Motion-robust 3D Black-blood Carotid Wall Imaging Using Flow-sensitive Dephasing Preparation and Stack-of-Stars Trajectory

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Target Audience: Clinicians and researchers with interest in high-resolution carotid wall imaging.

Purpose: High-resolution, volumetric carotid vessel wall imaging is a promising method for the rapid assessment of plaque burden [1, 2]. Such an imaging procedure, however, is frequently challenged by complex motions originated from pulsation of carotid arteries, swallowing, breathing, and bulk motion of patient [3]. Radial sequences have exhibited benign artifact behavior against motion due to oversampling of central k-space data [4]. The goal of this work is to develop a motion-robust, black-blood 3D carotid wall imaging technique using a stack-of-stars (Stars in short) sampling scheme. The efficacy of using such a method is compared to the conventional carotid wall imaging with Cartesian sampling.

Methods: Imaging sequence: A prototype sequence was implemented supporting both Cartesian and Stars sampling schemes with matched imaging parameters. Blood nulling was realized by repeatedly applying flow-sensitive dephasing (FSD) preparation [5] (also known as MSDE) before each 3D FLASH readout train. Following each FSD module and fat saturation pulse, same radial view (for Stars) or same Ky line (for Cartesian) for all partitions was acquired with a centric k-space ordering. FSD and fat saturation were applied again before proceeding to the next radial view (or Ky line for Cartesian). Volunteer Study: Five healthy subjects were scanned on 3T clinical MR scanners (MAGNETOM Skyra or Prisma, Siemens AG, Germany). An eight-channel carotid coil (4 elements on each side) was used as signal receiver in combination with a 20-channel head-neck coil. Protocols for Cartesian and Stars were matched and imaging parameters included: FOV = 14 x 14 cm^2; 64 partitions with 12.5% slice oversampling; isotropic acquisition voxel size = 0.73 x 0.73 x 0.73 mm^3; flip angle = 8°; TR/TE = 8.0/2.5 ms; cumulative first moment in FSD = 946 mT ms^2/m. In three volunteers, additional image sets were acquired with the subject instructed to swallow once every 30 seconds for both Cartesian and Stars acquisitions. Data analysis: Data sets with instructed motion were excluded from quantitative analysis. Carotid wall signal and residual blood signal in the lumen were measured for both left and right carotid arteries. Noise was measured from background air surrounding the neck. Image quality was qualitatively scored by two reviewers on a scale of 1 (major signal loss or artifact) to 4 (sharp vessel wall, artifact free). Vessel wall SNR (wall signal divided by standard deviation of noise), vessel wall – lumen CNR and image quality from two sampling schemes were compared using a paired t-test.

Results: Carotid artery wall images were successfully acquired from all subjects. Imaging time was 1:52 minutes for each 3D measurement. SNR values (Fig. 1) from these two methods were comparable (Cartesian vs Stars: 17.9 ± 4.0 vs 19.2 ± 4.7, p = 0.08). Stars protocol led to higher vessel wall – lumen CNR (Cartesian vs Stars: 6.1 ± 3.4 vs 7.9 ± 3.9, p = 0.002) and better image quality (Cartesian vs Stars: 2.3 ± 0.4 vs 3.4 ± 0.7, p = 0.004). Fig. 2 shows maximum intensity projection (MIP) of a Stars image set. Fig.3 illustrates images acquired without and with instructed swallowing events. Vessel wall is well delineated with both Cartesian and Stars sampling without instructed motion. With swallowing occurred every 30 seconds, Cartesian images are completely corrupted while vessel wall structures are largely preserved using Stars sampling trajectory.

