Free-breathing cardiac black blood imaging using 1D navigator driven reconstruction

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INTRODUCTION: Double Inversion Recovery Fast Spin Echo (DIR-FSE) sequences, resulting in black-blood images, are widespread in cardiac exams [1] as they offer high resolution and great contrast between blood pool and myocardium. To handle cardiac and respiratory motions, the sequence is triggered on ECG signal and the patient is asked to hold his breath. Though well established, the later procedure is highly dependant on patient cooperation. Moreover imperfect breath holds may impair image quality and thus prevent accurate diagnosis.

Free breathing acquisitions have been enabled either by respiratory self gating techniques based on navigators [2] or by motion compensated reconstruction [3]. Few methods have combined both approaches. Odille et al. [4] have recently proposed a cardiac and respiratory motion compensated reconstruction, driven by 1D navigators. This method has only been applied to cardiac cine with 2D SSFP sequences. The aim of the present study was to extend this method to ECG-gated DIR-FSE sequences. The use of 1D navigator instead of external sensors prevent from using additional hardware to synchronously record physiological signals and the combination of both motion information should further improve the quality of reconstructed images.

MATERIAL & METHOD:

MR experiments: Two healthy volunteers underwent a cardiac examination, one at 1.5T and the other at 3T (SIGNA HDxt, GE Healthcare, Milwaukee, WI). For each subject, one short axis slice was chosen. One image was first acquired during breath hold with the standard DIR-FSE sequence (TE=35ms, TI=500ms, matrix size: 256x256, FOV=36cm, BW=250kHz, slice thickness=6mm, ETL=16). Then three acquisitions were performed while free breathing with a modified DIR-FSE sequence including an additional center k-space profile at the beginning of each echo train. The same acquisition parameters were used. The center profiles were not used for gating purpose but were taken into account in the free breathing reconstruction process. Signals from a respiratory belt were carried by a custom Maglife patient monitoring system (Schiller Medical, France) and recorded with a dedicated home-made hardware [5].

Processing of the center profiles: Motion information was extracted from the central profiles using Ahn's algorithm [6]. The displacement d that occurs between the acquisition of the reference profile S_{ref} and the current profile S is thus estimated as:

$$d = \arg\left(\sum S^*(k)S(k+1)\right) - \arg\left(\sum S^*_{ref}(k)S_{ref}(k+1)\right) \qquad \text{Eq.1}$$

Only the signal acquired by the coil element closer to the heart has been used for the reconstruction and the first central profile has been chosen as reference.

Free breathing reconstruction: The Generalized Reconstruction by Inversion of Coupled System (GRICS) enables to reconstruct black blood images from free breathing acquisitions [3]. It is based on a non rigid motion model linearly constrained by physiological signals, such as pneumatic respiratory belts, which is updated through an iterative reconstruction process. In this work, motion information extracted from k-space center profiles (instead of external sensors) was used to drive the motion model. Resulting image was compared with standard breth-held image and image reconstructed with GRICS using respiratory signals. Finally, GRICS reconstruction was performed by taking advantage of both motion signals. Image quality was assessed by computing image entropy (IE) on the whole image (which increases with noise) and gradient entropy (GE) on the cardiac area (which decreases with edge blurring).

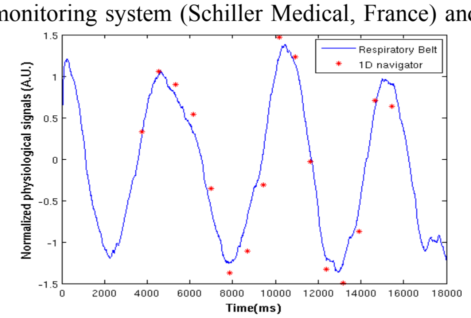

Figure 1: Comparison of motion information extracted from k-space center profiles (red dots) and from a respiratory belt (blue line)

		Breath hold	Free Breathing		
			Nav	Belt	Both
Vol. 1.5T	IE	3.66	3.70	3.68	3.67
	GE	3.70	3.62	3.59	3.65
Vol. 3T	IE	4.10	3.97	3.98	3.96
	GE	3.77	3.42	3.39	3.44

Table 1: Assessment of image quality

RESULTS: The motion information d extracted from central profiles was in good agreement with the signals of the respiratory belt (Fig.1). Image quality of image reconstructed with GRICS using central profiles was similar to that obtained with respiratory signals and was further improved with both signals (Table1 and Fig. 2).

CONCLUSION: The additional central profiles provide motion information without extra acquisition time and with minimal increase of SAR deposition. The use of such information in GRICS reconstruction provides the same reconstruction quality as using respiratory belt, with no recording hardware required. Results are further improved when both sources of motion information are used. For the sake of comparison with breath held images, the matrix size was restricted to 256 but can be easily extended to 384 or 512, as breath holding and thus acquisition time is no longer a limit.

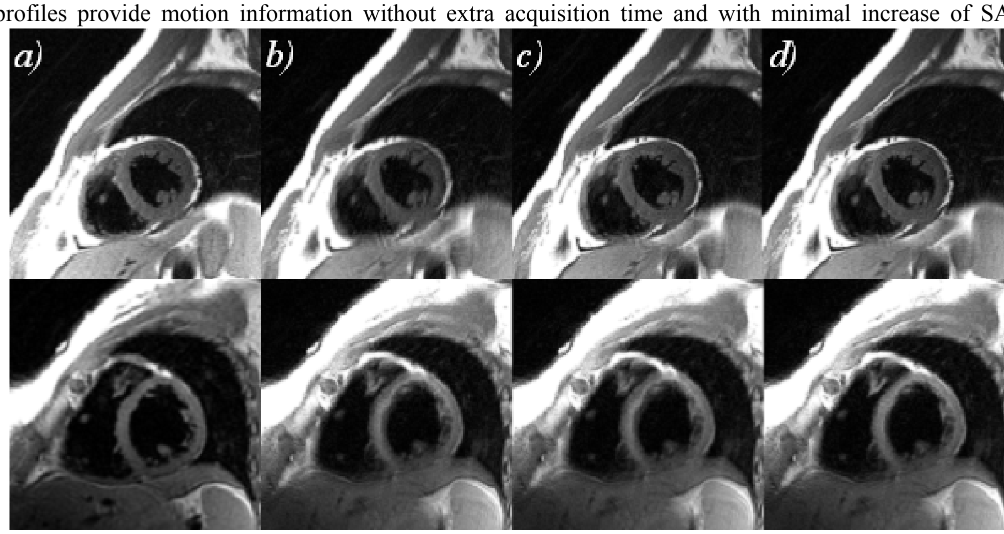

Figure 2: Images obtained on both volunteers at 1.5T (Top) and 3T (Bottom), during a) breath hold and free breathing with GRICS reconstruction using b) 1D navigator, c) respiratory belt and d) both sources of motion information.

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