Effective Application of Multiple Overlapping Thin-Slab Acquisition and Magnetization Transfer Contrast Pulse to Compatible Dual-Echo Arteriovenography (CODEA)

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Introduction

A newly introduced compatible dual-echo arteriovenography (CODEA) is a technique for simultaneous acquisition of time-of-flight (TOF) MR angiogram (MRA) and blood oxygenation level-dependent (BOLD) MR venogram (MRV). The technique improved the previous dual-echo MRA/MRV technique (1), by maximally separating the K-space center regions for the two echoes achieved through an *echo-specific K-space reordering scheme* and by applying scan parameters compatible between the MRA and MRV. Because of the less restriction to the RF pulse parameters (e.g., excitation RF pulse profile, flip angle, MTC pulse), MRA (first echo) and MRV (second echo) can be acquired with optimal RF pulse parameters for each K-space center region. Pursuant to the echo-specific RF pulse parameters, the multiple overlapping thin-slab acquisition (MOTSA) and MTC pulse were incorporated into the CODEA and their effectiveness was assessed on improved image quality.

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 were scanned.

For the CODEA technique, a double-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 a K-space reordering scheme* where 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 1st PE axis. Imaging parameters were: TR = 50 ms, TE = 3.2 / 24 ms, acquisition BW = 150 / 34 Hz/pixel, matrix size = 512×208×32, corresponding FOV = 220×179×44 mm^3, gap between the two slabs = −5 mm, NEX = 1, and total scan time = 9.8 min. Partial (67%) and full echo samplings were used in the first and the second echoes, respectively. The 1st PE loop was located outside the 2nd PE loop. The K-space center region in the first echo (TOF-weighted region) was acquired with a minimum-phase ramped excitation pulse with flip angle of 25° (22.5°–27.5°) and with a spatial presautration pulse, and the K-space center region in the second echo (BOLD-weighted region) with a minimum-phase flat-profile RF excitation with flip angle of 15°.

For the non-CODEA technique (as the comparison reference to CODEA), a dual-echo arteriovenogram was acquired *without K-space reordering scheme* with the scan parameters identical to the abovementioned double-slab CODEA except flip angle of 20°, flat RF excitation profile, sequentially-increasing PE mode, and no presaturation pulse, all of which were applied to the entire K-spaces of both echoes.

To examine the effects of MTC pulse, two single-slab CODEA datasets were additionally acquired without and with an MTC pulse. Scan parameters for these single-slab acquisitions were identical to the abovementioned double-slab CODEA except for the matrix size of 512×208×64 and corresponding field of view of 220×179×88 mm^3. Only for the single-slab acquisition with the MTC pulse, the spatial presaturation was not applied to maintain the specific absorption rate low and TR was increased to 58 ms to accommodate the MTC pulse.

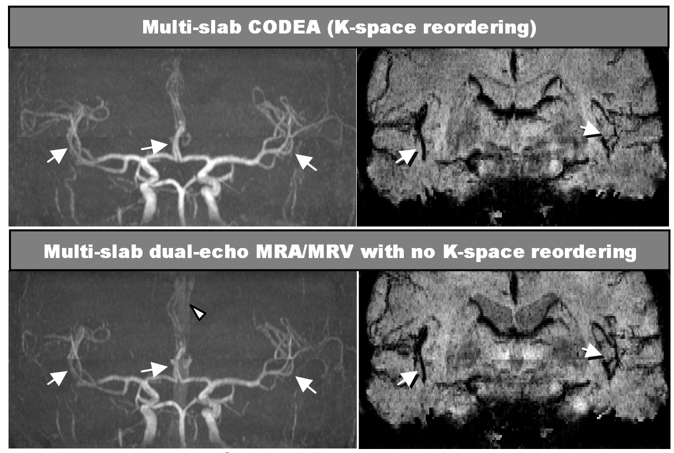

FIG. 1. **Comparison of multi-slab CODEA and multi-slab dual-echo MRA/MRV without the K-space reordering scheme**

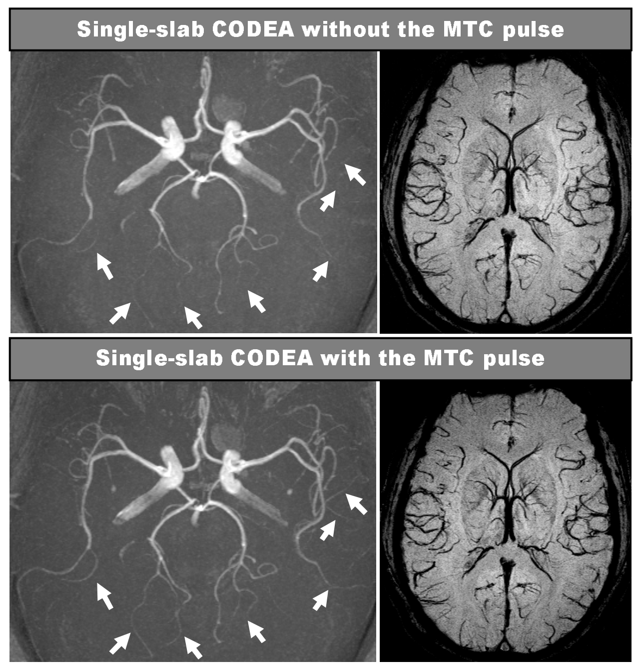

FIG. 2. **Comparison of CODEA without and with the MTC pulse**

Results and Discussion

Multi-slab (double-slab) CODEA MRA demonstrated uniform signal intensity and seamless vascular continuity in the overlapping and adjacent slices in the slabs (arrows in Fig. 1a), while the non-CODEA MRA showed spatially-varying signal intensities in the same area (arrows in Fig. 1c). Two additional drawbacks of the non-CODEA MRA observed in all the subjects were a reduced vascular contrast (because of decreased inflow enhancement with the intermediate flip angle) and signals from large veins (which could not be eliminated without an appropriate spatial presaturation pulse) (arrowhead in Fig. 1c). Unlike the MRA, no considerable differences in MRV image quality were observed between the double-slab CODEA and non-CODEA techniques, with equally uniform and continuous MRV signal intensity in the overlapping and adjacent vessels (arrows in Fig. 1b and d).

The MTC pulse selectively suppressed the background tissue signal in the MRA, thus enhancing the arterial contrast for all the subjects (arrows in Fig. 2a and c). The tissue signal intensity in the CODEA MRA with the MTC pulse was reduced by 13 ± 2% ($N = 3$) compared to that without the MTC pulse. On the other hand, the effect of the MTC on the CODEA MRV was negligible (Fig. 2b and d): the tissue signal intensity increased by 4 ± 5% ($N = 3$) with the MTC pulse. Note that tissue T_1 is 1−1.5 s at 3T (2) and that the tissue signal intensity is expected to increase by approximately 6% with the TR increase (from 50 to 58 ms) at the given flip angle (15°). This calculation along with our background tissue signal measurements again indicates that the MTC had little effect on the CODEA MRV.

These preliminary results showed that techniques commonly used in conventional 3D TOF MRA such as MOTSA and MTC pulse could be readily incorporated into the CODEA. Compared to the single-slab acquisition, the MOTSA technique improved the visualization of small blood vessels in our study (data not shown), as reported in a previous study (3). On the other hand, the tissue SNR (hence venous CNR) in the CODEA MRV is expected to be higher in the single-slab acquisition than in the MOTSA. This trade-off in the MRA/MRV vascular contrast, which is associated with the number of the slabs, cannot be resolved in the CODEA method.

References

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