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Evaluation of breath-hold techniques for pancreatic cancer SBRT via intra-fractional kV imaging and fiducial tracking

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BACKGROUND

The accuracy and consistency of motion management are crucial in the stereotactic body radiation therapy (SBRT) of pancreatic tumors, due to their susceptibility to respiration-induced motion and proximity to normal gastrointestinal organs. Surface-guided radiotherapy (SGRT) can be utilized to monitor and facilitate consistent breath-holds, while implanted fiducials can act as effective surrogates for target tracking and beam gating.

OBJECTIVE

This work investigates the accuracy and consistency of three breath-hold (BH) techniques for pancreatic cancer SBRT by utilizing the fiducial locations in intrafractional triggered kV imaging. We hypothesize that **SGRT-based end-of-expiration BH (SGRT ExBH) and deep-inhalation BH (SGRT DIBH) can improve targeting accuracy and treatment efficiency compared to conventional spirometry-based DIBH (ABC DIBH) for pancreas SBRT.**

RESULTS

SGRT ExBH and DIBH were more accurate and more consistent with 96.9% and 93.6% of the fiducial deviations within 5 mm and average fiducial deviations of -0.07 ± 2.36 mm and 0.12 ± 2.46 mm, compared favorably with the 88.6% and -1.11 ± 3.28 mm for ABC DIBH. Patients treated with SGRT-based BHs on average spent 8 minutes less in the vault with more consistent treatment durations (average in-vault time of 49 ± 11 minutes, 48 ± 11 minutes, and 56 ± 19 minutes for SGRT ExBH, SGRT DIBH, and ABC DIBH, respectively).

CONCLUSION

In addition to facilitating faster and more uniform treatments, SGRT-based breath-hold techniques improved targeting accuracy and precision for pancreatic cancer SAbR as validated by intra-fractional fiducial tracking, proving its capacity as a viable replacement for spirometry breath hold techniques.

MATERIAL & METHODS

Online Treatment

36 pancreatic cancer patients treated with SBRT SIB 40-50/25-30 Gy in 5 Fx

- 12 with active breathing coordinator (ABC)-enabled DIBH
- 13 with SGRT-based DIBH
- 11 with SGRT-based expiration BH (ExBH).

SGRT BHs 3-mm translational and 3-degree rotational limits

Triggered Imaging kV acquired @ each beam-on and every 30-degree gantry rotation on a Varian TrueBeam. Automatic detection of 1 to 6 implanted fiducials as the surrogates of the true target position for treatment beam gating. Beam-on only when triggered imaging verified that the fiducials were within a 3-mm margin.

Offline Evaluation

To compare the targeting accuracy and precision between different breath hold techniques, the superior-inferior (SI) deviations (the only resolvable direction from 2D kV imaging) of the fiducials from their reference locations were extracted from over 1000 triggered kV images.

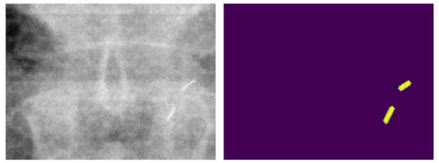

Figure 1. Examples of (left) kV image showing two fiducial markers through the spine and (right) the fiducials detected via imaging processing techniques (smoothing, thresholding, and Hough line transform). The centroid of each fiducial is compared with their expected SI location on the planning CT.

Treatment efficiency was quantified via patient in-vault time tracked by an in-house Bluetooth-based real-time location system.

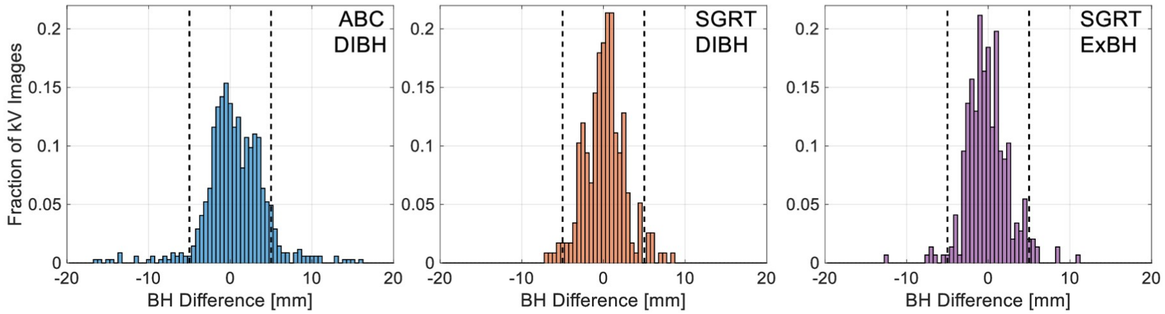

Figure 2. Fractions of fiducials and their SI deviations for the three BH techniques for all evaluated patients.

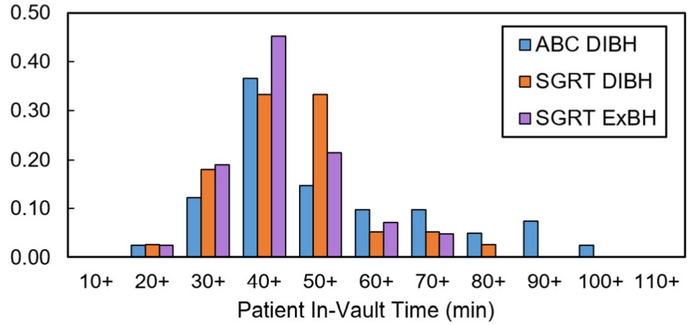

Figure 3. Distribution of the patient in-vault time per fraction for approximately 40 fractions treated using each BH technique.

Technique	Patient In-Vault Time (min)	Fiducial Deviation <= 1 mm	Fiducial Deviation <= 3 mm	Fiducial Deviation <= 5 mm
SGRT ExBH	48 ± 10 [25, 83]	32.8 %	81.9 %	96.9 %
SGRT DIBH	49 ± 12 [28, 80]	38.9 %	82.5 %	93.6%
ABC DIBH	56 ± 19 [28, 106]	25.5%	68.1%	88.6%

Table 2. Summary of the treatment efficiency and targeting accuracy for the three BH techniques.

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