3D Large Coverage Atherosclerotic Plaque Assessment with Single Scan (APASS): Preliminary Application in Carotid Artery and Femoral Artery

Shuo Chen[1], Zechen Zhou[1], Huijun Chen[1], Bida Zhang[2], Rui Li[1], Jinnan Wang[3,4], Chun Yuan[1,3], and Xihai Zhao[1]

[1]Center for Biomedical Imaging Research, Department of Biomedical Engineering, School of Medicine, Tsinghua University, Beijing, Beijing, China, [2]Healthcare Department, Philips Research China, Shanghai, China, [3]Department of radiology, University of Washington, Seattle, United States, [4]Philips Research North America, Briarcliff Manor, NY, United States

Introduction: It has been well established that atherosclerotic vulnerable plaques are associated multiple vascular beds simultaneously. Histology-validated 2D multi-contrast MRI techniques [3] are commonly used in evaluation of plaque vulnerability. However, the small coverage (32mm), low inter-slice resolution (2mm), and long scan time (>20min) limit the application of this technique in clinical practice. Recently, several 3D plaque imaging techniques have been proposed to speed up the MR scan by providing large coverage and isotropic high resolution. For comprehensively characterizing plaque components, 3D multi-contrast black blood sequences [5] with large coverage (250 mm) and isotropic 0.8 mm resolution are suggested but are limited by its longer scan time (15 min) and potential inter-scan mis-registration. MATCH[4], as an inherent co-registered multi-contrast 3D imaging sequence with a single scan within 5min, is restricted by its larger slice thickness (2 mm) and small coverage (32 mm). **In this study, we sought to develop a 3D large coverage Atherosclerotic Plaque Assessment with Single Scan (APASS) technique that can be used to image the plaque burden and compositions simultaneously in one scan in a short time.**

Methods:

Sequence Design: As shown in Figure 1a, the proposed sequence consists one inversion pulse (IR), followed by 3 acquisition modules, and an iMSDE[6] prepulse is applied before module2. All three acquisition modules are spoiled gradient echo (SPGR/T1_TFE) shots. Schematic tissue signals are shown in Figure 1b. Three sets of images were acquired directly by APASS and two more additional sets of images can be generated by post processing (Figure 1c). Module 1: full resolution images acquired by SPGR with inversion time (TI) which meets the SNAP TI condition (negative blood signal, positive wall and IPH signals)[7]; Module 2: full resolution iMSDE prepared centric order SPGR acquisition, which will generate black blood images with similar contrast to 3D-MERGE[8]; Module 3: low resolution SPGR acquisition which can be used for phase sensitive reconstruction[9] and calcification identification. Furthermore, APASS module 2 images can be used to evaluate plaque burden and lipid rich necrotic core (LRNC) and phase corrected CR images can be utilized to determine stenosis and IPH/thrombus [7].

Human Study: Two healthy volunteers (2 male, mean age 28.5 years) were recruited for carotid artery imaging. The imaging parameters were as follows: FOV 40(AP)x160(RL)x160(FH) mm^3, voxel size 0.8x0.8x0.8mm^3, TR 10/10/10ms for 3 modules, flip angle 11°/5°/5°, profile order linear/centric/linear, TFE factors 98/98/48, iMSDE duration 15ms, number of average 1, total scan time 3min26s. Another two healthy volunteers (1 male, mean age 24.5 years) were recruited for femoral artery imaging. The imaging parameters were as follows: FOV 60(AP)x320(RL)x250(FH) mm^3, voxel size 1x1x1mm^3, TR 10/10/10ms for 3 modules, flip angle 11°/5°/5°, profile order linear/centric/linear, TFE factors 98/98/48, iMSDE duration 11ms, number of average 1, total scan time 7min24s.

