Prospective Self-Gating To Eliminate Motion Artifacts in 3D Carotid Artery Wall Imaging

Z. Fan[1,2], S. Zuehlsdorff[3], P. Lai[4], Y. Chung[3], J. Agraz[1,2], and D. Li[1,2]

[1]Radiology, Northwestern University, Chicago, IL, United States, [2]Biomedical Engineering, Northwestern University, Evanston, IL, United States, [3]Cardiac MR R&D, Siemens Healthcare, Chicago, IL, United States, [4]Applied Science Laboratory, GE Healthcare, Menlo Park, CA, United States

Introduction: 3D variable-flip-angle TSE (SPACE) has been proposed for carotid vessel wall imaging [1]. However, a relatively long imaging time renders this technique more prone to image artifacts caused by apparent motion such as swallowing. Self-gating technique [2] has recently been used to exclude data acquired during swallowing, yet two shortcomings remain. First, a single self-gating (SG) line acquired immediately before readout in each TR may not be adequate to detect motion if the readout duration is relatively long (300 ms in SPACE). Second, real-time update of the reference line used for the cross-correlation analysis is necessary because of potential involuntary "drift" during 3D imaging [3]. This work aimed to improve the SG method by addressing these problems.

Theory: Fourier transform of a central *k*-space line is a 1D projection of the entire imaging volume along the readout direction. In SPACE imaging, two projections (SG lines) are acquired immediately before and after readout in each TR (echo train), respectively, and cross-correlation coefficients (CC) between each projection profile and the corresponding reference profile acquired at the beginning of the scan are calculated. Bulk motion of the imaging volume during the period of any TR will be detected if either of the two CC values is less than the pre-defined thresholds and image data will be rejected and re-acquired in the next TR. In addition, reference projections are automatically updated if CC< threshold occurs 6 (user-specified) times in succession.

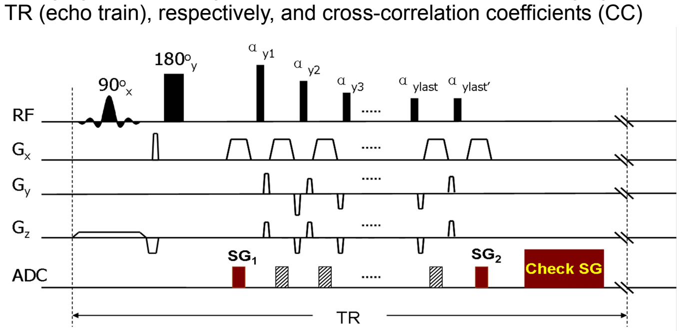

Fig. 1. Self-gated SPACE sequence diagram.

Materials and Methods: The clinically available SPACE sequence was modified by adding two SG readouts prior to and following the imaging echo train (**Fig. 1**). Online processing of the SG signals was performed during each TR, including Fourier transform, cross-correlation with the reference projection profile, and acceptance/rejection feedback. The relevant information was also displayed at a customer window during scanning.

Five healthy volunteers were scanned on a 3T MR system (MAGNETOM Trio, Siemens) with a 4-chanel bilateral carotid coil. Self-gated SPACE was first applied as a scout scan (15 s) to enable selecting two appropriate threshold values for SG line 1 and 2, respectively. Two ECG-triggered 3D SPACE scans were subsequently performed, with one gated (Threshold > 0.8) and the other non-gated (Threshold = 0). The imaging parameters included: TR = 3 heartbeats, trigger delay = 450-600 ms, TE = 155 ms, echo train length = 72, coronal acquisition with readout in superior-inferior direction, FOV = 140x140 mm^2, matrix=198x192 (interpolated to 396x384), 36 0.72-mm-thick partitions (interpolated to 72), GRAPPA = 2, 2 averages, bandwidth = 555 Hz/pixel, acquisition time = 108xTR in the absence of motion. To evaluate the effectiveness of the SG method, subjects were asked during both scans to voluntarily swallow at five preset stages, corresponding to the 30th, 45th, 54th, 65th, 80th TR if the scan does not involve motion. The 3D datasets from both gated and non-gated scans were reviewed on a workstation.

