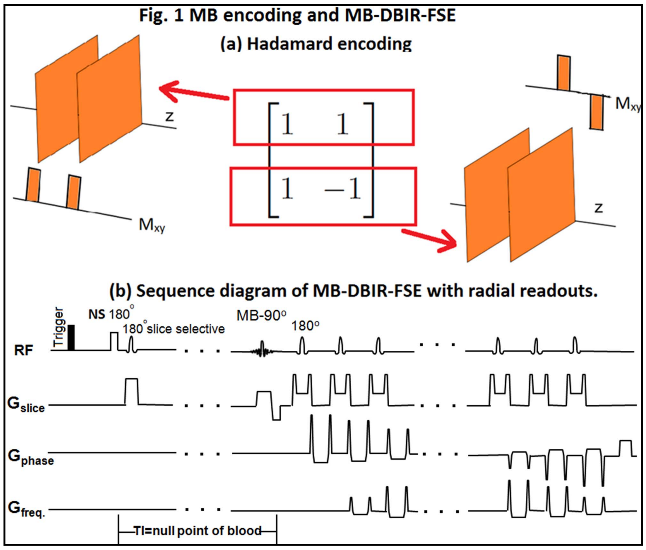
IMPROVED SLICE COVERAGE IN DBIR-FSE WITH MULTI-BAND ENCODING

Sagar Mandava[1], Mahesh Bharath Keerthivasan[1], Diego R. Martin[2], Ali Bilgin[1,3], and Maria I. Altbach[2]

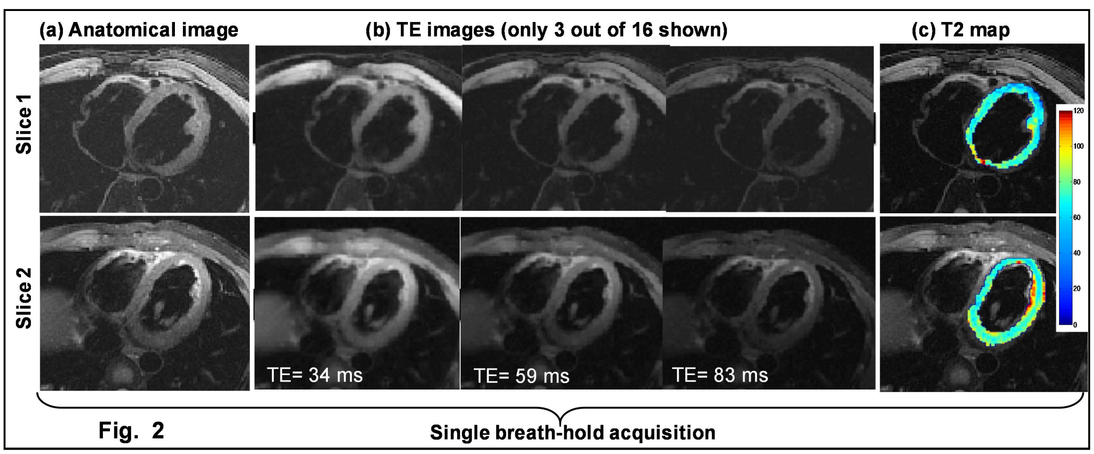
[1]Electrical and Computer Engineering, University of Arizona, Tucson, AZ, United States, [2]Medical Imaging, University of Arizona, Tucson, AZ, United States, [3]Biomedical Engineering, University of Arizona, Tucson, AZ, United States

PURPOSE: The double inversion recovery (DBIR) fast spin-echo pulse (FSE) sequence is commonly used for looking at edema and other morphological changes in the myocardium[1,2]. The DBIR preparation period is used for suppressing the signal from flowing blood. DBIR uses a non-selective (NS) inversion pulse followed by a slice-selective inversion pulse and there is only one point in time during the recovery of the inverted magnetization at which the blood signal is completely nulled. Due to the need for a NS excitation, only one slice can be acquired at the null point of blood after each DBIR preparation period. This renders the DBIR-FSE pulse sequence time inefficient for multi-slice acquisitions[3]. To improve the slice efficiency of the technique, methods to interleave the slices across different DBIR periods have been developed[4,5]. However, these schemes acquire data from only one slice after each DBIR preparatory period at the expense of SNR efficiency.



