Fast 3D isotropic high spatial resolution MRI of peripheral vessel wall at 3T

Guoxi Xie[1,2], Xiaoming Bi[3], Jing An[4], Xin Liu[1], Hairong Zheng[1], Debiao Li[2], and Zhaoyang Fan[2]

[1]Shenzhen Key Lab for MRI, Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen, Guangdong, China, [2]Biomedical Imaging Research Institute, Cedars Sinai Medical Center, Los Angeles, CA, United States, [3]Siemens Healthcare, Los Angeles, CA, United States, [4]MR Collaborations NE Asia, Siemens Healthcare, Beijing, China

Introduction: Peripheral artery disease (PAD) is a slow and progressive circulation disorder which not only causes pain and disability, but also is associated with a high risk of heart disease. Dark-blood 2D TSE can be used to detect early changes in the vessel wall but it provides poor slice resolution and needs long scan times. Flow independent dark-blood 3D MRI is suitable for peripheral artery vessel wall imaging with large coverage. Previous studies have proposed SPACE and MERGE for 3D peripheral artery vessel wall imaging [1,2]. However, SPACE still needs long scan time while MERGE is sensitive to B_0 inhomogeneous. In this work, a 3D DANTE-Prep dark-blood GRE sequence was developed for peripheral artery vessel wall imaging. It allows screening bilateral 30-cm-long peripheral arteries within 4 minutes with isotropic high spatial resolution.

Sequence: A recently proposed dark-blood technique, DANTE-Prep module [3], was employed for suppressing blood signal (Fig. 1). The DANTE-Prep module uses a series of pulse trains to generate incoherent phase accumulation in flow spins to robustly suppress flow signal. Fat suppression was applied before GRE readout for optimal outer wall definition and to avoid chemical shift artifacts [2]. The signal behavior of the proposed sequence is determined by both DANTE-Prep and GRE readout modules, e.g., DANTE prep flip angle and number of pulse trains, and GRE flip angle and turbo factor. Bloch equation was used to simulate the signal behavior and to optimize these parameters for peripheral artery vessel wall imaging.

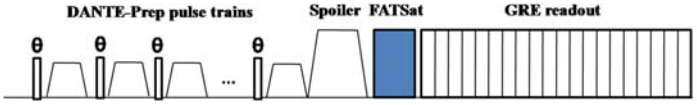

Fig. 1. Sequence diagram for the fast 3D peripheral artery vessel wall imaging. A DANTE module for dark-blood preparation is followed by spoiler gradient, fat saturation pulse and GRE readout with centric reordering.

Experiments: The IRB approved study scanned 4 healthy volunteers (age 28±4) on a 3T MR scanner (MAGNETOM Verio, Siemens, Germany). Parameters for DANTE-Prep module include: coronal orientation, gradient amplitude = 20 mT/m, flip angle = 15° , pulse trains = 150. Parameters for GRE readout include: TE/TR = 3.8/8.9ms, flip angle = 8°, 3D acquisition with isotropic resolution 0.72×0.72×0.72 mm^3, bandwidth = 131 Hz/pixel, turbo factor = 131, acceleration factor (GRAPPA) = 2. The total scan time is 3:26 min. Conventional multi-slice 2D TSE with saturation bands was also performed as reference. For wall area quantification, the 2D TSE scan was performed with slices perpendicular to one leg. The imaging parameters included: TE/TR = 6.9/900ms, slice thickness = 3mm, in-plane resolution 0.72×0.72 mm^2, bandwidth = 338 Hz/pixel, number of average = 2, 12 slices in each scan. The total scan time is 2:10 min.

Image analysis: Due to the parallel imaging, the noise cannot be simply measured in the air for the DANTE-Prep GRE scans. Similar to the reference [1], the standard deviation (SD) of the vastus medialis muscle signals enclosed within manually-drawn regions of interests (ROI) greater than 25 mm^2 was used as the noise. 3D images were reformatted to the same position and thickness as the 2D images before signal measurement. Total 48 images were measured (12 slices/subject). Wilcoxon signed rank test was conducted for wall thickness and lumen area measurements with $p<0.05$ considered as significant.

Results and discussion: Vessel wall was visualized in all subjects with good flow suppression (Fig 2). Quantitative measurements of SNR, CNR, wall thickness and lumen area are listed in Table 1. The wall thickness and lumen area were not significantly different between the DANTE-Prep GRE and 2D TSE scans. Although the wall SNR and wall-blood CNR were lower on the DANTE-Prep GRE sequence, the wall SNR and wall-blood CNR were sufficient to accurately depict the vessel wall. Besides, the DANTE-Prep GRE sequence was much more efficiency than 2D TSE. It only took 3:26 min to cover a large area while 2D TSE would take about 18 min to cover the same one.

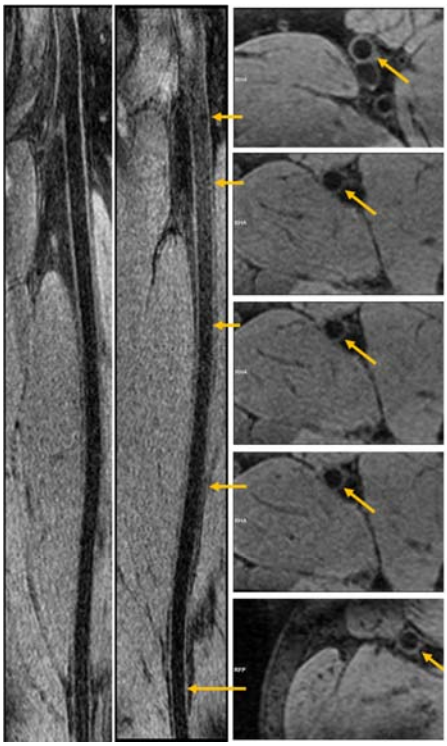

Fig.2. Representative images of left and right femoral arteries from a subject (curved maximum intensity projection of images from one 3D measurement)

Conclusion: A fast 3D high resolution approach with DANTE preparation and GRE readout was developed for peripheral vessel wall imaging. *In vivo* experiments show the proposed sequence could accurately depict the vessel wall with adequate SNR/CNR and excellent imaging efficiency. The technique could potentially serve as a fast screening modality for PAD. Further evaluation of the sequence on patients with PAD is warranted.

Table 1. Image quality comparison between the proposed DANTE-Prep GRE sequence and 2D TSE methods

Method	Wall SNR	Lumen SNR	Wall/blood CNR	Wall thickness (mm)	Lumen area (mm^2)
DANTE-Prep GRE mean±std	9.4±2.6	5.5±2.4	3.8±1.4	1.2±0.1	19±3
2D TSE mean±std	14.8±4.7	4.8±2.3	9.9±2.9	1.2±0.1	19±4
Wilcoxon test	--	--	--	0.19	0.36

Reference: [1] Zhang Z, et al. Investigative radiology, 2009, 44(9): 619. [2] J. Chi, et al. Clinical Radiology. 2013, e213-e221. [3] Li L, et al. MRM, 2012, 68(5): 1423-1438.