A New Approach for Noncontrast MR Imaging of Carotid Artery Disease

Na Zhang[1,2], Anqi Pei[3], Lei Zhang[1,2], Xiaoxin Tong[3], Xin Liu[1,2], and Yiu-Cho Chung[1,2]

[1]Paul C. Lauterbur Research Centre for Biomedical Imaging, Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen, Guangdong, China, People's Republic of, [2]Key Laboratory of Health Informatics, Chinese Academy of Sciences, Shenzhen, Guangdong, China, People's Republic of, [3]Department of Neurology, Peking University Shenzhen Hospital, Shenzhen, Guangdong, China, People's Republic of

Introduction Carotid artery disease is commonly examined by color Doppler and takes about 20 minutes. Studies [1-2] suggested that MRI is a better imaging modality as it can characterize plaque components and allows the assessment of plaque vulnerability. Using 2D imaging techniques, a standard protocol for carotid plaque examination takes about 45 minutes and Gd-based contrast agent is needed [3].The technique has several limitations compared to color Doppler. Firstly, the need for Gd-based contrast agent excludes patients with renal insufficiency. Secondly, the long scan time compared unfavorably with color Doppler, and thirdly, the coverage is limited to carotid bifurcation and sometimes carotid plaque may extend beyond that region [4]. In light of these limitations, we propose here a multi-contrast three dimensional (3D) carotid vessel wall imaging protocol without the use of Gd-based contrast agent. Preliminary evaluation on volunteers and patients found that the scan times were comparable to that of color Doppler examinations.

Methods Protocol: Protocol development was based on a 3.0T whole-body MRI system (MAGNETOM TIM Trio, Siemens, Germany). Three sequences were used. T1w SPACE [5] gives good contrast between plaque and vessel wall. The strong T2 contrast in T2w SPACE [6] helps identify various plaque components [7]. MPRAGE has very good sensitivity to hemorrhage [8]. Also, blood signal in MPRAGE is much less sensitive to flow velocity, and hence is useful in identifying flow artifacts that may appear in the other two sequences. High resolution 3D TOF imaging was not performed as its diagnostic value is unclear [9]. Proton density weighted imaging was not used due to its low imaging efficiency. Table 1 shows the imaging parameters used in the protocol. Imaging: The study was IRB approved. 7 healthy volunteers (5 male, age 24-39) and 3 patients (male, age 52-62) with clinically confirmed cerebrovascular ischemia and carotid plaque build-up (using color Doppler) were recruited for this study. Informed consent were obtained form all participants. A specially designed 8-channel carotid coil (4 channels on each side) was used for signal reception. For each subject, scout was first performed, followed by a very low resolution time of flight (TOF) scan to help localize the carotid artery bifurcation (Fig.1). The 3 protocols described above were then performed. Image analysis: 3D images from the three protocols were visualized using graphical tools available on a workstation (Leonardo, Siemens, Germany). To help identify plaque features and flow artifacts, the three image sets were co-registered using Syngo Fusion (Siemens, Germany) (two at a time). Two reviewers assessed the quality of the images from the three protocols using a four-point score as follows: score 4 = excellent display of vessel wall shape, lumen and plaque components; score 3 = good visualization of plaque components but moderate display of vessel wall and lumen; score 2 = moderate display of vessel wall, lumen and plaque components; score 1= poor display of vessel wall, lumen and plaque components or motion artifacts. The image quality scores were analyzed statistically using SPSS version 17.0 (Chicago, IL).

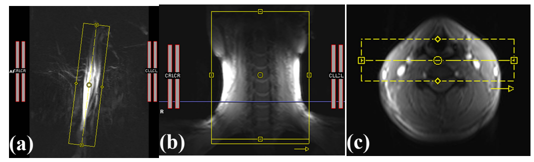

Fig.1 Localizing the 3D imaging slab using the TOF and scout images.

Table 1 Imaging parameters used in the study. Fat saturation was used for all techniques.

	TR/TE (ms)	Band-width	# of slices	Spatial resolution	Scan Time	Echo train/TI	Parallel imaging	flip angle
T2w-SPACE	1900/186	574 Hz/px	56	0.7 mm3	3 :33 min	59/-	iPAT	variable
T1w-SPACE	700/22	751 Hz/px	56	0.7 mm3	3 :55 min	39/-	iPAT	variable
MPRAGE	1300/5.98	240 Hz/px	88	0.6 mm3	4 :30 min	-/630	No	12°

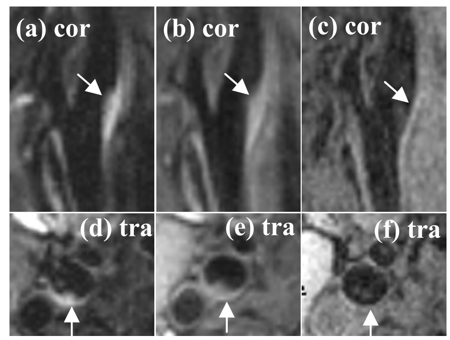

Fig.2 The representative images of T2w-SPACE (a, d), T1w-SPACE (b, e), and MPRAGE (c, f) from a healthy volunteer.

