Whole-brain intracranial arterial wall imaging at 3 Tesla: 3D TSE with CSF attenuation and enhanced T1 weighting

Zhaoyang Fan[1], Qi Yang[1,2], and Debiao Li[1]

[1]*Biomedical Imaging Research Institute, Cedars-Sinai Medical Center, Los Angeles, California, United States,* [2]*Radiology, Xuanwu Hospital, Beijing, China*

Introduction: The intracranial artery system can be involved in arterial wall disease such as atherosclerosis and vasculitis. High resolution dark-blood MRI has been used to evaluate the intracranial arterial wall and provide findings indicative of wall thickening, intraplaque hemorrhage, or inflammation. T1-weighted 3D variable-flip-angle TSE has gain popularity in this research area due to its high time efficiency, large spatial coverage, isotropic acquisition, and the ability to reveal high-T1-signal wall abnormalities either pre or post gadolinium contrast injection [1-3]. However, several limitations remain with the technique. First, the signal of cerebrospinal fluid (CSF) is not adequately suppressed. It can be challenging to discern the outer boundary of smaller vessels, e.g. the distal segments of the middle cerebral arteries (M2 and M3), and thus potentially difficult to depict positive wall remodeling. Second, spatial coverage is limited in previous studies at 3T mainly because of the conflicting requirements on scan time, signal-to-noise ratio, and desired spatial resolution. As a result, lesions at small arteries could be missed. The aim of this work was to develop a 3D TSE technique that provides CSF attenuated 0.5-mm isotropic resolution whole-brain wall imaging within a reasonable scan time.

Methods: *Sequence* Inversion recovery was utilized to enhance T1-weighting and partially suppress CSF signals. To maximize T1 contrast, a method previously developed for optimal T1-weighted brain tissue imaging was adopted [4]. Specifically, a restore radio-frequency pulse module with the last pulse being –90 is applied at the end of each TSE echo train; this allows the remaining magnetization of each of tissues, after the long three-stage T2 decay, to be transferred to the -z axis, and subsequently all tissues start to undergo inversion recovery. Due to the whole-brain coverage, a nonselective excitation RF pulse can be employed, which helps reduce echo spacing and achievable TE. To avoid signal modulation, the first echo of each train is skipped. *Human Study* Seven volunteers (4F 3M, 32-65 yo) were scanned on a 3T system (Siemens Verio) using a 32-channel head coil. The conventional 3D TSE sequence (denoted as SPACE) and the modified sequence (IR-SPACE) were performed in a random order. The common imaging parameters included: sagittal orientation, TR/TE 800/10 ms, FOV 180x200 mm^2, matrix 346x384, resolution 0.5 mm, scan time = 12 min. Echo train length was chosen as 37 to yield adequate signal intensity and T1 weighting while shortening scan times. In the 3 of 7 subjects, gadolinium (OptiMark) was also administered followed by an additional IR-SPACE scan. *Data Analysis* To evaluate the contrast gain and loss when using IR-SPACE vs. SPACE, the contrast ratios (**CR** = [Sa-Sb]/Sb) between white matter and gray matter, between the wall and CSF, and between the wall and lumen were measured. Additionally, the sharpness (the maximal slope along the manually drawn line intersecting the vessel wall) at the outer boundaries was measured using in-lab MATLAB program for following segments: distal basilar, supraclinoid (C4) segment of the internal carotid artery (ICA), M1, M2, and M3 of the middle cerebral artery (MCA).

Results: Increased T1-weighting was observed when using IR-SPACE and confirmed by the increased white-gray matter CR (0.26 vs. 0.20, p=0.033). The use of inversion recovery slightly sacrificed the wall signal and thus reduced the wall-lumen CR (5.56 vs. 7.75, p=0.025), but significantly improved the contrast between the wall and surrounding CSF (0.59 vs. 0.12, p<0.001). Wall sharpness was significantly improved (t-test p<0.001) when all segments were assessed together (**Fig. 1**), although the basilar artery showed little improvement because fast-flowing CSF at this location can be well attenuated by the inherent SPACE dark-blood effect. This facilitated the visualization of outer wall boundary, particularly at M2 and M3 (**Fig. 2**). In 3 volunteers, wall thickening and mild stenosis were observed in IR-SPACE and two of them showed pre-contrast high-T1-signal (**Fig. 3**). However, they were not revealed by the conventional SPACE, presumably due to the lack of inversion recovery. In 2 of the 3 subjects who received contrast, post-contrast enhancement was observed which respectively indicated atherosclerotic inflammation (eccentric enhancement) at the MCA (**Fig. 4**) and vasculitis (concentric enhancement) at the vertebral (**Fig. 5**) arteries.

