3D Dark Blood Cine Magnetic Resonance Imaging of the Carotid Arteries

Ioannis Koktzoglou[1,2], Tina Desai[2,3], and NavYash Gupta[2,3]

[1]*Radiology, NorthShore University HealthSystem, Evanston, Illinois, United States,* [2]*The University of Chicago Pritzker School of Medicine, Chicago, IL, United States,* [3]*Vascular Surgery, NorthShore University HealthSystem, Skokie, IL, United States*

TARGET AUDIENCE: Vascular imagers of the carotid arteries.

PURPOSE: To propose and test a 3D dark-blood cine magnetic resonance imaging (MRI) pulse sequence capable of displaying the carotid arterial wall and its motion with fine temporal resolution and submillimeter spatial resolution over the cardiac cycle.

METHODS: This study was IRB approved. Imaging Sequence**:** A cardiac-gated 3D radial sequence was constructed to provide for a high spatial resolution static and cardiac-phase-resolved dynamic dark-blood imaging the carotid arterial wall (**Figure 1**). Radial views were sampled in a quasi-random order to support arbitrary temporal resolutions with minimal image undersampling artifact; sliding window reconstruction with the KWIC data weighting filter[1] was used generate a series of 20 temporal frames spanning the cardiac cycle. Temporal footprints (TF) of 10% to 40% of the total duration of the acquisition window were tested. Other imaging parameters were: non-selective RF excitation; cubic 22 cm field-of-view and 288 matrix; 0.8 mm isotropic spatial resolution; TR/TE/flip of 8.7 ms/4.2 ms/6°; 165 Hz/pixel bandwidth; ≈30,000 total projections; 50-88 projections acquired in each heartbeat (heart rate dependent); 393-464 s acquisition time, multiple motion sensitizing driven equilibrium (MSDE) preparations per heartbeat (1st order gradient moment of 982 mT·ms^2/m); 9 fat saturation RF pulses per heartbeat.

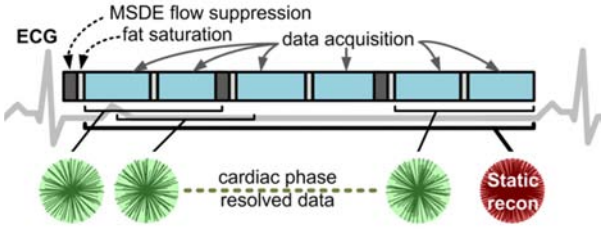

Figure 1. Timing diagram of the dark-blood 3D cine vessel wall imaging sequence. Subsets of radial views are grouped to generate the time-resolved 3D volumes; a static 3D volume is generated from all acquired views.

Imaging Protocol: MRI was performed on a 32-channel 3T system (MAGNETOM Verio, Siemens) using a neck coil and a 4-channel carotid coil. The number of MSDE preparations applied in each heartbeat (nMSDE) was optimized in a preliminary study of 8 volunteers; nMSDEs of 0,1,2,3, and 6 were tested. Using the optimal nMSDE value, 7 additional volunteers and one patient subject were imaged. Validation of carotid arterial lumen and wall areas derived from the time-resolved and static reconstructions was made with respect to 14-slice 2D cine FLASH imaging and 3D dark-blood MERGE[2] imaging, respectively.

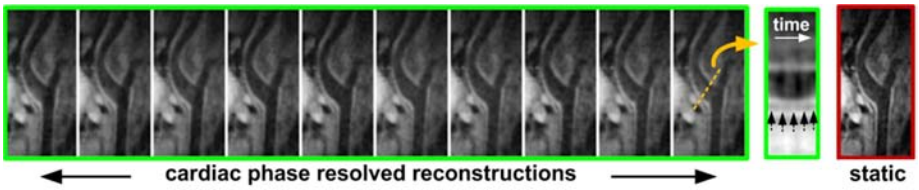

Figure 2. Select temporal frames (left) of the presented radial 3D dark blood cine method demonstrate the motion of the carotid wall throughout the cardiac cycle (arrowheads). The static reconstruction (right) derived from all projections displays the wall with improved spatial resolution.

RESULTS: The optimization study revealed that execution of 3 MSDE pulses each heartbeat minimized the coefficient of variation of signal within the carotid arterial lumen and provided near optimal contrast-to-noise ratio between the arterial wall and the lumen. Under this configuration, the method displayed the arterial wall and its pulsation over the cardiac cycle with submillimeter isotropic resolution (**Figure 2**). The image quality of the static reconstruction was comparable to that obtained with Cartesian 3D MERGE (**Figure 3**).

Arterial lumen areas obtained with the radial 3D dark-blood cine method agreed with values obtained using bright-blood 2D cine imaging (n=2060, Bland-Altman mean differences of 1.0% and 4.2% for TF of 10% and 40%, respectively). Arterial wall areas derived from the static reconstructions agreed with measurements obtained with Cartesian 3D MERGE MRI (n = 112; intraclass correlation coefficient of 0.946, P < 0.001; Bland-Altman mean difference of 0.96 mm^2).

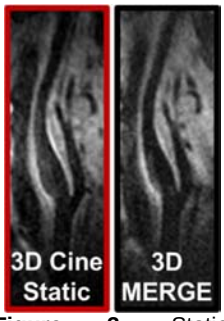

Figure 3. Static reconstruction of the proposed method (left) and the reference standard protocol (right) demonstrate similar image quality.

DISCUSSION: We demonstrated the feasibility of blood-suppressed 3D cine MRI of the carotid arteries. Because the presented method generates 3D static as well as cardiac phase-resolved data in a single acquisition, it has the potential to simultaneously quantify carotid stenosis, plaque volume, and characterize carotid plaque motion with fine spatial and temporal resolution. Given the association of all these indices with cerebrovascular risk[3-6], future studies will seek to determine whether data provided by the proposed method can improve MRI-based assessment of cerebrovascular risk in patients with carotid atherosclerosis.

CONCLUSION: 3D dark-blood cine MRI of the carotid arteries with submillimeter isotropic spatial resolution and fine temporal resolution is feasible, and can provide a constellation of data for assessing cerebrovascular risk.

REFERENCES: 1. Song et al. MRM 2000;44-825-832. **2.** Balu et al. MRM 2011;65:627-637. **3.** NASCET N Engl J Med 1991; 325:445-453. **4.** Rozie et al. Eur Radiol 2009; 19:2294-2301. **5.** Iannuzzi et al. Stroke 1995; 26:614-619. **6.** Meairs et al. Stroke 1999;30:1807-1813.

ACKNOWLEDGEMENTS: This work was supported in part by American Heart Association SDG0835367N.