High Resolution Three Dimensional Intracranial Arterial Wall Imaging at 3T Using SNR-optimized T1 Weighted SPACE

Lei Zhang[1,2], Qing Zhai[3], Na Zhang[1,2], XiaoXin Tong[3], Xin Liu[1,2], and Yiu-cho Chung[1,2]

[1]*Paul C. Lauterbur Research Center for Biomedical Imaging, Shenzhen Institution of Advanced Technology, Chinese Academy of Sciences, Shenzhen, Guangdong, China,* [2]*Shenzhen Key Laboratory for MRI, Shenzhen, Guangdong, China,* [3]*Department of Neurology, Peking University Shenzhen Hospital, Shenzhen, Guangdong, China*

Introduction: Intracranial atherosclerosis is a major cause of ischemic stroke [1]. Luminographic techniques such as CT, TOF and MRA cannot depict vessel walls and have limited ability in identifying vulnerable plaques. Dark blood 2DTSE techniques have been used for ICA vessel wall imaging (e.g., [2]), but they suffer from low scan efficiency, partial volume effect [3] and limited anatomical coverage for the tortuous vessels. T2 prepared VISTA has been proposed for this purpose [4] at 7T. Yet the need for ultrahigh field system limits its clinical utility. At 3T, a spatial resolution of 0.5mm can be achieved in 8 min with VISTA using a long TR, relatively short TE and long echo train [5]. This technique's proton density contrast may have limited value in plaque characterization where fibrous cap of plaques and their lipid cores are better depicted by T1 weighting. T1w-SPACE [6] has been proposed for this application [7]. Here, we evaluated the performance of T1w-SPACE in ICA vessel wall imaging and its clinical relevance in patients.

Materials and Method: Imaging parameters for T1w SPACE: The sequence should (1) give good contrast between CSF and vessel wall (since intracranial vessels are surrounded by CSF), and (2) have sufficient spatial coverage to include major vessels in that region. To understand the effect of various imaging parameters on the two requirements, Bloch equation simulation was performed based on 3T field strength. Tissue relaxation times were: vessel wall T1/T2=1200ms/70ms, CSF T1/T2=4300ms/2200ms. TR was varied from 500ms to 2000ms, and the corresponding contrast between vessel wall and CSF, normalized against spatial coverage, was plotted against TR for scan times of 8, 10 and 12min. Other simulation parameters were: 320 phase encoding lines, echo train length (ETL)=33; TE=25ms; echo spacing (ESP)=5ms.

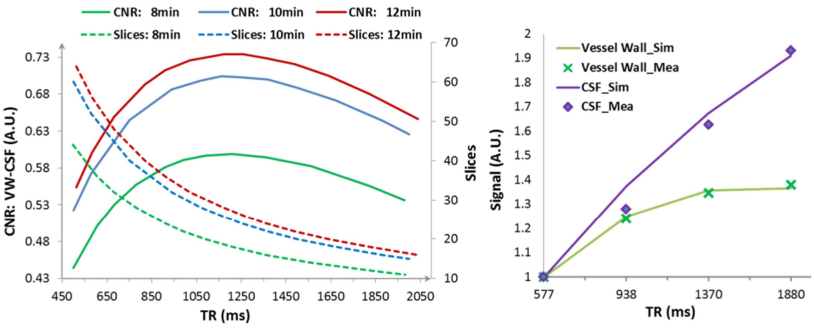

Fig. 1 (a) CNR as a function of TR at a scan time of 8min, 10min, 12min (normalized by slice number); (b) experimental results versus simulation results (normalized).

Volunteer study: The simulation results were verified by an IRB approved volunteer study. A 3T MRI system (Magnetom TIM Trio, Siemens, Erlangen, Germany) together with a 32-channel head coil was used for the experiments. Based on simulation, a scan time of 10min was used for *in vivo* validation due to CNR efficiency consideration. 4 healthy volunteers were recruited with informed consents. Intracranial arteries were scanned using T1w-SPACE with these parameters: FOV=160mm×160mm; partition thickness=0.5mm; ETL=33; ESP=5ms; base matrix=320×320 (isotropic voxel size of 0.5mm); bandwidth=500Hz/pixel, TR was varied from 577ms (52 partitions) to 1880ms (16 partitions); TE=25ms; no iPAT was used.

