Improving 3D MERGE Black-Blood Imaging Using An Additonal Time Delay and Compressed Sensing

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Purpose:

Among three-dimensional (3D) black blood techniques, the 3D motion-sensitizing driven equilibrium (MSDE) rapid gradient echo (3D MERGE) technique is a promising method. It uses the MSDE black-blood preparation which is demonstrated to outperform all other black-blood preparations and can achieve good blood suppression,[1] even in a large imaging volume.[2] However, the black-blood techniques based on MSDE are faced with the fact of signal loss.[2] There are two reasons mainly responsible for this problem. One is the effect of eddy currents generated by the high amplitude of motion sensitizing gradients in the prepulse [3], the other results from the intrinsic T2 decay during MSDE. In our work, an additional time delay (TD) was introduced to 3D MERGE sequence to improve signal intensity for vessel wall imaging.

Materials and Methods :

In order to improve signal intensity, a time delay (TD) was inserted into the 3D MERGE sequence (Fig. 1), and the compressed sensing (CS), an undersampling technique, was used to maintain a constant scan time. Here, we define this novel imaging sequence as TDCS-3D MERGE which utilizes the 3D MERGE with an additional TD and CS. After institutional review board approval and written informed consent, nine healthy volunteers (age 35±8 years, four males) were recruited for this study. MR images of the carotid arteries were acquired on a clinical 3T scanner (Signa TM; GE Medical Systems, Milwaukee, WI). All subjects were scanned in supine position using a body coil for excitation and an eight-channel phased-array bilateral carotid coil (GE Medical Systems) for signal reception. The procedures of vessel wall imaging were as follow: First, conventional 3D MERGE was fully acquired in the axial plane, and then five TDCS-3D MERGE scans were acquired in the identical plane. Each TDCS-3D MERGE scan was implemented with a combination of TD and acceleration factor (AF) to make the scan time constant. The scan time of 3D MERGE and each TDCS-3D MERGE were equal. Finally, a T1 weighted (T1W) 2D double inversion recovery fast spin-echo (DIR-FSE) imaging was performed to allow comparisons of the accepted DIR-FSE carotid wall imaging protocols with the proposed TDCS-3D MERGE imaging sequence for morphology measurements. Meanwhile, eight out of nine subjects were scanned with slice thickness of 1.6 mm in 3D MERGE and TDCS-3D MERGE for the purpose of statistical analysis, the other subject were scanned with slice thickness of 0.6 mm for the imaging at high isotropic spatial resolution and did not receive 2D T1W DIR-FSE imaging. Five TD values of 100, 200, 300, 400 and 500 ms were used. The corresponding AFs were 1.4x, 1.7x, 2.1x, 2.4x and 2.8x for 1.6 mm of slice thickness and 1.3x, 1.5x, 1.8x, 2x and 2.3x for 0.6 mm of slice thickness.

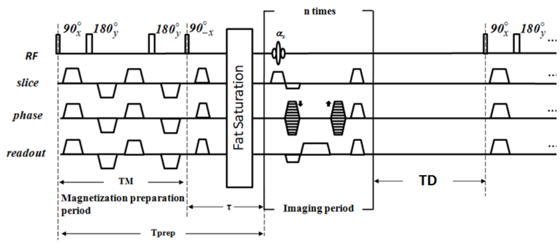

Fig. 1. Signal improvements for different T1 values by using a time delay in 3D MERGE.

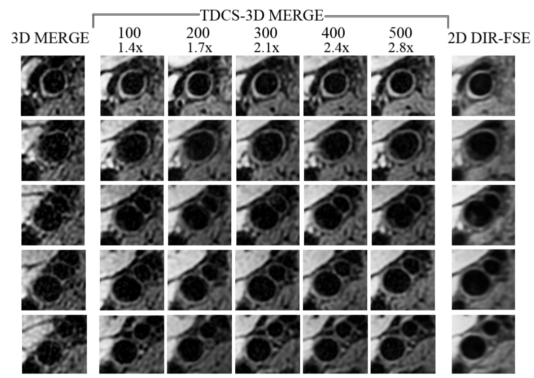

Fig. 2. Representative images with slice thickness of 1.6 mm.

Results:

Statistically significant differences between 3D MERGE and each combination of TDCS-3D MERGE were detected. The differences in wall-lumen CNR between 3D MERGE and each combination were statistically significant. For lumen SNR, there were no statistically significant differences ($P > 0.05$ for all paired t-test comparisons). Figure 2 shows representative images with five axial slices. It is observed that the delineations of outer vessel wall boundary and lumen-wall interface in 3D MERGE are obscure. In contrast, all of TDCS-3D MERGE images exhibit significant improvement of vessel wall signal, especially for TD values equal or more than 200 ms. In the aspect of blood suppression, all of TDCS-3D MERGE images exhibited good blood suppression efficiency which was consistent with that in 3D MERGE. Morphometric measurements of vessel wall area (WA) and lumen area (LA) made from the TDCS-3D MERGE with two (TD, AF) combinations of (300, 2.1x) and (500, 2.8x) and 2D T1W DIR-FSE images were highly correlated. Figure 3 shows images acquired at high isotropic spatial resolution imaging. Two board-certified radiologists concluded that all images of TDCS-3D MERGE exhibit visible improvement in outer vessel wall boundary and lumen-wall interface when compared with images from conventional 3D MERGE.

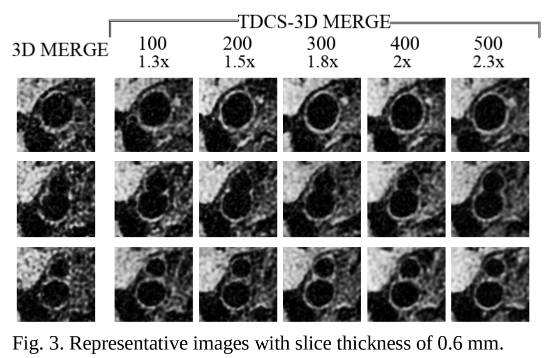

Fig. 3. Representative images with slice thickness of 0.6 mm.

Discussion:

Although long TD, greater than 500 ms, could be used for further signal improvement, it was not adopted due to the consideration of tissue contrast. Inserting an appropriate TD in the conventional 3D MERGE sequence can effectively decrease the SAR generated by the hard pulses of MSDE, and experimental results suggest that the stable and effective blood suppression can be achieved for all TDCS-3D MERGE scans.

Conclusions:

The TDCS-3D MERGE can significantly improve the image quality for 3D black-blood imaging, while the scan time is not prolonged. Therefore, it is believed that this technique could be valuable to provide fast and high-quality 3D vessel wall imaging.

References:

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