Audiovisual biofeedback improves image quality and reduces scan time for gated 3D MRI

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Purpose Respiratory-related motion blurring and ghost artifacts [1] can be reduced using respiratory-gating techniques with RF navigator [2] or respiratory bellows belt [3]. However, variations in cycle-to-cycle breathing can cause inadequate respiratory-gating in image acquisition, resulting in image distortions of moving organs and lengthening the scan time. Audiovisual (AV) biofeedback [4] has been previously demonstrated to improve breathing regularity in 2D MRI. The aim of this study is to demonstrate that AV biofeedback improves image quality and reduces scan time for gated 3D MRI.

Methods An AV biofeedback system has been employed to provide respiratory guidance during MR scans. The respiratory motion signals were obtained using the real-time position management (RPM) system (Varian) consisting of an infrared camera and a marker block on the abdomen in Figure. 1. The improvement in gated 3D MR images using the AV biofeedback system combined with thoracic MRI was investigated with two healthy human subjects. For thoracic imaging, T2-weighted SPACE (Sampling Perfection with Application optimized Contrast using different angle Evolutions) MR pulse sequence with liver dome scout (RF navigator) in Siemens Skyra 3T scanner was employed and typical parameters were TR/TE = 2200/89 ms, flip angle = 170°, FOV = 380 x 380 mm^2, voxel size = 1.19 x 1.19 x 4 mm^3 and image matrix = 320 x 320 x 52. In this study, each subject underwent two sessions to assess of the image quality and gating efficiency with (AV: AV biofeedback breathing) and without (FB: Free breathing) AV biofeedback combined with gated 3D MR images with an RF navigator technique. Respiratory acceptance positions at 10% (near maximum exhalation), 50% (middle) and 90% (near maximum inhalation) were selected with a ±2 mm acceptance window range (except for ±4 mm in 90% in Subject 2). To investigate the improvement in gated 3D MR images from the two measurements, respiratory-related motion artifacts have been qualitatively evaluated. In addition, gating efficiency related to 3D MR data acquisition time has been evaluated with abdominal motion and diaphragm motion analysis.

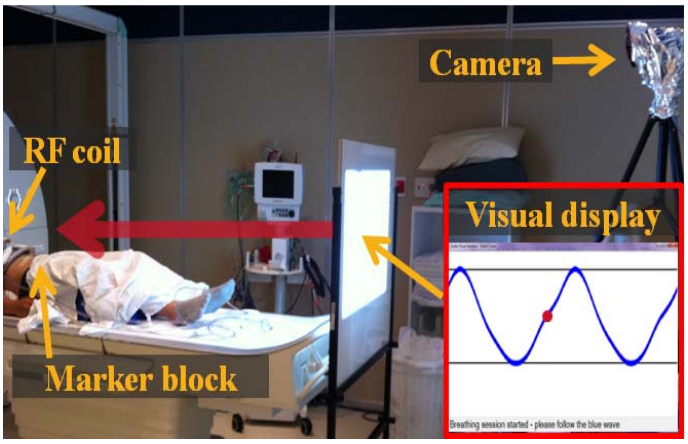

Figure 1. *AV biofeedback system for gated 3D MR imaging in a 3T Siemens MRI.*

Results and Discussion Using the AV biofeedback system, respiratory-related motion blurring artifacts have been noticeably reduced as shown in Figure. 2. Irregular respiratory motion was observed with FB (a1 and b1) and 3D MR images were significantly blurred due to the variation of respiratory motion such as baseline shift and amplitude. In contrast, the reproducibility of respiratory motion was considerably improved in AV (a2 and b2) and the edge and intersection of organs were sharpened and clear. Moreover, 3D MR images with AV included more detailed information such as a clearly separated diaphragm and lung lobes. Image quality was improved at all acceptance positions due to the improvement in breathing regularity quantified by the reduction of root mean square error (RMSE) in displacement and period as shown in Table 1. An average reduction in scan time was from 356 s to 251 s and a reduction from 882 s to 337 s was seen in subject 1 at 90% acceptance window and 36 s at 90% (±4 mm) in subject 2. This study demonstrated the improvement of gated 3D MR images via AV biofeedback coming from respiratory motion reproducibility, leading to regular internal organ displacement [4] and resulting in improved image quality during gated 3D MR imaging. In addition, scan time was simultaneously lessened.

