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PHYSICS CONTRIBUTION

DIGITAL TOMOSYNTHESIS FOR RESPIRATORY GATED LIVER TREATMENT: CLINICAL FEASIBILITY FOR DAILY IMAGE GUIDANCE

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Purpose: Breath-hold (BH) treatment minimizes internal target volumes (ITV) when treating sites prone to motion. Digital tomosynthesis (DTS) imaging has advantages over cone-beam CT (CBCT) for BH imaging: BH-DTS scan can be completed during a single breath-hold, whereas BH-CBCT is usually acquired by parsing the gantry rotation into multiple BH segments. This study evaluates the localization accuracy of DTS for BH treatment of liver tumors.

Methods: Both planning CT and on-board DTS/CBCT images were acquired under BH, using the planning CT BH window as reference. Onboard imaging data sets included two independent DTS orientations (coronal and sagittal), and CBCT images. Soft tissue target positioning was measured by each imaging modality and translated into couch shifts. Performance of the two DTS orientations was evaluated by comparing target positioning with the CBCT benchmark, determined by two observers.

Results: Image data sets were collected from thirty-eight treatment fractions (14 patients). Mean differences between the two DTS methods and the CBCT method were <1 mm in all directions (except the lateral direction with sagittal-DTS: 1.2 mm); the standard deviation was in the range of 2.1–3.5 mm for all techniques. The Pearson correlation showed good interobserver agreement for the coronal-DTS (0.72–0.78). The interobserver agreement for the sagittal-DTS was good for the in-plane directions (0.70–0.82), but poor in the out-of-plane direction (lateral, 0.26).

Conclusions: BH-DTS may be a simpler alternative to BH-CBCT for onboard soft tissue localization of the liver, although the precision of DTS localization appears to be somewhat lower because of the presence of subtle out-of-plane blur. © 2011 Elsevier Inc.

Digital tomosynthesis, Image guidance, Respiratory motion, Breath hold, liver.

INTRODUCTION

One of the challenges in irradiating sites such as the liver is organ motion. Studies have shown that liver motion associated with breathing can be several centimeters (1–5). To minimize the motion, treatment using abdominal compression, under deep inspiration breath-hold (BH) or active breathing control (ABC) has been used (6–16). These motion-management techniques can reduce large planning target volumes required to account for liver motion, allowing higher doses to be delivered without increasing normal liver toxicity (9, 17).

The reproducibility of organ position using ABC or BH has been studied for lung and liver cancer patients (7, 10, 11, 18). Dawson *et al.* (7) reported 2.5-mm intrafraction reproducibility and 4.4-mm interfraction reproducibility of liver position relative to the vertebral bodies for six patients using daily orthogonal kilovoltage (kV) imaging. Eccles *et al.* (18) reported the interfraction reproducibility ranges from 1.5 to 7.7 mm in the superior–inferior direction, with average difference of diaphragm positions relative to vertebral body position per patient in the range of 0.1–12.0 mm. Kimura *et al.* (11) also found that the BH reproducibility was 4.0 ± 3.5 mm (intrafraction) and 5.1 ± 4.8 mm at the end-inspiration phase (interfraction). Similarly, Kim *et al.* (10) found the standard deviation of diaphragmatic position for BH ranged from 0.13 to 2.57 mm, with an average of 0.97 mm. These findings indicate a change in diaphragm position from day to day despite using ABC or BH in the same planned position. Therefore, quick daily imaging is preferred to verify target position before treatment (6, 17, 19).

For ABC or deep-inspiration BH treatment, the ideal localization imaging technology should have fast acquisition (*i.e.,* within about 20 s or single BH equivalent) and provide sufficient three-dimensional (3D) visualization of soft tissues.

