Investigating Stability and Reproducibility of Deep Inspiration Breath Hold for Liver Stereotactic Body

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Introduction

Deep inspiration breath hold (DIBH) is a technique that is routinely used treatment of many cancers in therapy. Of grave concern is when the technique is used in the modalities that require the highest level of precision, stereotactic body radiation therapy (SBRT). The DIBH technique is used daily for liver SBRT at UT Southwestern Medical Center using the Active Breathing Coordinator system (ABC, Elekta AB), however it's accuracy and reproducibility have been suspected. In the work, we show preliminary data from a pilot study investigating the variation in diaphragm position both during and between breath holds. Additionally, we examine the possible correlation between detected surface guided radiation therapy (SGRT, AlignRT, Vision RT, Ltd.) abdomen surface motion amplitude and diaphragm position.

Materials & Methods

Stability and reproducibility of DIBH was quantified by investigating the diaphragm position of a cohort of seven patients undergoing liver SBRT. We developed a DRR based approach to quantify diaphragm position. In the DRR approach, the variation in diaphragm position was extracted from CBCT projection data by comparing projections to the corresponding DRRs from the planning CT. On each projection image, the diaphragm/lung edge was enhanced by vertical pixel shifting, subtraction and filtering. Each row of the edge-enhanced image was then integrated and the required shift to align the projection to the DRR was recorded as the diaphragm position variation. Mean diaphragm position variation between (inter-)DIBH was denoted as reproducibility and standard deviation of diaphragm position during (intra-)DIBH as stability. Finally, for a subset of the patients, the recorded abdomen surface amplitude was captured with AlignRT system to assess for correlation between diaphragm motion and surface variation. Figure 1 shows the variation in diaphragm position between two breath holds using the Amsterdam-Shroud method. This served as a validation for the DRR based approach, which was favored due to the removal of changes in diaphragm magnification during the rotation (since isocenter is typically location inferior to the diaphragm, Figure 1).

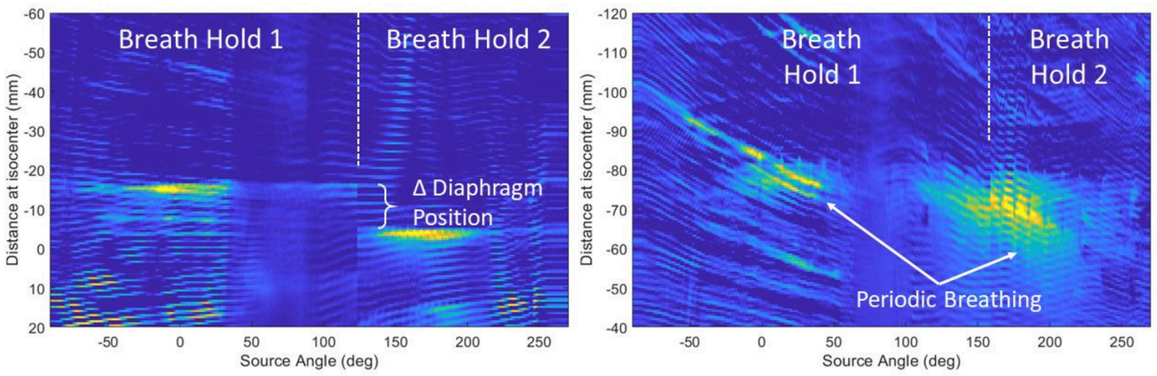

Figure 1: Change in diaphragm position from projection data using the Amsterdam-Shroud method for two different patients.