Conclusion The study was the first to demonstrate that audiovisual biofeedback improves image quality and reduces scan time for gated 3D MRI.

References [1] L. Wood, *et al.* Med Phys **12**, 143 (1985). [2] P. Spincemaille, *et al. MRM.* **60**, 158 (2008). [3] C. Santelli, *et al. MRM.* **65**, 1097 (2011). [4] T. Kim, *et al.* Med Phys **39**, 6921 (2012).

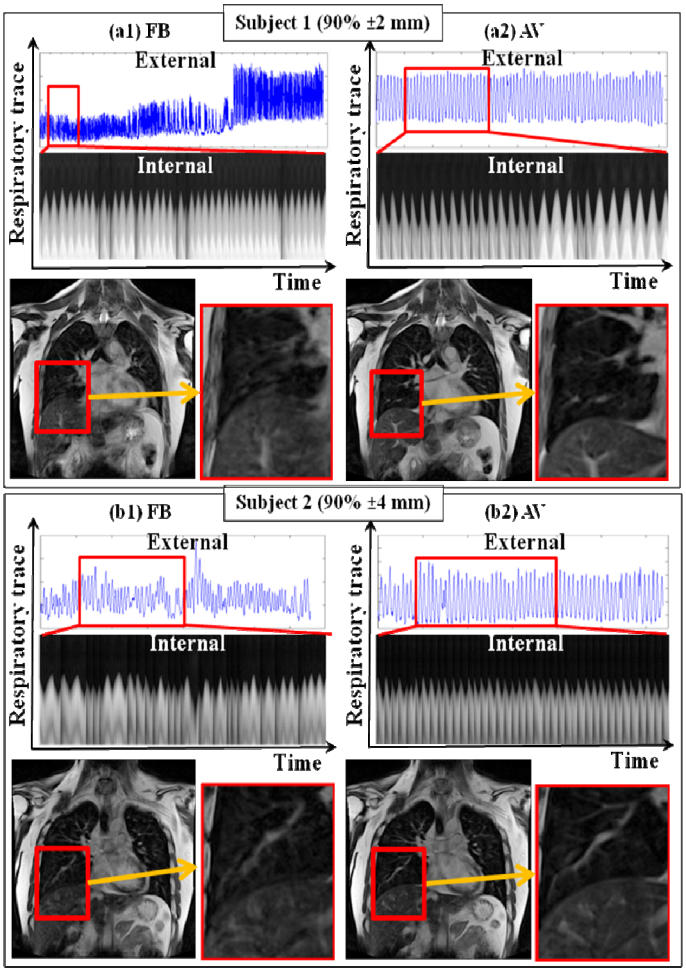

Figure 2. *An example of improvement when AV biofeedback was employed during gated 3D MR imaging.*

Table 1. *Gated 3D MR imaging scan time and breathing variation.*

Subjects	Acceptance positions	Session (FB)			Session (AV)		
		Scan time (s)	RMSE in		Scan time (s)	RMSE in	
			Displacement (mm)	Period (s)		Displacement (mm)	Period (s)
S1	10%	262	1.9	0.23	262	0.8	0.25
	50%	263	1.2	0.58	262	0.9	0.68
	90%	882	3.5	3.70	337	0.8	0.24
S2	10%	218	1.4	0.47	214	0.8	0.19
	50%	261	1.4	1.01	219	0.7	0.36
	90% (±4 mm)	252	1.4	1.06	216	0.7	0.60
Average		356	1.8	1.18	251	0.8	0.39