Results 3D images were successfully obtained from all subjects. The average scan time for each subject was 13 minutes. Table 2 shows the average image quality score of the 3D image sets from 2 reviewers. Image quality of MPRAGE is comparatively lower than the other two image sets. Compared to T1w SPACE and T2w SPACE, blood in MPRAGE was grey and vessel wall was well depicted. Its different contrast mechanism helps identify flow artifact in the two TSE based image sets. Fig.2 showed representative images of T2w-SPACE, T1w-SPACE, and MPRAGE acquired from a healthy volunteer. The plaque-mimicking flow artifacts (arrows) shown on T2w- and T1w-SPACE images were easily identified from the registered MPRAGE images. Fig.3 showed images from one carotid artery disease patient. The plaque at the bifurcation matched the results from color Doppler except that the latter missed the plaque 42.5mm away from the carotid bifurcation.

Table 2 The image quality score (mean ± standard deviation) of the three imaging protocols.

	T2w-SPACE	T1w-SPACE	MPRAGE
Health Volunteers	2.50 ± 0.57	2.91 ± 0.64	1.84 ± 0.70
Patients	3.38 ± 0.57	3.42 ± 0.71	2.46 ± 0.77
Total	2.76 ± 0.69	3.06 ± 0.69	2.02 ± 0.77

Discussions The proposed non-contrast 3D carotid vessel wall imaging technique can be completed in about 13 minutes and provides high isotropic spatial resolution images of 0.6-0.7 mm^3. Use of coronal plane and 3D imaging simply workflow significantly compared to the standard 2D approach where carotid bifurcation must first be identified before imaging planes can be prescribed. Registration of 3D images among different contrasts helps match up anatomical details and identify flow artifacts. The different signal contrast in images acquired from the three protocols help characterize plaque components complementarily. Image quality of T1w and T2w images are generally good. The low image quality of MPRAGE may be attributed to the relatively low SNR. Our preliminary found that when longer TR and TI are used, image quality of MPRAGE was significantly improved.

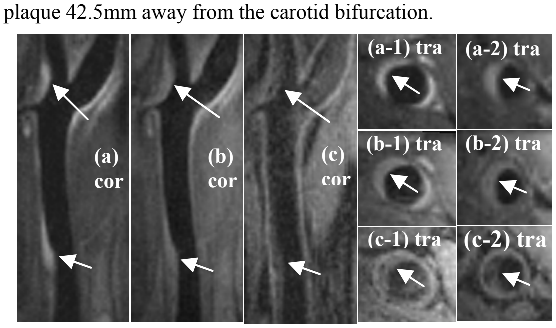

Fig.3 The typical plaque images of T2w- (a) and T1w-SPACE (b), and MPRAGE (c) from a patient with CIS and color Doppler confirmed plaque. The bright signal of the plaque at bifurcation (long arrows) in T2w image suggested the inflammation. The heterogenous signal intensity of the plaque suggested the complex plaque, hence the high-risk plaque.

Conclusion The preliminary study demonstrated that non-contrast 3D carotid vessel wall imaging with examination time comparable to color Doppler is clinically feasible. It allows visualization of plaque morphology and characterization not feasible with color Doppler. The new approach also reduces operator dependency in the examination, improving reproducibility and facilitates patient followup.

References[1] Yuan C, JACC Cardiovasc Imaging, 1(1):58-60, 2008. [2] Yuan C et al., J Nucl Cardiol, 15(2):266-75, 2008. [3] Kerwin WS et al., Radiology, 241(2):459-468, 2006. [4] Underhill HR, et al., Am Heart J 155(3):584, 2008. [5] Chung YC et al., SCMR, p.426, 2008. [6] Chung YC et al., Proc. 15th ISMRM, p.683, 2007. [7] Toussaint JF et al., Circulation 94, p.932, 1996. [8] Moody AR et al., Circulation, 107:3047, 2003. [9] Touze E Stroke 38, p.1812, 2007.

Acknowledgements This research is supported by a grant from Shenzhen, China: ZYA200903260065A.