Respiration-induced B0 fluctuation of spine

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Introduction: In spine imaging, physiological effects such as cardiac pulsation, respiration, and organic motions can induce signal intensity and phase fluctuations. Additionally, B_0 field variations due to respiration can also be a potential problem due to its close proximity to the lungs. It has been demonstrated that respiration induced resonance frequency offsets can be a non-negligible factor for functional brain and breast imaging [1, 2]. These existing studies have shown the respiration induced B_0 fluctuations by using a breath holding method, which acquires phase images during maximum inspiration and expiration states [3]. The degree of B_0 fluctuations during respiration has not been studied for spine imaging. This study therefore focuses on the relative B_0 fluctuations induced by susceptibility changes attributed to movements of lungs and diaphragm during the respiratory interval in different parts of the spine imaging.

Methods: We obtained sagittal spine images (C-spine, T-spine, L-spine) using Siemens 3T MR system (TIM TRIO) with standard 12-channel head-and-neck coil and body coil. The spine image obtained from healthy volunteer (N=4). We used an RF-spoiled single slice 2D gradient echo (GRE) sequence with image parameters FOV=21cm×21cm, resolution=128×96, slice thickness=5.5mm, TR/α=5ms/25°, echo time TE=2.21ms, 450Hz/pixel RBW (receiver bandwidth), total acquisition time 50 sec. Free breathing data were acquired from the same sagittal spine slice measured 100 times while the subject was breathing slowly (approximately 15~20 breathing cycles). The phase difference maps (Δφ) between each respiration step were created by dividing the two complex images and extracting the phase. A mask for the high signal-to-noise ratio (SNR) region was applied by thresholding using the magnitude image. The Δφ map was converted to a frequency-shift (field) map by $\Delta f=\Delta\varphi/(2\pi TE)$, expressed in Hz.

Results: Averaged relative frequency shift values are determined for regions (ROI) of the CTL spine as shown in the yellow box of Fig. 1 (a)-(c). Table 1 shows the maximum and average frequency changes during inspiration and expiration. At the C-spine, Δf_{max} in ROI(C) is higher than other regions since the airway, attributable to susceptibility changes, is near region (C). The lung is located nearest to the T-spine and therefore experienced largest maximum B_0 fluctuations from 13~48 Hz depending on the location during respiration. The frequency variations decrease when the ROI is further away from the lungs at the L-spine. Especially, the influence of the airway motion during respiration step in thorax system so Δf_{max} in ROI(C) is larger than ROI(D).

Fig 2 shows the relationship of the respiration steps evaluated by the respiratory belt and the instant frequency from the regions shown. The gating gage increase represents inspiration, and decrease represents expiration step. As seen, the frequency variations correlate well with the respiration cycle. Generally, when the respiratory indicates a peak value, frequency changes are also very large. These patterns are shown irrespective of the location of ROI as expected.

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ROI		Δf_{max} [In– Ex] ± std (Hz)	Δf_{mean} [In– Ex] (Hz)
Fig 1.(a)	A	7.26 ± 1.18	5.38
	B	12.86 ± 3.06	10.46
	C	22.91 ± 3.76	18.11
Fig 1.(b)	D	13.71 ± 3.57	9.85
	E	22.89 ± 2.88	9.56
	F	47.8 ± 11.41	34.95
Fig 1.(c)	G	26.35 ± 6.8	18.3
	H	17.66 ± 4.41	14.45

Table 1: Δf_{max} is maximum field difference obtained between inspiration and expiration from four normal subjects. Δf_{mean} is averaged field difference value during respiration cycle.

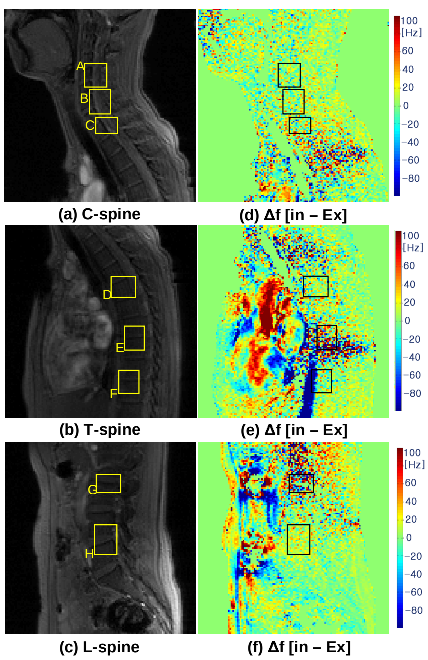

Fig 1: (a-c) Magnitude image of C, T, L–spine (d-f) relative phase difference Δf map image between inspiration and expiration

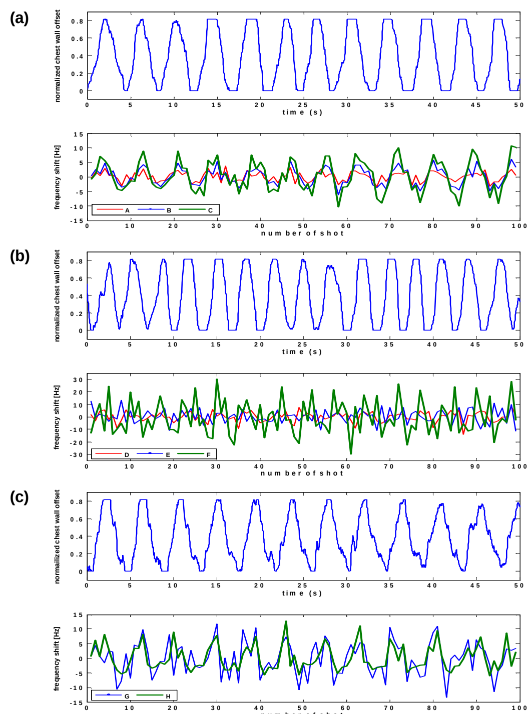

Fig2 (right): Correlation of respiration gating and frequency shift value. (a) C-spine (b) T-spine (c) L-spine

Conclusion: We obtained experimentally the amount of respiration induced B_0 field fluctuation of the spine. Depending on the location of the spine, maximum field fluctuations as high as ~45 Hz occurs due to respiration. These numbers can be non-negligible for advanced imaging techniques such as DWI of the spine. The B_0 fluctuations are most severe in regions near the lung and close to airway pathways. Finally, the patterns of B_0 fluctuations are highly correlated with the respiration state. Therefore, using respiration monitoring, methods to correct for B_0 fluctuations can be devised.

References

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