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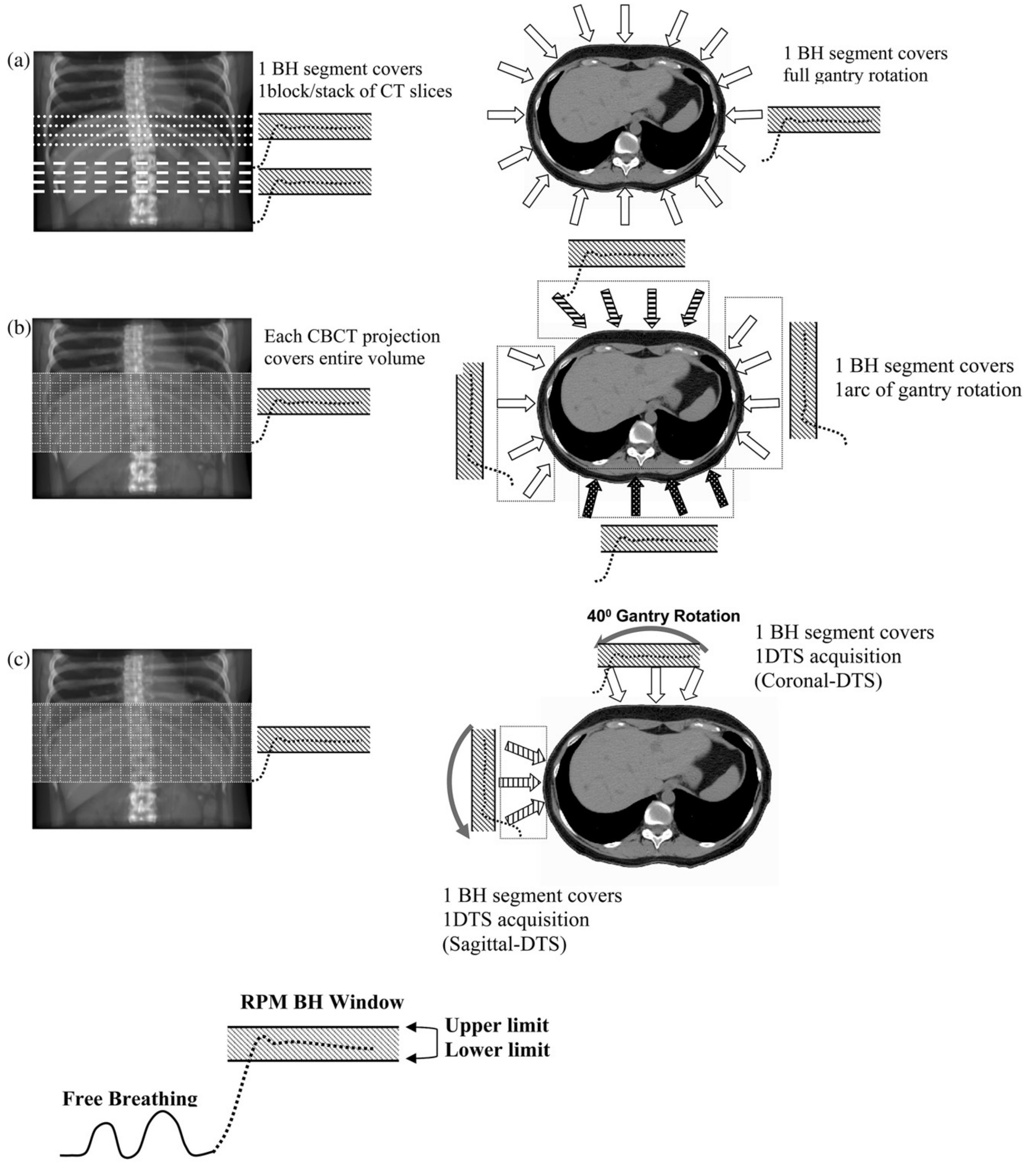

Fig. 1. Distribution of the multiple breath-hold (BH) segments over the imaging acquisition geometry. The BH window is monitored via the respiration monitoring (RPM) system (Varian Medical Systems, Palo Alto, CA) and is shown separately. The shadowed boxes indicate the RPM BH windows that are used to monitor each BH level. The reference BH windows were set at CT simulation and used for all treatment and imaging. During each BH session, it is required that the BH signal remains within the predetermined upper and lower limits. (a) CT geometry. One BH segment allows the scan of 1 block/stack of CT slices. Each BH segment covers a subset of CT slices, and multiple BH segments are distributed in the superior to inferior direction. (b) CBCT geometry. Each BH segment covers a subset of projection images or gantry rotations. Each projection images the entire scan volume. Multiple BH segments are distributed along the gantry rotation direction. (c) Digital tomosynthesis (DTS) geometry (coronal and sagittal). Only a single BH is needed for one BH-DTS acquisition. Each projection images the entire scan volume. Multiple BH segments are required to obtain different DTS views and orientations. The coronal-DTS and sagittal-DTS shown in the figure are considered two independent DTS imaging data sets.