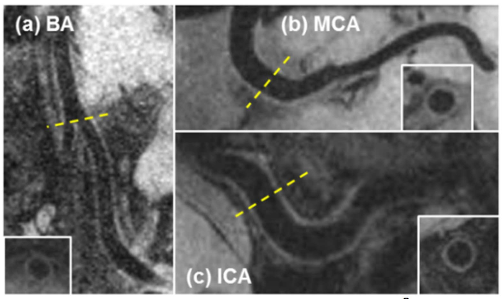

Fig. 2. 3D T1w-SPACE images (0.5mm^3 isotropic) of intracranial vessel wall of a healthy volunteer. (a) basilar artery (BA); (b) middle cerebral artery (MCA); (c) petrous internal carotid artery (ICA).

Patient study: Six patients (all with informed consent) with clinically confirmed cerebrovascular ischemia were scanned. Choice of imaging parameters for T1w SPACE was guided by both simulation results and clinical needs. Fig. 1 (a) showed that a TR of 1160ms gives highest SNR but the slab covers only 13 mm. To ensure the slab includes most of the 3 major intracranial vessels (middle cerebral artery, basilar artery and petrous internal carotid artery), a 35-40mm thick slab is needed. Priority is thus given to spatial coverage. Imaging parameters for T1w-SPACE were identical to the volunteer study except for two changes. Firstly, TR=800ms, and spatial coverage was maximized within a 10 min scan time. The TR chosen decreases CNR by 8.8% but increases spatial coverage by 35% (26 slices to 40 slices). Secondly, parallel imaging (iPAT) rate 2 was used, and the number of partitions was again maximized. The SNR degradation is governed by the g factor (close to 1 with a 32 channel coil). This protocol was evaluated in 3 healthy volunteers for image quality. In patient imaging, localizers were first used, followed by 3D TOF (TR/TE=24/3.91ms; flip angle=18°; voxel size: 0.4×0.4×0.5 mm^3; iPAT=2; scan time=6.3min). T1w SPACE images were then acquired. One dose of Gd-based contrast agent was injected to the patient and identical T1w SPACE was repeated post-contrast. Vessel wall images were evaluated by visual inspection for enhancement of arterial wall.

Results: The studies were successful completed in both healthy volunteers and patients. Volunteer study agreed with numerical simulation (Fig.1b). CNR between vessel wall and CSF was highest with TR of 1160ms and a 10min scan time showed the best CNR efficiency. Vessel wall was visualized in all the major intracranial arteries (Fig.2: TR=1160ms, iPAT=2). In the patient study, vessel walls were enhanced in all patients. ICA images from one patient were shown in Fig.3. TOF (a) showed no apparent stenosis at MCA, but on pre-contrast images (b), eccentric wall thickening at M1 segment of MCA was visualized. Post-contrast images (c) showed the enhanced MCA. The TOF-based MR angiogram and the dark blood images matched each other.

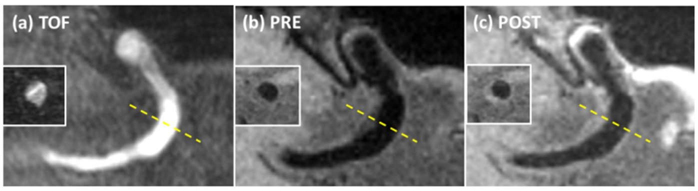

Fig. 3 A 60-year-old man with TIA of the right MCA territory. (a) TOF shows no apparent stenosis; (b) T1w-SPACE shows focal eccentric wall thickening of the MCA; (c) after gadolinium administration, T1w-SPACE shows an eccentric wall enhancing plaque on the anterior wall of the right MCA.

Discussion and Conclusion: The Bloch equation simulation showed the relationship among various imaging parameters affecting CNR of T1w-SPACE and greatly facilitates the choice of imaging parameters for it. At a isotropic spatial resolution of 0.5mm, T1w-SPACE can be used to visualize vessel wall pre- and post-contrast sequence. The technique may be used to screen intracranial arterial diseases in patients with high risk of ischemic stroke.

References: [1] Mazighi M et al., Stroke 30:1142, 2008; [2] Swartz RH et al., Neurology 72:627, 2009; [3] Antiga L et al., MRM 60:1020, 2008; [4] A.G. van der Kolk et al., Stroke 42::2478, 2011; [5] Qiao Y et al., JMRI 34:22, 2011; [6] Park J et al., MRM 58; 982, 2007; [7] Chung YC et al., Proc. 18th ISMRM, p.2255, 2010.

Acknowledgements: This research is supported by Shenzhen Key Laboratory for MRI, China: CXB201104220028A.