A Double Navigator Approach to Double Inversion Recovery Fast Spin Echo Imaging in Black Blood Cardiac MRI

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Introduction

Breath hold double inversion recovery (DIR) black blood 2D fast spin echo (FSE) has been routinely used to study cardiac disease [1]. The navigator approach can be used to improve patient comfort and cooperation over the breath hold method [2]. In previous work, a single navigator echo was acquired immediately before the FSE readout to provide motion gating using a fixed acceptance window (Fig.1). The separation between DIR and FSE readout is typically 300-600 ms, during which respiratory displacement can be as large as the slice thickness (8mm). Corresponding misregistration between DIR and FSE readout can lead to serious artifacts and signal dropout. Additionally, drifts in the respiration pattern will substantially prolong scan time and degrade image quality.

We developed a navigator method for DIR FSE that addresses both the misregistration and the respiratory drift problems identified above. A second navigator is introduced immediately before the DIR preparation to reposition in real-time the selective inversion to the location of the image slice. A modified PAWS gating algorithm is used to achieve minimal scan time under drifting respiration [3]. Residual motion within the gating window is corrected to further minimize motion artifacts and to register the image slice with the DIR inversion location.

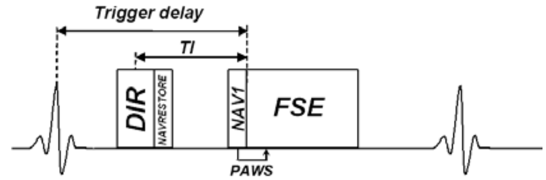

Fig. 1: Single navigator gated DIR 2D FSE (prior work does not use PAWS and/or NAVRESTORE).

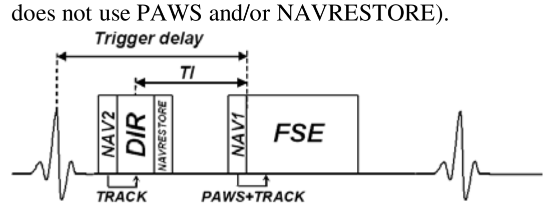

Fig. 2: Double navigator gated DIR 2D FSE pulse sequence diagram. See text for abbreviations.

Methods

The developed double navigator algorithm is illustrated in Fig. 2. A second navigator (NAV2) was inserted before the DIR preparation and used to adjust the location of selective inversion to ensure registration with the imaging slice. As with the single navigator method, a navigator (NAV1) immediately before the FSE readout was used for gating data acquisition (using 2-bin PAWS), slice tracking and in plane motion correction (TRACK). A 180º navigator RF pulse (NAVRESTORE) following the DIR reinverted the tissue for NAV1 [4]

Each navigator echo consisted of a pencil-beam excitation through the right hemi-diaphragm. A real-time gating program running on the internal real-time operating system of the scanner collected navigator signals, extracted respiratory motion and controlled data acquisition accordingly. A 0.75mm bin width (resulting in a 1.5mm gating window) was used in the PAWS algorithm, which automatically completed acquisition at the most likely position. For slice tracking and motion correction a tracking factor of 0.6 was used [5].

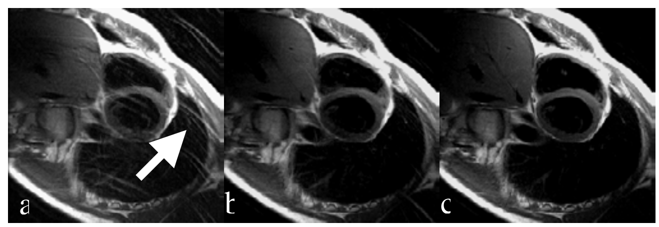

Fig. 3: Comparison of short axis views using a single navigator (a), a double navigator with slice tracking (b), and a breath-hold scan (c). The double navigator markedly reduced ghosting artifacts over (a) and provides quality similar to breath hold (c).

This navigator algorithm was compared with the single navigator approach in Fig. 1 and breath-hold scans in 5 healthy subjects. Experiments were performed on a 1.5T GE Excite MR scanner using a 4-element cardiac coil. Imaging parameters for all scans were: slice thickness 8 mm, FOV 30 cm, 6 to 9 slices (short axis heart view), BW ±62.5kHz, 256x256 matrix, ETL 24, TE 42 ms, single RR double inversion recovery (DIR) preparation, and peripheral pulse gating.

Results

Fig. 3 shows a comparison of a single navigator (Fig.3a), a double navigator (Fig.3b) and a breath hold (Fig.3c). The double navigator method allowed good image quality comparable to the breath-hold scans in all subjects. Increased ghosting artifacts were observed when using the single navigator approach. Scan efficiencies ranged between 17% and 56% (average 31%) for both single and double navigator methods. Heart rates ranged between 60 bpm and 74 bpm (average 66 bpm).

Discussion and Conclusion

This preliminary study shows that the double navigator approach provides more effective motion suppression than a single navigator for free-breathing DIR 2D FSE. Image quality was found to be comparable to that obtained during breath-holds.

The double navigator method can be extended to other cardiac MRI sequences, such as DIR 3D FSE. For black blood cardiac MRI, 2D FSE acquisition may be preferred over 3D because of suboptimal suppression of blood signal in thick slabs, particularly in the presence of slow flow. The approach presented here can be generalized to fat navigators which track motion of the heart directly [6] and multi slice gating techniques such as Simultaneous Multiple Volume (SMV) [7] can be employed to increase scan efficiency.

In conclusion, our study indicated that a double navigator gated DIR 2D FSE with PAWS gating and motion correction shows promise as a free-breathing alternative to the current standard breath-hold protocol while delivering similar image quality.

References [1] Simonetti et al, Radiology 1996; 199:49-57 [2] Botnar R et al, Circulation. 2000 Nov 21;102(21):2582-7 [3] Jhooti P et al. MRM 2000;43:470-480. [4] Stuber M et al., MRM. 2001 Feb;45(2):206-11. [5] Wang Y et al, MRM 1995; 33:713-719 [6] Nguyen TD et al. MRM 2003;50:235-241. [7] Kolmogorov NK et al., Radiology 2001; 211(P), 221