Intra-Fraction Motion and Dosimetric Accuracy of Liver Stereotactic Body Radiation Therapy during Free-Breathing, Exhale and Inhale Active Breath-Hold

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Background:

Liver stereotactic body radiation therapy (SBRT) enables treatment of unresectable intrahepatic tumors while sparing surrounding normal tissue that has low radiation tolerance [1]. Rapid expansion of SBRT treatments led to the development of immobilization devices to standardize patient positioning and improve positioning accuracy [2]. Voluntary breath-holds, such as SDX (Dyn'r Medical Systems Aix-en-Provence France), can be used to reduce intra-fraction motion with visual feedback that aids in obtaining reproducible breath-holds. However, margins on planning-tumor volume (PTV) in liver SBRT treatments are not clearly defined for voluntary breath-hold techniques.

Purpose:

To evaluate intra-fraction motion and resulting dosimetric effects during stereotactic body radiation therapy (SBRT) of liver tumors under breath-hold (exhale and inhale) and free-breathing.

Methods:

Pre/post CBCT images were acquired for patients receiving free-breathing (N=8), exhale (N=11) and inhale breath-hold (N=5) SBRT. Dose prescribed was 33–50Gy in 5 fractions. Margins used were ITV or CTV plus 5mm axially and 8 or 10 mm superior-inferior (SI). CBCTs were co-registered by physicians with standard clinical alignment bias to the PTV using rigid registration in MIM 6.8.3 (MIM Software Inc.) and iso-center point shifts were computed in anterior-posterior (AP), left-right (LR) and SI directions. Dosimetry effects of intra-fraction shifts were estimated by rigid-transform of planned dose-distributions to evaluate target and OAR dose.

Results: CBCT co-registration

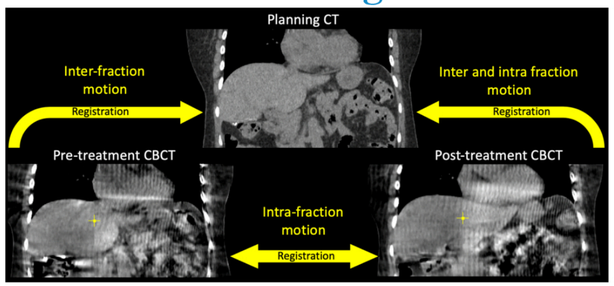


Figure 1 shows relations between planning CT, pre-treatment CBCT (during setup) and post-treatment CBCT that could be used to measure motion from inter-fraction, intra-fraction and both. Rigid registration was used to determine intra-fraction motion by computing iso-center point shifts (yellow crosshair) between pre/post CBCTs.

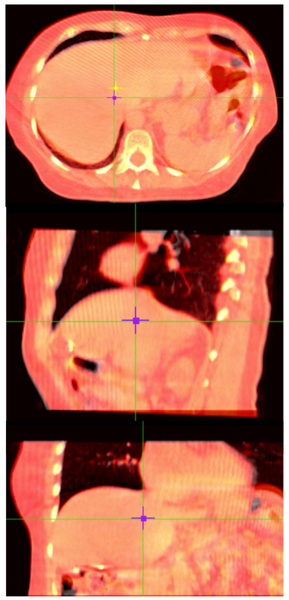


Figure 2 (left) shows pre and post CBCT registration performed by physicians. Soft-tissue contrast (of the liver) and PTV contours were used to guide clinical alignment biased to the region of the PTV, as is done during treatment.

Figure 3 (right) shows an example of dosimetric effects due to intra-fraction motion with reduced GTV coverage. For free breathing treatments, mean liver dose threshold was exceeded in 4/8 fractions with an overall increase of 57 ± 22%. For exhale breath-hold, GTV was under-covered (by more than 10%) in 4/11 fractions and small bowel dose to 0.5cc would be exceed in 2/11 fractions. For inhale breath-hold, GTV was under-covered in 1/5 fractions and large bowel dose threshold would be exceeded in 1/5 fractions.

