Motion-compensated TSE imaging of the carotid arteries using FID-based navigator gating

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INTRODUCTION: Multicontrast-weighted MRI has the capability to characterize and quantify different components of carotid atherosclerotic plaques [1,2]. However, the introduction of carotid plaque MRI in the clinical routine is hampered by motion artifacts caused by swallowing, breathing, etc. [3]. At our institution, about 25% of all carotid scans are severely degraded by motion. Free induction decay (FID) navigators can detect motion with negligible effects on imaging data/magnetization and with little or no time penalty [4]. The aim of this study was to develop a framework for prospective FID-based navigator gating to suppress motion artifacts in conventional carotid MRI and to evaluate its feasibility.

METHODS: An FID-navigator, comprising a spatially-selective low flip-angle sinc-pulse followed by an ADC-readout, was added to a conventional 2D/3D turbo spin-echo (TSE) sequence (Figure 1). Real-time navigator processing was implemented, which delivered accept/reject-and-reacquire decisions to the sequence. The motion detection algorithm used here is similar to that described by Kober et al [4]. In each TR, an FID-navigator signal, which takes both FID magnitude and phase into account, is computed by comparing the incoming FID to a reference signal computed from a few learning TRs. A gating threshold is dynamically updated during the scan.

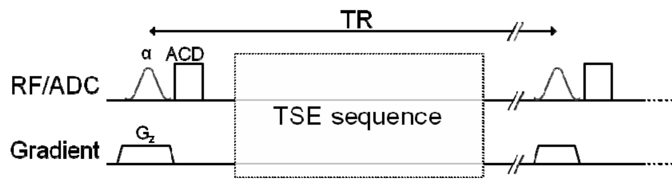

Figure 1. Schematic of the FID-navigator, which is applied prior to the TSE-sequence in each TR. With its separate excitation, the navigator slab is independent of the imaging slice/volume.

As the FID-signal signal represents the sum of the transverse magnetization of all excited spins, the spatial extent of the navigator excitation slab is preferably positioned so as to detect the motion of interest. In this implementation, the orientation and spatial extent of the excitation slab used for FID-gating was adjustable on the scanner user-interface.

To evaluate feasibility, three volunteers were scanned with a pulse-gated 2D T2-weighted TSE sequence (pixel size 0.4x0.4 mm^2, slice thickness 2 mm) at a 3T Siemens Verio scanner equipped with a custom-built 8-element carotid coil. With volunteers instructed to perform frequent swallowing or heavy breathing, one navigator-gated and one non-gated data set were acquired at the level of the carotid bifurcation. In addition, a reference scan was acquired in absence of motion. The navigator slab, from which FID-signals were recorded, was positioned in the central parts of the neck to avoid strong signal from regions close to the surface coil to, as that may suppress FID-sensitivity to swallowing.

Two blinded reviewers compared carotid image quality between the reference, non-gated, and gated images. Quantitative image quality assessment was performed by measuring the mean signal intensity in the carotid artery wall in the gated and non-gated images.

RESULTS: FID-gated images exhibited considerably reduced motion artifacts compared to non-gated scans and were similar to the reference images (Figure 2). Image quality readings were first evaluated by Kruskal-Wallis test which showed statistical difference ($p < 0.005$) between the mean values of the three groups (reference, gated, non-gated) for both readers. Following that, pairwise Wilcoxon signed-rank tests were performed: The image quality difference between reference and gated images was not significantly different whereas gated vs non-gated images were different ($p < 0.05$). Vessel wall signal intensity was higher in the gated vs non-gated images ($p < 0.05$, two-tailed paired Student's t-Test).

DISCUSSION: The proposed FID-based navigator appears robust and capable of compensating motion effects in carotid MRI. By applying the low flip-angle FID-navigator before the host sequence (TSE), it does not affect the timing and contrast characteristics of the TSE sequence. The total duration of the navigator is currently about 9 ms, which will slightly affect the efficiency of multislice-2D and 3D applications. Future work will be directed at reducing the navigator time penalty, optimizing the navigator signal and threshold calculation, as well as application-specific positioning of the navigator slab. In summary, this study demonstrated initial feasibility of a novel approach to motion compensation that may improve the clinical capability of MR imaging of carotid plaques.

REFERENCES: [1] Saloner et al. Stroke 2007. [2] Dong et al, JCMR 2009. [3] Boussel et al, JMRI 2006. [4] Kober et al, MRM 2011.

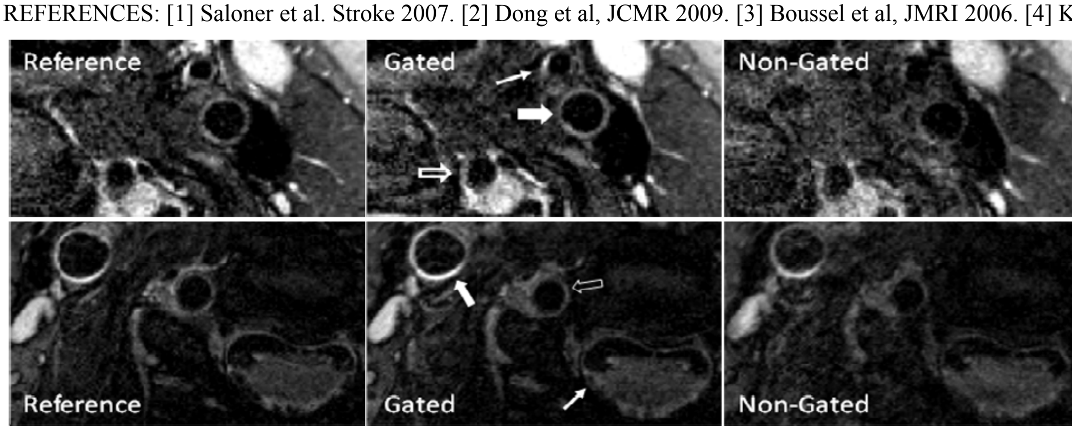

Figure 2. Comparison of reference (left), gated (middle) and non-gated (right) T2w images from two normal volunteers acquired during swallowing (top) and heavy breathing (bottom). The proposed gating approach greatly reduces the motion artifacts seen in the non-gates images. Solid arrows: Internal carotid artery. Open arrows: Vertebral artery. Narrow arrow in upper panel: External carotid artery. Narrow arrow in lower panel: Spine.