Influence of different breathing manoeuvres on internal and external organ motion: Use of fiducial markers in dynamic MRI

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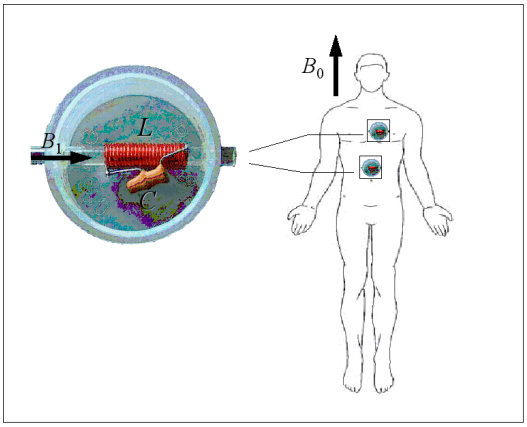
Purpose External markers on the body surface to calculate and simulate tumor position is a frequently applied indirect method in high-precision radiotherapy. The precision of the correlation of internal organ and external chest wall motion is of high importance in these techniques. The purpose of this study was to investigate the influence of different breathing manoeuvres on internal organ and external chest wall motion using dynamic MRI (dMRI) and a fiducial marker.

Methods and Materials Lung and chest wall motion of 16 healthy subjects (13m/ 3f) were examined using a real-time trueFISP dMRI (TR/TE = 3.8 ms/1.8 ms; readout bandwidth 890 Hz/pixel; matrix 154x256; field of view: 375x400 mm^2; partial fourier 5/8) and a small inductively coupled solenoid-marker coil (l=2cm, ø5mm, #turns=21, inductance = 625 nH, Fig. 1) filled with water/ Gd-DTPA solution (100 : 1). The coil was positioned on either abdomen or thorax (Fig. 1). The projection direction of the marker coil position measurement could be set independently of the orientation of the imaging slice.



To suppress background signal during marker tracking weak dephasing gradients (G_{Deph} = 2 mT/m, τ = 200 µs) were applied orthogonal to the readout direction. Three different breathing manoeuvres were performed (predominantly “abdominal breathing”; “thoracic” and unspecific “normal breathing”). The cranio-caudal (CC), antero-posterior (AP) and medio-lateral (ML) lung distances were correlated with marker coil position during forced and quiet breathing.

Fig. 1 *The coil was placed on the volunteers’ abdomen and chest with axis perpendicular B0 field for optimal coupling with the rf field (B1).*

Results Differences of the CC distance between maximum forced inspiration and expiration was significant between abdominal and thoracic breathing (6.1 ± 1.2cm vs 3.4 ± 1.8cm, p<0.05). Correlation between CC distance and coil position was best for forced abdominal breathing and a marker coil in abdominal position (r=0.89 ± 0.04, Fig. 2, Tab. 1), for AP and ML distance forced thoracic breathing and a coil in thoracic position was best (r=0.84 ± 0.03 and 0.82 ± 0.03, Tab. 1). In quiet breathing correlation was lower.

Conclusion DMRI in combination with a fiducial marker coil provides quantitative information on the correlation of internal organ and external chest wall motion. Correlations are highly dependent on the breathing manoeuvre and of high importance for high-precision radiotherapy techniques.

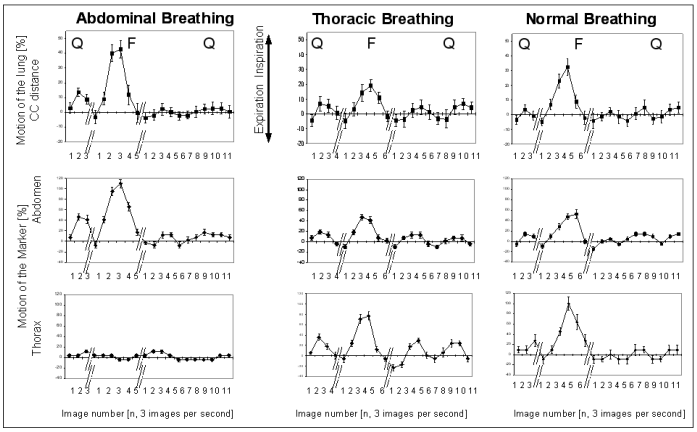


Fig. 2 *Relative craniocaudal (CC) distance using abdominal, thoracic and normal breathing (F forced respiration; Q quiet respiration). Baseline is the mean distance in quiet respiration.*

	r	Marker coil position			
		I. Abdomen		II. Thorax	
		F	Q	F	Q
CC Distance	Abdominal breathing	0.89 ± 0.04	0.83 ± 0.03	0.53 ± 0.14	0.56 ± 0.17
	Thoracic breathing	0.69 ± 0.06	0.61 ± 0.06	0.75 ± 0.04	0.70 ± 0.05
	Normal breathing	0.76 ± 0.04	0.77 ± 0.07	0.71 ± 0.06	0.69 ± 0.05
AP Distance	Abdominal breathing	0.67 ± 0.05	0.63 ± 0.06	0.59 ± 0.09	0.57 ± 0.1
	Thoracic breathing	0.67 ± 0.05	0.66 ± 0.04	0.84 ± 0.03	0.80 ± 0.04
	Normal breathing	0.66 ± 0.05	0.65 ± 0.05	0.74 ± 0.04	0.71 ± 0.05
ML Distance	Abdominal breathing	0.63 ± 0.06	0.62 ± 0.05	0.58 ± 0.16	0.54 ± 0.11
	Thoracic breathing	0.67 ± 0.03	0.66 ± 0.04	0.82 ± 0.03	0.74 ± 0.03
	Normal breathing	0.68 ± 0.05	0.65 ± 0.05	0.73 ± 0.06	0.72 ± 0.05

Table 1 *Correlation (r) between CC distance, AP distance, ML distance and coil position in forced (F) and quiet (Q) breathing manoevres.*