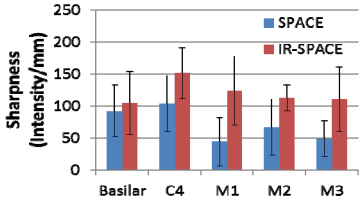

Fig. 1 Sharpness measurement

Discussion and Conclusion: In this study we developed a whole-brain T1-weighted intracranial arterial wall imaging technique. The preliminary data has shown that the technique offers good image quality and sharper delineation of outer wall boundary as well as enhanced T1 contrast weighting. It is expected that the technique would be useful in the assessment of both plaque burden and high-T1-signal wall abnormalities in the incracranial artery wall. Patient studies are underway to validate its clinical utility. Further reduction in the scan time will be warranted to make the technique more clinically practical.

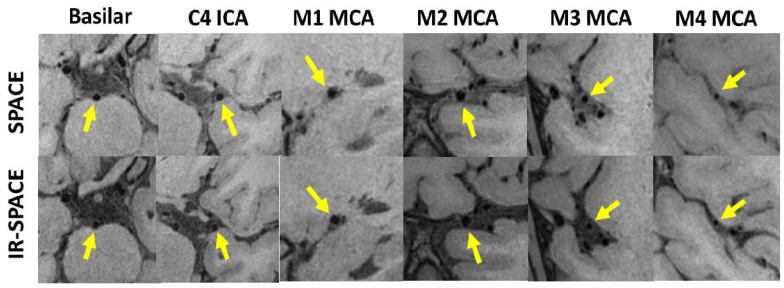

Fig. 2 IR-SPACE better depicts wall outer boundary due to attenuation of CSF

References: [1[Qiao Y et al. Radiol 2014;271:534. [2] Sakurai K et al. J of Neuroradio 2013;40:19. [3] Ryoo S, et al. Stroke 2014;45-2457. [4] Park J et al. Magn Res Med 2007;58:982. [5] van der Kolk AG et al. Eur Radiol 2013;23:2996.

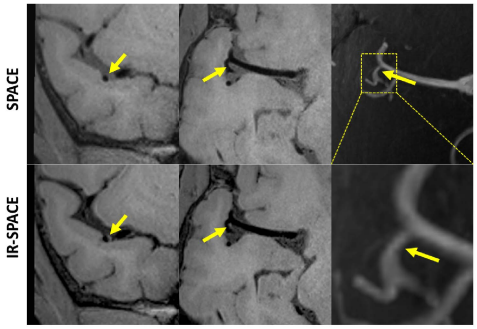

Fig. 3 Mild wall thickening and stenosis (confirmed by TOF) is shown in a 65 yo volunteer with IR-SPACE but not with conventional SPACE.

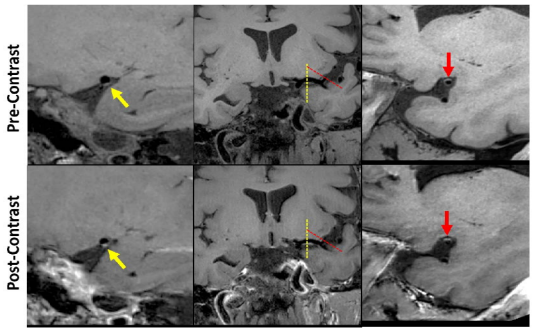

Fig. 4. Eccentric enhancement indicative of wall atherosclerosis inflammation is shown in a 50 yo volunteer at the MCA M1 and M2.

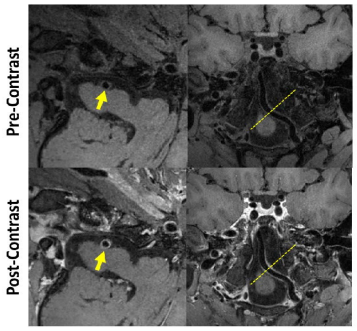

Fig. 5. Concentric enhancement indicative of vasculitis is shown in a 39 yo volunteer at the vertebral artery.