

Middle cerebral artery (MCA) vessel wall imaging using T1-enhanced iMSDE

Jinnan Wang¹, Niranjana Balu², Peter Börner³, and Chun Yuan²

¹Philips Research North America, Briarcliff Manor, NY, United States, ²University of Washington, ³Philips Research Europe

Introduction Intracranial atherosclerotic disease (IAD) represents 9-15% of all the ischemic strokes in US¹ and its prevalence can be even higher in certain populations². It is suggested as the most common cause of stroke worldwide³. According to an autopsy study on 300+ subjects, approximately 40% of all IAD does not present any luminal stenosis but rather presents only outer wall remodeling⁴. In all IADs, the ones rooted in the middle cerebral artery (MCA) are of particular importance due to the key area it serves. It is therefore desirable to measure MCA vessel wall size using imaging approaches. A number of MR techniques have been proposed for MCA imaging⁵⁻⁷, but they are either limited by the outer wall boundary contrast or by the lack of sufficient flow suppression. The goal of this study is to propose a modified iMSDE (improved Motion-Sensitized Driven-Equilibrium⁸) prepared MCA imaging technique that can accurately visualize the intracranial vessel wall (IVW) in vivo.

Methods Pulse Sequence Design A challenge in MCA imaging is the differentiation between the outer wall boundary and the brain tissues. They usually demonstrate similar signal behaviors due to similar T1s. On elderly patients, however, certain amount of cerebrospinal fluid (CSF) can often be found within the lateral cerebral fissure, providing a unique contrast in delineating MCA outer wall boundary. Due to the very long T1 of CSF, a T1 weighted sequence can create a CSF suppression effect on images. The pulse sequence of this technique is shown in Fig.1. The T1 enhanced iMSDE sequence utilized an inversion pulse (IR) immediately before the iMSDE module to further suppress the cerebrospinal fluid signal with added T1 weighting. The 3D k-space was acquired in a low-high fashion to maintain the black-blood contrast. The minimum TR for each gradient echo was used to restrict the total scan time.

Parameter Optimization To optimize the echo train length (TFE factor) for the best vessel wall characterization, a Bloch equation based simulation was used to determine the signal level when the center of the k-space was acquired. To create a strong contrast for vessel wall characterization, the ratio $r = S_{\text{wall}} / (S_{\text{lumen}} + S_{\text{CSF}})$ was

used as a measure of the visibility of the MCA wall. A higher ratio indicates more preferred parameters for the IVW imaging.

MR Imaging and post-processing In this IRB approved study, six healthy subjects (Age: 32-67) were scanned after obtaining their informed consents. All scans were acquired using a 3T clinical scanner (Philips Achieva R3.2, the Netherlands) with 16-channel phased array brain coil. The IVW imaging volume was planned based on a multi-slab TOF localizer. Benefited from iMSDE's insensitivity to the flow direction, coronal acquisition was used to maximize the coverage in the foot-head direction. The imaging plane was also usually properly angled to accommodate the structural variation among individuals. The imaging parameters were: 3D T1 enhanced iMSDE prepared TFE, TR/TE 10/4.8ms, flip angle 10°, FOV 160×160×32mm³, Matrix 200×200×40, NSA 1, total imaging time: 4min19sec. Images were zero-padded to 0.4×0.4×0.4mm³ and reformatted to the cross-sectional direction along artery centerlines for vessel wall visualization.

Results Parameter Optimization The TFE factor optimization plot is shown in Fig. 2. The wall signal ratio saturates once the TFE factor increases beyond 48. To avoid a recovery of blood signal in the peripheral of k-space, the lowest TFE factor of 48 was used in the protocol.

MR imaging Successful blood suppression was achieved on all subjects across a large range of the FOV – even on the tortuous segments of the arteries. More segments of outer wall boundaries were successfully visualized on elderly subjects compared to their younger counterparts. As shown in Fig.3, MCA vessel wall were successfully visualized on major (b-d) MCA segments for a 67 year old subject. Small lateral branches of MCA (e, f) were also well visualized.

Conclusion A T1 enhanced iMSDE sequence was proposed to characterize middle cerebral artery vessel wall. Both luminal and outer wall boundaries of the MCA segments can be accurately characterized using this sequence.

References: 1. White H et al, Circulation 2005. 2. Wityk RJ et al, Stroke 1996. 3. Gorelick et al, Stroke 2008. 4. Mazighi M et al, Stroke 2008. 5. Klein IF et al, Neurology 2006. 6. Qiao Y et al, JMRI 2011. 7. van der Kolk AG et al, Stroke 2011. 8. Wang et al, JMRI 2010.



Fig. 1 Pulse sequence of the T1 enhanced iMSDE for MCA vessel wall imaging, with an optimized TFE readout of approximately 500ms. IR for CSF saturation and iMSDE for blood suppression.

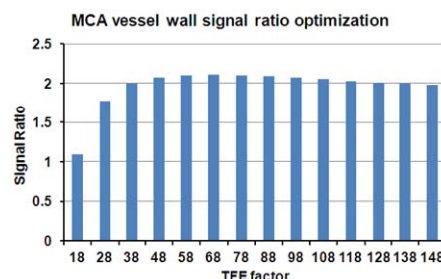


Fig. 2 TFE factor optimization for MCA vessel wall imaging. The signal ratio is defined in the *Methods* section. The signal ratio saturates after the TFE factor increases beyond 48. To avoid k-space filling effect, TFE factor 48 was used in the final protocol.

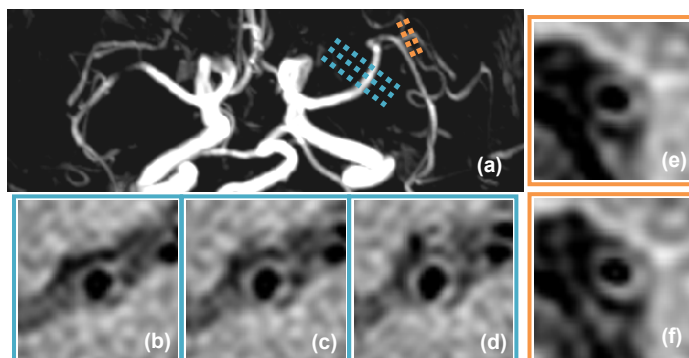


Fig. 3 Sample MCA images acquired on a 67yo volunteer. MIP of the intracranial arteries was shown in (a), on which the dotted lines indicate where the cross-sectional images were acquired. MCA segments (b-d, cyan dotted lines) demonstrated good blood suppression and nice outer wall boundary delineation. Small lateral branches of MCA (e, f, orange dotted lines) were also well visualized.