Results: The CC values from SG line 2 (0.90-0.96) were lower than those from SG line 1 (0.995-0.999), indicating that the signal level may affect the cross-correlation analysis (**Fig. 2**). Thus, the thresholds used for SG line 1 and 2 were always different. In all five subjects, swallowing was detected when instructed. Real-time update of the reference projection occurred in two cases. Swallowing motion resulted in severe vessel wall blurring and residual signal in the lumen on non-gated images (**Fig. 3**), which were dramatically reduced by the SG procedure. Image quality assessment (0-5; 0 poor, 5 excellent) [4] showed a significantly higher score (3.6±0.5) on gated images as compared to non-gated images (1.6±0.5).

Conclusions: Preliminary results demonstrated the effectiveness of the SG technique used in 3D SPACE for motion compensation. Two SG lines in combination with real-time update of the reference line make swallowing motion-gating robust. Work is now focused on automatic threshold selection.

References: [1]. Fan Z, et al. JMRI (in press). [2]. Fan Z, et al. ISMRM 2009(#1828). [3]. Chan CF, et al. ISMRM 2009(#1829). [4] Chan CF, et al. JMRI 2009;29:211-216.

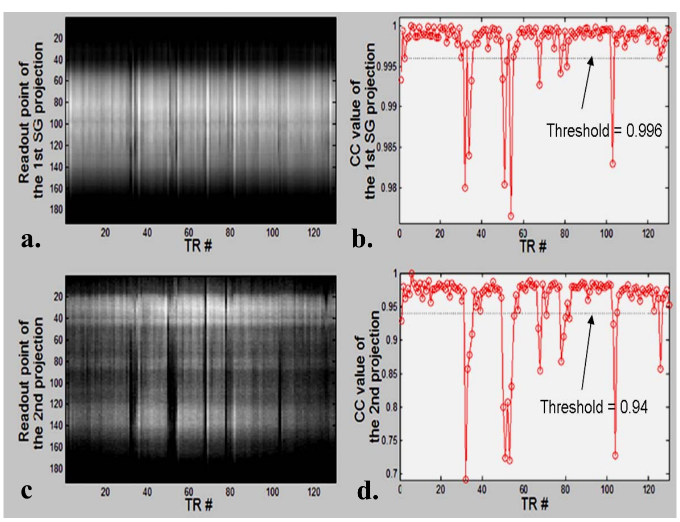

Fig. 2. Representative projection and correlation coefficient series from SG line 1 (a, b) and 2 (c, d). In this case, the 1st and 2nd SG lines detected 12 and 21 TRs affected by swallowing, respectively, with 10 TRs in common.

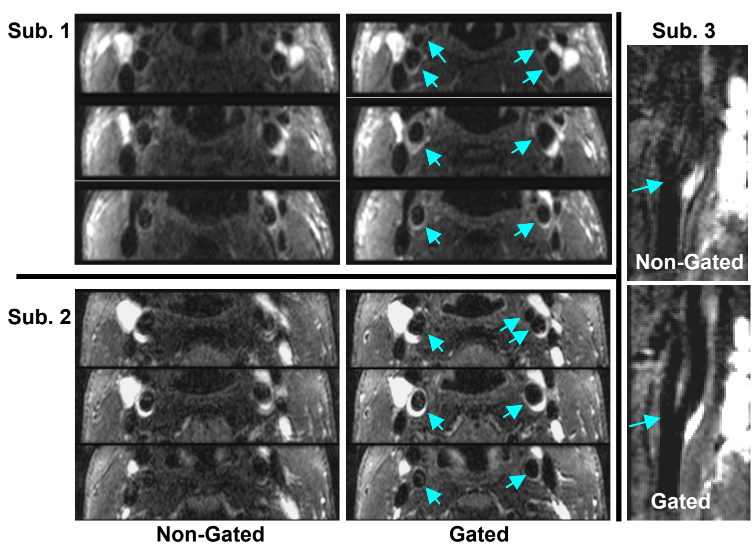

Fig. 3. Matched cross-sectional (Subject 1, 2) or longitudinal (Subject 3) images reformatted from non-gated and gated SPACE datasets. Note that the vessel wall are blurred by swallowing without SG but substantially improved with SG.