Compatible Dual-Echo Arteriovenography (CODEA) using an Echo-specific K-space reordering scheme

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Introduction

Time-of-flight (TOF) MR angiogram (MRA) (1) and blood oxygenation level-dependent (BOLD) MR venogram (MRV) (2) depict different neuronal and vascular abnormalities in brain diseases, hence it is desirable to acquire both of them in clinical brain imaging studies. A recent study has reported a new technical development relating to the simultaneous acquisition of TOF MRA and BOLD MRV with a dual-echo imaging technique (3). Despite this considerable advance, technical challenges remain in the simultaneous acquisition of MRA and MRV due to conflicting scan conditions required for the optimization of MRA and MRV, especially for the RF pulse conditions (i.e., excitation RF profile, flip angle, spatial presaturation pulse, MTC pulse). In this study, an echo-specific K-space reordering scheme is proposed to achieve dual-echo scan parameters compatible for both the MRA and MRV vascular contrast. Pursuant to this K-space reordering scheme, the scan parameter requirements for the MRA and MRV could be uncoupled and adjusted independently by maximally separating the K-space center regions acquired for the MRA from that for the MRV.

Material and Methods

All experiments were performed on a 3T whole-body scanner (Siemens Medical Solutions, Erlangen, Germany) with a vendor-supplied, circularly-polarized head RF coil. Three normal male volunteers who provided informed consent were scanned in this study approved by the Institutional Review Board.

A single-slab, dual-echo arteriovenogram was acquired with a 3D gradient echo sequence with the first-order flow compensation applied to both the slab-select and readout gradients and with the K-space reordering scheme demonstrated in Fig. 1. The initial ¼ of the K-space lines for the first echo were acquired at the end, while the final ¼ of the K-space lines for the second echo were acquired at the beginning along the 1^{st} PE axis, as shown in Fig. 1. According to this reordering scheme, the 1^{st} and 2^{nd} (PE) gradients in the second echo were designed and applied independently from those in the first echo (i.e., rewound and applied again in the middle). Imaging parameters were: TR = 50 ms, TE = 3.2 / 24 ms, acquisition bandwidth = 150 / 34 Hz/pixel, matrix size = 512×208×64, corresponding FOV = 220×179×88 mm^3, and NEX = 1. A partial Fourier sampling (75%) was employed to reduce the scan time and a slice oversampling (18%) to avoid a wrap-around artifact, both of them along the 2^{nd} PE direction. The scan time for a 3D dataset was 9.8 min. Partial (67%) and full echo samplings were used in the first and second echoes, respectively. The 1^{st} PE loop was located outside the 2^{nd} PE loop. The K-space center region in the first echo (TOF-weighted region in Fig. 1) was acquired with a minimum-phase ramped-profile RF excitation pulse with flip angle of 25° (20°–30°). On the other hand, the K-space center region in the second echo (BOLD-weighted region in Fig. 1) was acquired with a minimum-phase flat-profile RF excitation with flip angle of 15°. As the comparison reference to CODEA, the conventional single-echo TOF MRA and single-echo BOLD MRV were acquired in two separate imaging sessions with the scan parameters identical to those for the first echo (TOF-weighted regions) and the second echo (BOLD-weighted regions) of the CODEA, respectively, and applied to the entire single-echo K-space. A spatial presaturation pulse was applied for CODEA and single-echo TOF MRAs, and MTC pulse was not used for any acquisition so as to keep the specific absorption rate (SAR) low.

