Suppression of High Intensity Flow Artifacts in Subtractionless First-Pass Peripheral Angiography with Dual-Echo Dixon Imaging

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Introduction

Flow gives rise to various artifacts in magnetic resonance imaging, including signal loss, misregistration, and ghosting. Flow compensation, notably in form of velocity compensation or moment nulling of the gradients, permits the suppression of most of these artifacts. However, it leads to longer echo and repetition times, which basically prohibit its use in applications with stringent scan time constraints, such as first-pass peripheral angiography. Recently, a subtractionless approach to first-pass peripheral angiography based on dual-echo Dixon imaging has been proposed and has been shown to provide higher signal-to-noise ratios than the established subtraction approach and to reduce motion artifacts [1]. In this work, a method is suggested that allows suppressing especially high intensity ghosting from pulsatile flow in this subtractionless approach without prolonging echo and repetition times, and it is evaluated on clinical examples of first-pass peripheral angiography.

Methods

The proposed method typically requires no changes to the bipolar dual-gradient-echo acquisition employed for chemical shift encoding-based fat suppression and thus maintains echo and repetition times. To eliminate high intensity ghosting from pulsatile flow, it detects substantial signal losses between the first and the second echo. These signal losses are due to the so-called even echo rephasing effect, which is illustrated in Fig. 1. While the zeroth moment of the readout gradient vanishes at both echo times, which are indicated by the dashed vertical lines, the first moment vanishes only at the second echo time. Therefore, the source images from the first echo are more prone to flow artifacts than the source images from the second echo. To exclude dephasing between water and fat signal as origin of the signal losses, the method requires them to be more opposed-phase at the first echo time than at the second echo time. High intensity ghosting is then suppressed by removing excessive signal intensity from the first echo and thus adapting the signal level in the first echo to the signal level in the second echo.

This method was applied in subtractionless first-pass peripheral angiography based on dual-echo Dixon imaging. After administration of 0.1 mmol/kg Gadobutrol (Bayer Healthcare, Berlin, Germany), patients were imaged on a 1.5 T Ingenia scanner (Philips Healthcare, Best, The Netherlands) with a 3D T_1-weighted spoiled dual-gradient-echo sequence (TE_1/TE_2 = 1.8 ms/3.0 - 3.2 ms) at three stations [1]. Resulting source images were processed with mDIXON to obtain water-only images [2], and maximum intensity projections were calculated from these water-only images along the anterior-posterior direction for the visualization of the vasculature.

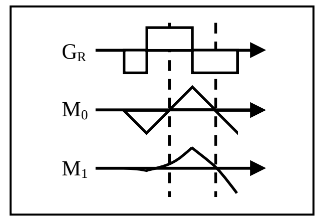

Fig. 1. Schematic illustration of the inherent velocity compensation of the second echo in a bipolar dual-gradient-echo acquisition. Shown are the readout gradient (G_R), and its zeroth (M_0) and first (M_1) moment.

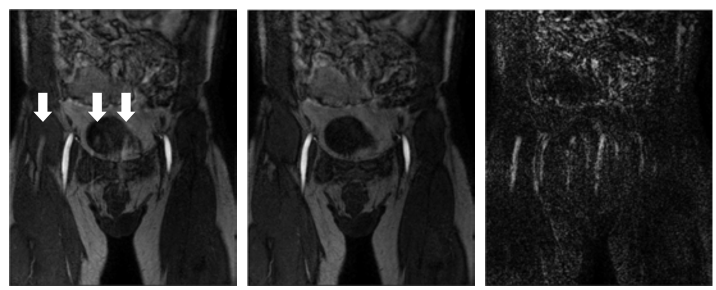

Fig. 2. Source images produced from the first (left) and the second (middle) echo of a bipolar dual-gradient-echo acquisition, and their difference (right).

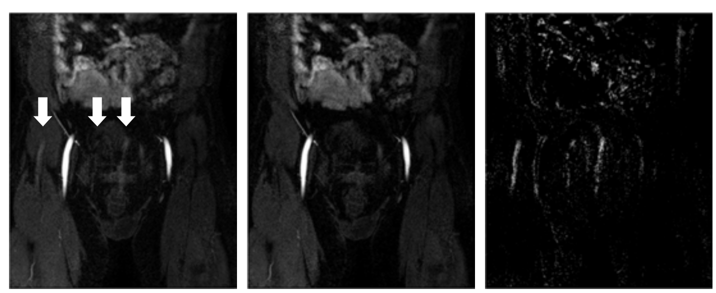

Fig. 3. Water images produced from a bipolar dual-gradient-echo acquisition without (left) and with (middle) the proposed flow artifact suppression, and their difference (right).

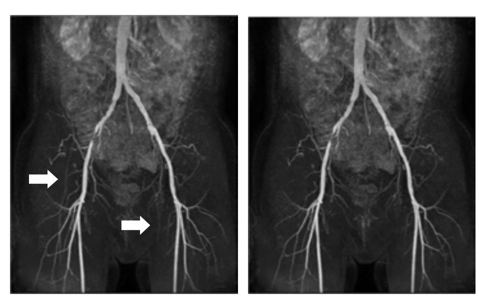

Fig. 4. Coronal maximum intensity projections of three-dimensional water images produced from a bipolar dual-gradient-echo acquisition without (left) and with (right) the proposed flow artifact suppression.

Results

The even echo rephasing effect is demonstrated in Fig. 2 on a selected slice from the aortoiliac station of one patient. Substantial ghosting is seen in the source image from the first echo (arrows), but not in the source image from the second echo. As evident from Fig. 3, it propagates, without flow artifact suppression, from the source image from the first echo into the water image (arrows), whereas this is prevented by the proposed method. A similar improvement is discernible in the maximum intensity projections in Fig. 4, which were obtained from the water images from the aortoiliac station of another patient.

Discussion

The proposed method efficiently eliminates high intensity ghosting from pulsatile flow retrospectively. Next to signal loss from turbulent flow, this is considered the most problematic artifact in first-pass peripheral angiography. The method does not address low intensity ghosting, since different echo times would be required for this purpose. However, this is usually of less concern in the visualization of the vasculature with maximum intensity projections. Finally, the method may be extended to also detect substantial signal losses from turbulent flow, but this has not been observed with the echo times employed in this work so far, not even behind high grade stenoses.

References

1. Leiner T, et al. Proc ISMRM 2012; 525. 2. Eggers H, et al. Magn Reson Med 2011; 65:96-107.