Efficient Simultaneous Multiple Volume Free Breathing Black Blood Cardiac MRI

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Introduction

Recently, the Simultaneous Multiple Volume (SMV) navigator algorithm, based on the simultaneous acquisition of different slices at different diaphragm positions, has shown a 2-3 fold improvement in scan speed using the same gating window compared to the conventional navigator gating based on sequential acquisition of slices [1]. For the black blood 2D Double Inversions Recovery (DIR) prepared Fast Spin Echo Sequence (FSE) sequence, current implementations use only one navigator echo [2], which does not allow adjusting both DIR location and slice location according to the respiratory position as required by the SMV algorithm.
Here, we report an implementation of SMV algorithm for DIR FSE sequence using an additional navigator placed before the DIR and real time slice following to select both DIR and slice locations according to current diaphragm position. This black blood SMV technique is compared with the conventional single navigator gating black blood technique.

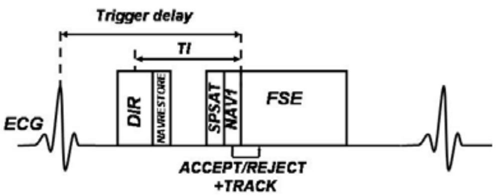

Fig. 1: Conventional navigator DIR 2D FSE.

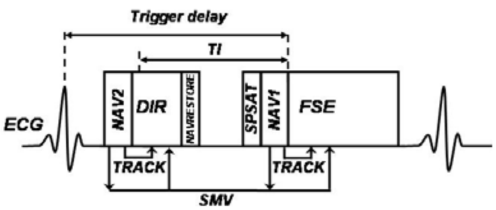

Fig. 2: SMV navigator DIR 2D FSE.

Methods

The conventional navigator DIR FSE sequence is illustrated in Fig. 1. The proposed SMV pulse sequence is shown in Fig. 2. A conventional navigator (here called NAV1) was acquired immediately before the FSE readout. The displacement given by NAV1 was used for PAWS [3] gating of the acquisition of phase encodings, for slice tracking and for in-plane motion correction (TRACK) [4]. The SMV gating algorithm determines which slice needs to be acquired based on the diaphragm position. Because the DIR preparation contains a slice selective pulse, a second navigator (NAV2) was inserted before the DIR preparation. The displacement given by NAV2 allowed the SMV algorithm to decide which slice was acquired in that heart beat. Additionally, the displacement was used to adjust the location of selective inversion to ensure registration with the imaging slice (TRACK). A navigator with 180º flip angle (NAVRESTORE) following the DIR reinverted the tissue for NAV1 [5]. A spatial saturation band was added to suppress chest wall signal (SPSAT).

Each navigator echo consisted of a pencil-beam excitation through the right hemi-diaphragm. A 2 mm bin width (resulting in a 4 mm gating window) was used in the 2-bin PAWS algorithm. For slice tracking and motion correction a tracking factor of 0.6 was used [6]. This SMV navigator algorithm was compared with the conventional navigator approach in Fig. 1 and breath-hold scans in seven healthy subjects. Experiments were performed on a 1.5T GE Excite MR scanner using an 8-element cardiac coil. Imaging parameters for all scans were: slice thickness 8 mm, FOV 34 cm, 6 to 9 slices (short axis heart view), BW ±62.5kHz, 256x160 matrix, ETL 24, TE 42 ms, double RR double inversion recovery (DIR) preparation, and vector ECG gating.

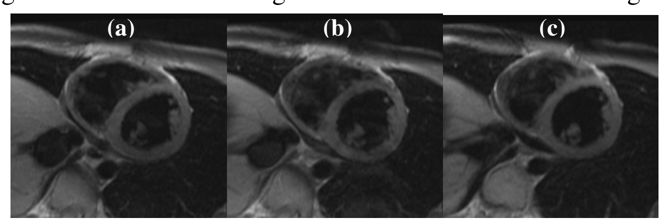

Fig 3. DIR FSE imaging (a) breath-hold (b) navigator gated (fixed window) and (c) navigator SMV. Similar image quality is obtained with each method.

Results

Fig. 3 shows a comparison of a conventional navigator (Fig.3a), a SMV navigator (Fig.3b) and a breath hold (Fig.3c). The navigator methods allowed good image quality comparable to the breath-hold scans in all subjects. Heart rates were 66±10BPM. Average scan efficiency was 29±11% for the conventional navigator scan versus 59±10% for the SMV navigator ($p<0.001$).

Discussion and Conclusion

This preliminary study shows the feasibility of free-breathing black blood cardiac MRI that is both scan time efficient and improves comfort for both patient and technologist. A significant increase in scanning efficiency was observed compared to the conventional gating method. Using the SMV approach, the optimal acceptance window is automatically selected for multiple slices simultaneously. In the present study, the accept-reject gating algorithm required multiple manual readjustments of gating window position in response to apparent respiratory drift in two subjects. In contrast, the SMV approach was able to complete the scan unsupervised for all subjects. In conclusion, these initial results suggest that free-breathing black blood imaging may be useful in cases where breath-holds are difficult or impossible to perform and may replace current breath-hold protocols.

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