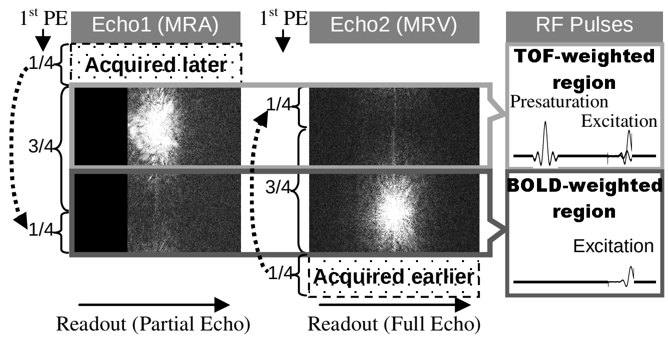

FIG. 1. **K-space distribution of CODEA**

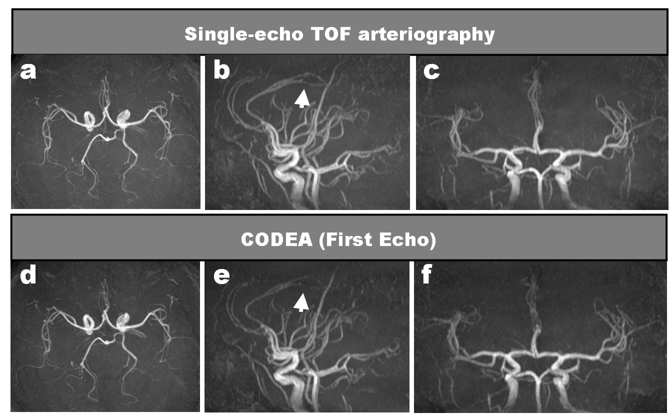

FIG. 2. **Comparison of TOF MRAs with single-echo and CODEA**

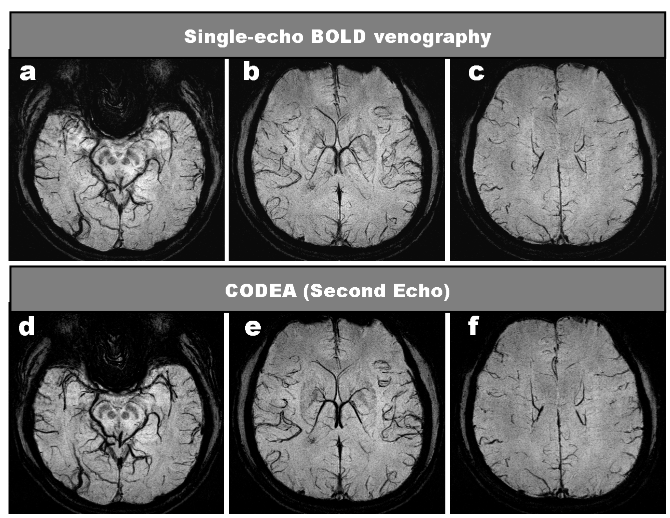

FIG. 3. **Comparison of BOLD MRVs with single-echo and CODEA**

Results and Discussion

The MRA's acquired using the CODEA technique were qualitatively comparable to those using the single-echo technique for all subjects (Fig. 2). A slight reduction in the vascular contrast was observed in some small downstream arteries (arrows in Fig. 2e). This is presumably due to the fact that the flip angle difference between the K-space center and edge regions was the highest in the downstream and that small downstream arteries are more likely subjected to the changes in the characteristics of the K-space edge region (as well as the K-space center region) than large anatomical structures. The vascular signal intensity shown in the sagittal and coronal projection images (Fig. 2e and f) was relatively uniform throughout the direction of blood movement, indicating that the expected signal degradation due to blood saturation was well compensated by the application of the ramped excitation pulse only to the K-space center region. In either CODEA or single-echo MRA, the spatial presaturation pulse was effective in suppressing venous signals (Fig. 2), accentuating the hyperintense arterial signal.

MRVs acquired with the CODEA and single-echo techniques were also qualitatively equivalent for all study subjects, even in the locations closer to the slab edge (Fig. 3f) where the flip angle difference between the K-space center and edge regions was the highest. The results suggest that the characteristics of the second echo in the CODEA MRV were predominantly determined by the flat excitation pulse applied only to the central K-space region.

Further study is required to evaluate the effect of different K-space reordering schemes on the echo-specific vascular contrast and its application to the optimization of the vascular contrast.

References

1. Wehrli et al, Radiology 160:781-785 (1986) 2. Reichenbach et al. Radiology 204:272-277 (1997). 3. Du and Jin, Magn Reson Med 59:954-958 (2008)