Results and Discussion

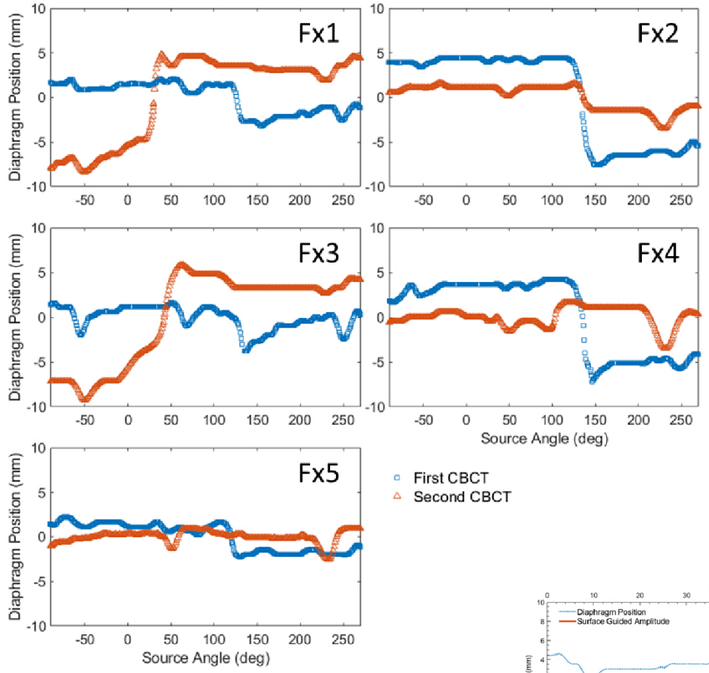

Figure 2: Diaphragm position during two CBCTs acquired on the same day for one patient.

In this preliminary work, a negative correlation for the presented patient was observed. We hope to further demonstrate this by adding the temporal component to the projection data and by improving workflows. Initial setup prior to CBCT does appear to play a role in the results, as does and body habitus. As such we are evaluating improvements by initially aligning the patient using a free breathing scan and using the SGRT to guide the CT and CBCT acquisitions.

Figure 2 shows detected diaphragm position for a patient throughout their course of treatment using the DRR based approach. As shown, this patient has two distinct breath holds per CBCT with the first breath hold typically ending between source angle 120-150°. The inter-breath hold diaphragm position variation was between 1.0 and 13.1 mm, with the maximum intra-breath hold diaphragm variation of approximately 5.1 mm. Among the seven patients investigated to date the average intra- and inter-breath hold diaphragm variation were 3.2 and 7.8 mm, respectively. While the maximum intra- and inter-breath hold variation were approximately 10.0 and 15.9 mm, respectively. Figure 3 shows correlation between diaphragm position and SGRT abdomen surface amplitude change, the correlation was -0.93, -0.54, -0.91 and -0.38 for fractions one to four, respectively. With fractions 2 and 4, having minimal variation during and between DIBH.

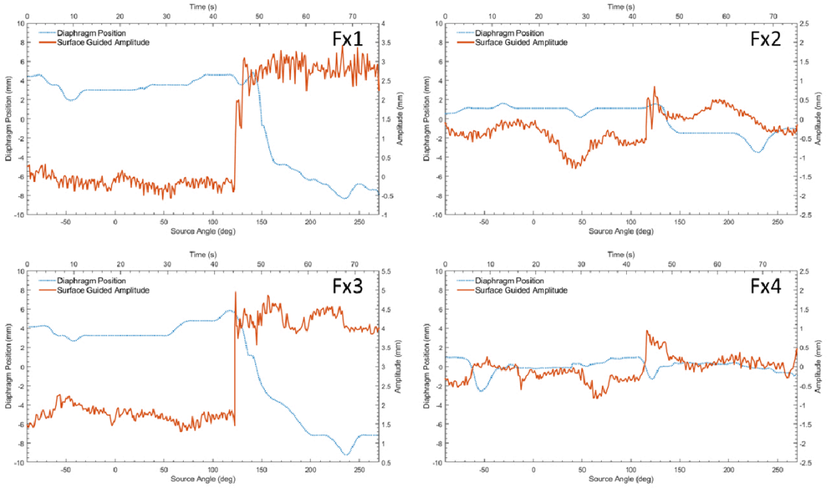

Figure 3: Diaphragm position from x-ray projection and surface guided change in abdomen amplitude.

Conclusions

Diaphragm position and lung volume varies greatly during and between DIBH. The observation of a negative correlation between diaphragm motion and surface variation indicates a potential of using SGRT for liver SBRT.