerator as a tool for image guided radiation therapy, was developed to acquire on-line volumetric and anatomical images [1]. The CBCT images are compared with the reconstructed radiograph from original treatment plan for the most accurate position setup [2-5].

The multi-purpose application of CBCT depends on the image quality [6,7]. However, CBCT on the heavy gantry has more scattering artifacts from the larger longitudinal field of view (FOV), and is limited in its scanning speed for the moving targets and organs. As compared to less than one second of scanning time for single rotation by conventional fan-beam CT (FBCT), the *International Electrotechnical Commission* regulates the minimum scanning time of 60 seconds per rotation by CBCT. The imaging artifact and distortion from the moving structures, especially respiration-induced organ motion, are inevitable when acquiring CBCT

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