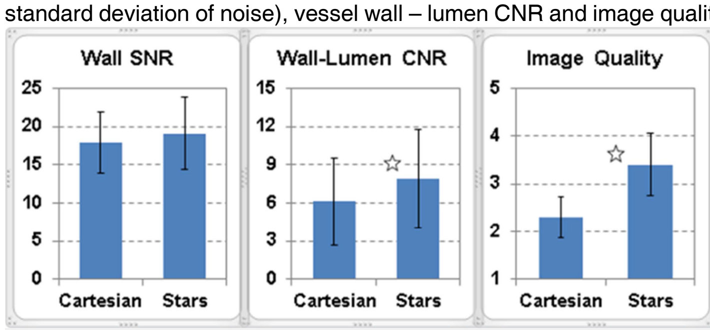

Figure 1. Comparison of vessel wall SNR, CNR and image quality using Cartesian and Stars trajectory. ☆ p < 0.05

Discussion and Conclusions: Good quality images were consistently acquired in all cases with Stars sampling. Compared to the Cartesian method, suppression of lumen blood was improved using radial sampling, due to incoherent spin dephasing from different radial views and destructive interference in the low-frequency regions [6]. Theoretical decrease of vessel wall SNR from Cartesian to Stars was not observed in this study, likely due to increased motion-induced signal loss in Cartesian imaging. The improved carotid wall delineation warrants further evaluation of this promising technique in patients with carotid artery disease.

References: [1] Koktzoglou I et al, JCMR 2007. [2] Balu IN et al, MRM 2011. [3] Boussel L et al, JMRI 2006. [4] Chandarana H et al, Invest Radiol. 2011. [5] Fan et al, MRM 2009. [6]. Flask CA et al, MRM 2003

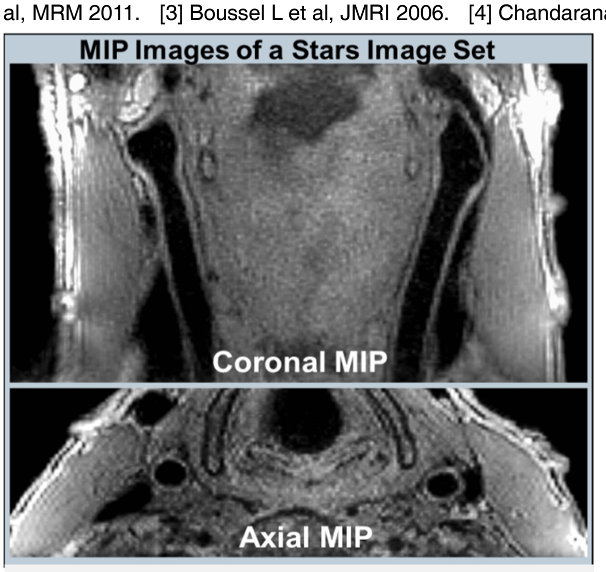

Figure 2. MIP images of a Stars image set in the coronal and axial orientations.

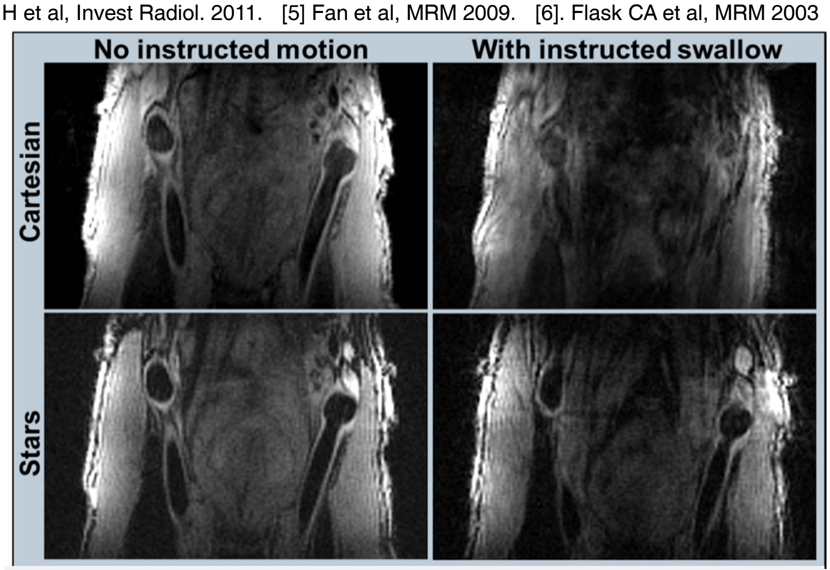

Figure 3. One partition out of a 3D volume using Cartesian and Stars trajectory without and with instructed swallowing. Note that Cartesian image with swallowing is completely corrupted, while vessel wall is well preserved using Stars trajectory with slight increase of streak artifact.