Results: Liver SBRT intra-motion

	Number of patients	Number of fractions	Margins
Exhale	3	11	5mm axial, 8 mm sup inf
Inhale	2	5	5mm axial, 10mm sup inf
Free-breathing	2	8	ITV + 5mm axial, 8 mm sup inf

Table 1 shows the number of patients, number of fractions and PTV margins that were used for treatments under exhale BH, inhale BH and free-breathing.

	Sup-inf shifts [range] (mm)	Left-right [range] (mm)	Ant-post shifts [range] (mm)	Mean shifts [range] (mm)
Exhale	3.4 [0 - 6.6]	3.0 [0.7 - 8.4]	5.9 [0.3 - 13.3]	7.9 [3.9 - 13.6]
Inhale	1.71 [0.2 - 5.6]	1.8 [0.9 - 3.0]	4.5 [3.2 - 6.8]	5.4 [3.4 - 8.8]
Free-breathing	13.0 [0.5 - 28.5]	3.8 [0.4 - 6.8]	6.5 [1.4 - 14.9]	15.8 [5.1 - 31.0]

Table 2 shows mean and ranges absolute positional-variation in the superior-inferior, left-right, anterior-posterior (left) and relative shifts (right) for exhale, inhale and free-breathing.

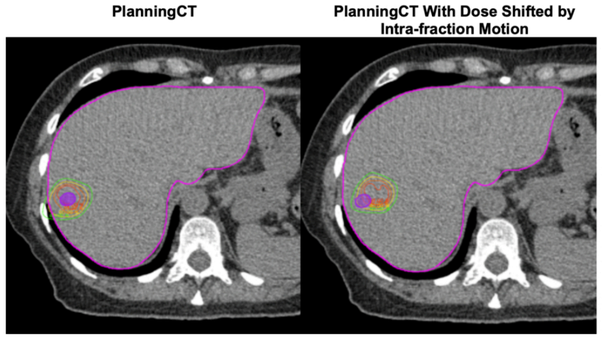
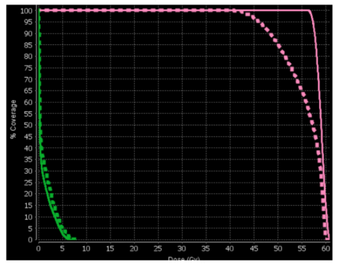


Figure 3 shows planning CTs with the dose distribution (left) and with intra-fraction motion (right) for respective DVHs for GTV (pink) and small bowel (green). The intra-fraction motion in this example was -8.4mm LR, 5.3mm AP and -4.8mm SI, which would result in a GTV coverage of 92% if it was repeated for all fractions.



Discussion:

Mean (± standard deviation) time between pre and post CBCTs was 11.9 ± 2.1min, 29.4 ± 4.7min and 27.2 ± 5.2min for free-breathing, exhale and inhale breath-hold respectively. Dose constraints used for small bowel and large bowel were 30Gy and 32Gy to 0.5cc respectively, and mean liver dose of 13-16Gy (depending on prescribed dose as per RTOG 1112). PTV margins used for free-breathing were ITV + 5mm axially + 8mm SI, and exhale and inhale breath-holds were CTV + 5mm axial + 8mm or 10mm SI. Figure 2 shows co-registered CBCTs with isocenter shifts anteriorly between yellow and purple crosshairs. Mean absolute and relative shifts are summarized in Table 2, showing that there is a systematic shift in the AP direction.

Conclusion:

Intra-fraction tumor position can be quite variable, beyond current PTV expansions anteriorly. On the other hand, SBRT liver treatments using breath-hold were less than 5.9mm. Larger margins could be needed in anterior-posterior direction to more accurately maintain GTV coverage and OAR thresholds.

References:

1. Schefter, Tracey E., et al. "A phase I trial of stereotactic body radiation therapy (SBRT) for liver metastases." IJROBP, 62.5 (2005): 1371-1378.
2. Case, Robert B., et al. "Interfraction and intrafraction changes in amplitude of breathing motion in stereotactic liver radiotherapy." IJROBP, 77.3 (2010): 918-925.
3. Foster, Ryan, et al. "Localization accuracy and immobilization effectiveness of a stereotactic body frame for a variety of treatment sites." IJROBP, 87.5 (2013): 911-916.

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