Results:

The carotid arteries and femoral arteries were successfully imaged using proposed APASS sequence. Typical carotid artery images are shown in Figure 2. APASS images with well delineation of vessel wall acquired by module 2 are shown in Figure 2a and 2c. The APASS CR images generated by phase sensitive reconstruction with module 1 and module 3 are shown in Figure 2b and 2d. Five continuous reformatted slices with 2mm thickness around the carotid bifurcation are shown in Figure 2c and 2d. Figure 3 represents the typical femoral artery images acquired by APASS. Sufficient image quality was achieved by APASS imaging for vessel wall, CR and MRA images.

Discussion and conclusion: In this study, the feasibility of APASS technique was validated on healthy volunteers for both carotid artery (160mm, < 4min) and femoral artery imaging (250mm, <8min). We proposed a 3D MR imaging sequence with large coverage for plaque imaging which can provide inherently co-registrated multi-contrast images at a single scan within a short scan time. Future work includes patient study for the validation of feasibility of APASS imaging in identification of plaque components, including IPH, CA, LRNC et.al.

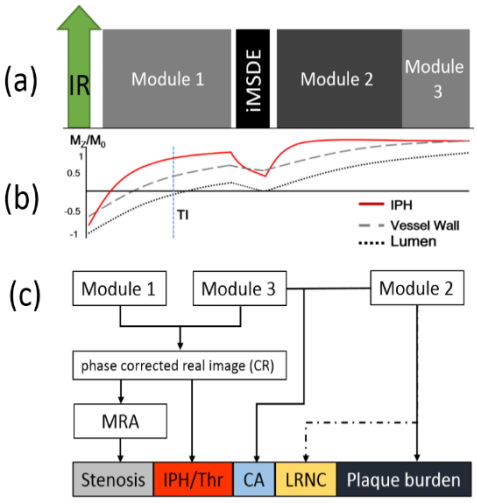

Figure 1**a.** APASS sequence schematic diagram; **b.** schematic tissue evolution curve in APASS; **c.**three data sets acquired by APASS directly (module 1-3) and two generated data sets (CR and MRA) are reviewed in combination to identify major plaque components and plaque burden.

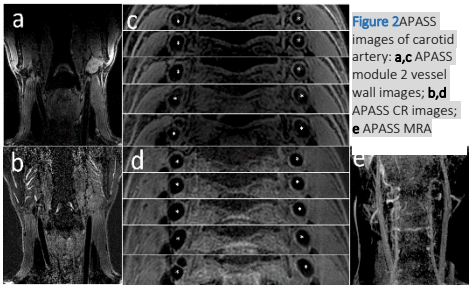

Figure 2APASS images of carotid artery: **a,c** APASS module 2 vessel wall images; **b,d** APASS CR images; **e** APASS MRA

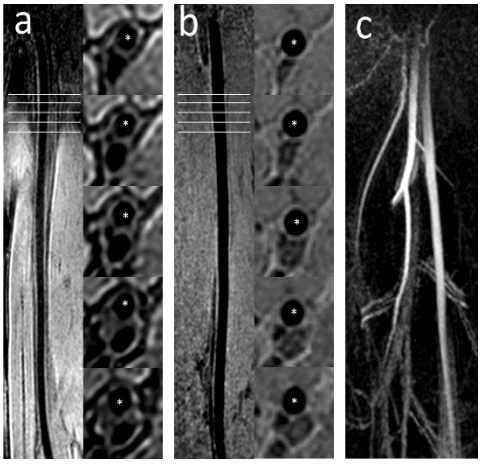

Figure 3 APASS images of femoral artery: **a,** APASS vessel wall images (module 2); **b,** APASS CR images (module 1,3); **c,** APASS MRA image.

References:[1] Sans S, Eur Heart J 1997. [2] Lloyd-Jones D, Circulation 2009. [3] Saam T, Radiology 2007. [4] Fan Z, JCMR 2014. [5] Zhou Z, ISMRM 2013. [6] Wang J, MRM2010. [7] Wang J., MRM 2013. [8] Balu N, MRM 2011. [9]Chen S, ISMRM 2014.