Variability in Liver Shape and Impact on GTV Position During Stereotactic Body Radiotherapy with Abdominal Compression

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Background: For patients receiving liver stereotactic radiotherapy (SBRT), abdominal compression can reduce organ motion and daily image guidance using liver to liver matching can reduce setup errors.

Purpose: To evaluate inter-fraction variability in liver shape and deformation using abdominal compression for SBRT.

Materials/Methods: Patients on an ethics approved SBRT liver protocol not suitable for ABC breath-hold were treated with abdominal compression if liver motion proved to be less than free-breathing motion under fluoroscopy and/or cine MRI. Daily image guidance for treatment using orthogonal imaging +/- cone beam CT (CBCT) was performed on a CBCT enabled LINAC. CBCTs of the liver under compression were acquired at treatment for offline evaluation and reconstructed to generate respiratory sorted CBCTs. The exhale-sorted CBCT was then exported to the treatment planning system where manual rigid liver-to-liver registrations to planning CTs (exhale) were performed, eliminating rigid residual offsets from the analysis. CBCT livers were contoured assuming a 100% match with the planning CT liver contour in regions where the liver was not well visualised on CBCT. Evaluation of spatial differences between CBCT and planning CT using in-house developed finite-element based deformable registration (MORFEUS).

Table 1. Method of Compression for all Patients

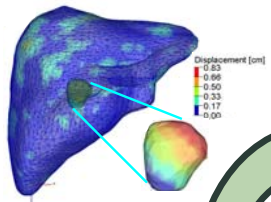
Method of Compression	Pts
Cushion + Belt secured over patient & bed	2
Elekta Stereotactic Body Frame (indexed)	2
PMH Stereotactic Body Frame (indexed)	12

Results: 83 CBCTs from 16 patients, with 30 GTVs were analysed. For all fractions where CBCTs were acquired in the final treatment position (58 Fx, 10 pts), inter-fraction variability in liver position relative to bones was determined using daily liver-liver registrations(Table 2).

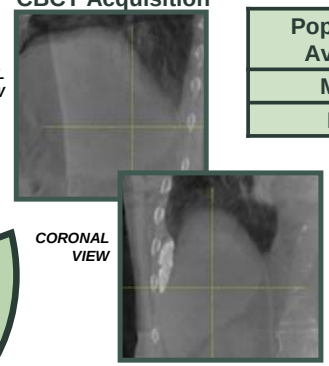
Table 2. Liver Position Relative to Bones(cm)

	RL	CC	AP
Σ	0.22	0.41	0.30
σ	0.28	0.31	0.30

A. Abdominal Compression



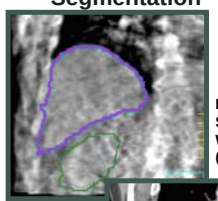
F. Deformable Registration of Exhale CBCT to Planning CT



B. Free-Breathing CBCT Acquisition

SAGGITAL VIEW

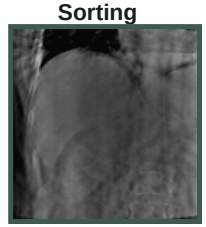
CORONAL VIEW



E. Exhale Sorted Liver Segmentation

EXHALE SORTED CBCT WITH CONTOURS (BLUE=CBCT LIVER)

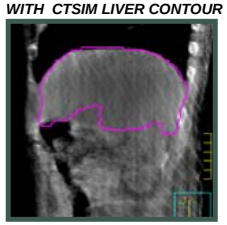
CTSIM LIVER WITH CONTOURS (PINK= PLANNING CT LIVER)



C. Respiratory Sorting

EXHALE SORTED CBCT

D. Rigid Liver to Liver Registration



EXHALE SORTED CBCT LIVER WITH CTSIM LIVER CONTOUR

CTSIM LIVER WITH LIVER CONTOUR (PINK)

Table 3 demonstrates population average mean and max deformations of the entire liver volumes compared to planning CT liver volumes. The deformation metric of the 95th percentile of liver volume was used to exclude deformations potentially due to contouring errors biasing the results. Table 4. demonstrates the volume displacements summary. Intra-observer contouring error was mean (std) 0.19(0.07), 0.26(0.06), 0.17(0.03) and 0.34(0.08)cm in the ML, AP, SI and vector directions for 95% of the liver volume. The impact of GTV position due to liver deformation was predicted using centre of mass (COM) displacements of the GTV from the planning CT, based on liver deformations, as GTVs were not visible on CBCT. Although small in most patients, a single patient had mean displacements of 0.49, 0.68 and 0.17cm in the ML, AP and SI directions (Table 4).

Table 3. Percent Liver Volume Deformation (%Vol.)

Population Average	% Vol. >0.3cm	% Vol. >0.5cm	%Vol. >1.0cm
Mean	21.7	8.7	2.6
Max	36.3	15.9	6.7

Table 4.

		Offset (cm) ML	AP	SI	Vector
Liver Volume Mean Displacements	Σ	0.11	0.14	0.07	0.21
	σ	0.06	0.21	0.05	0.21
95th Percentile Liver Volume Displacements	Abs Ave	0.28	0.36	0.27	0.50
	Σ	0.14	0.13	0.09	0.24
	σ	0.19	0.15	0.11	0.30
Ave. displacement of GTV COM	Ave	-0.26	-0.25	-0.45	
	Std	0.10	0.10	0.08	

Liver Volume and GTV Centre of Mass Displacement Summary

Conclusions: Liver deformations using abdominal compression were small in most patients (<5mm), smaller in magnitude than other geometric uncertanties. However, one patient did have substantial deformation under the compression plate resulting in clinically significant changes in GTV position warranting methods to ensure reproducibility and quality assurance of abdominal compression.

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