In this work we develop a simultaneous multi-slice DBIR-FSE scheme by using multi-band (MB) excitation pulses which excite several slices on each DBIR period. This improves SNR efficiency by √N for N slices and ensures that all the slices are affected by the same inversion time (e.g., the null point of blood). We developed MB DBIR-FSE for both Cartesian and radial k-space trajectories. The method is demonstrated here using radial k-space data because of the added advantage of yielding high-resolution T2 maps and TE images from a single breath hold acquisition[6,7].

METHODS: MB-RF pulses: MB pulses excite multiple parallel planes of magnetization simultaneously. The pulses are usually tailored to impart a specific phase offset to the slices relative to each other. This acts as a source of phase encoding and with an appropriate choice of the imparted phase the signal excited in the slice dimension can be resolved into individual slices. For a two-slice experiment one choice for RF phase encoding models the phase according to entries from the Hadamard matrix and requires the use of two different MB pulses. As illustrated in Fig. 1a, the first MB pulse imparts the same phase to both the excited slices while the second MB pulse imparts a 180° phase to one of the excited slices relative to the other[8]. The MB pulses can be generated by summing single band pulses with appropriate frequency offsets and phase modulation; the former controls the slice position in the excited slab and the latter controls the phase given to the slice. For Hadamard encoding this approach yields pulses that are comparable to ones that are generated by more sophisticated designs via the Shinnar-Le Roux (SLR) transform[9]. **Acquisition:** The radial MB DBIR-FSE pulse sequence was implemented at 3T (Siemens Skyra) by modifying the standard cardiac gated DBIR-FSE pulse sequence. Our implementation generates two slices (both acquired at the null point of blood) in a breath-hold. As illustrated in Fig. 1b, MB pulses for two-slice Hadamard encoding were designed and incorporated as the excitation pulse into a cardiac gated radial DBIR-FSE sequence. The radial views were acquired using a bit reversed view ordering to minimize the artifacts from T2 decay. The acquisition interleaves the MB pulses across TR's. The selective inversion and refocusing RF pulses are slab selective and cover both excited slices. Since the same radial views are acquired for both the MB pulses the signal can be separated into individual k-space data sets via the application of an inverse Hadamard transform and the slices of interest can be generated by a subsequent non-uniform fast Fourier transform operation. Images were acquired using an echo train length of 16, echo spacing of 9.2 ms, 192 radial views per slice, 256 readout points, and two 6mm slices in a 2cm slab. Other imaging parameters were: TR=1RR, 977 Hz/pixel, FOV= 430 mm. Radial k-space data were reconstructed off-line using customized software. The reconstruction yielded the following images per slice: an anatomical image (reconstructed using radial lines from all TE's), 16 TE images (reconstructed from undersampled TE data: 12 radial lines per TE), and a T2 map (generated from the TE images)[6,7].



RESULTS: Figure 2a shows representative anatomical (axial) images of the heart of the two slices acquired with MB DBIR-FSE in a <u>single breath hold</u>. Since the two slices are excited simultaneously at the null point of blood, the signal from blood flow is well suppressed in both slices. The two slices per breath hold were acquired without sacrificing spatial resolution or SNR. Since we used a radial k-space trajectory we are able to generate 16 TE images from each slice (only 3 out of 16 TE images are shown in Fig. 2b) an advantage over the Cartesian DBIR-FSE method which only yields a single TE image per k-space data set. Since the TE images are co-registered, by the nature of the FSE acquisition, a T2 map is automatically generated from them. Figure 2(c) shows colorized T2 maps of the left ventricle overlaid on the anatomical image.

CONCLUSION: A scheme for improving the slice efficiency of the DBIR-FSE pulse sequence via MB excitation is presented. Using the proposed scheme we acquire data from two slices simultaneously with the entire data acquisition window constrained to a single breath hold. As data from both slices are acquired simultaneously at the null point of blood the signal from blood is equally suppressed in both the slices. The method can be implemented with Cartesian or non-Cartesian trajectories. As shown in this work using a radial trajectory has the advantage of yielding images with various degrees of TE contrast and a quantitative T2 map for each of the two slices. All this information (2 slices x 16 TE images x T2 maps) is derived from data acquired in a single breath hold which significantly improves the current time efficiency of DBIR methods. The proposed scheme can be extended to excite more than two slices simultaneously.

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