Effect of Cardiac Gating in High-Resolution MRI of the Carotid Vessel Wall

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Introduction: MR imaging of the carotid bifurcation has become a commonplace method for detecting and stratifying patients with vascular disease. As spatial resolution demands are increased, the beat-to-beat pulsation of the arterial wall over each cardiac cycle can cause blurring artefacts in the phase encode direction that degrade image quality and possibly alter the perception of plaque area. Previous studies have investigated the use of cardiac gating to compensate for this loss of resolution [1, 2]. However these studies have generally used thick slice acquisitions which suffer from partial volume effects of the thick slices. Additionally, they do not address the size of the gating window, which can be crucial as larger stationary periods impose much less of an acquisition time penalty. This work attempts to address these questions in a healthy volunteer population.

Methods: All healthy volunteers (n=5) aged 25-31 were scanned in a 3T Philips Achieva system using a small surface receive coil positioned near the bifurcation of the carotid artery. A bright blood, 3D T1 TFE sequence was used to give a clear delineation between vessel wall and dark background (TR/TE/α = 9.8ms/2.5ms/15°, voxel size = 0.5x0.5x0.8mm). Acquired data were retrospectively rebinned into 20 segments throughout the cardiac cycle with no data sharing between cycles. The number of slices was increased such that both carotid bifurcations were covered. Imaging times ranged from 4 minutes 58 seconds to 9 minutes 14 seconds. Each cycle was then Fourier transformed and raw k-space data was appropriately taken from each cardiac cycle bin to simulate an increase in gating window from 5% in end diastole to 100% in increments of 5%. Lumen wall images were then segmented using a 2 cluster k-means algorithm that classified the pixel as either lumen or wall based on the intensity. From these segmented images, a lumen size was computed, and a mean difference in the phase encoding direction was calculated. One volunteer was recalled to obtain comparative ungated and gated scans with a gating window of 50% end diastole using a 3D T1 black blood sequence centered at the carotid bifurcation (TR/TE/α = 14ms/4.1ms/15°, voxel size = 0.5x0.5x0.8mm).

Results: Figures 1 illustrates luminal boundary motion near the carotid bifurcation over the course the cardiac cycle in a healthy volunteer, showing a relatively low-motion period in the latter half of the cycle. Figure 2 shows the apparent increase of vessel wall dimension as a function of simulated gating window. The increase in vessel dimension has a sigmoidal shape with an inflection point near 50%, below which the apparent increase in vessel dimension is less than 1 pixel. Among this volunteer population, this region also corresponds to low vasomotion variability which increases dramatically as the gating window is increased beyond 50%. Figure 3 shows a representative slice from the comparative ungated (left) and gated (right) scans at 50% end diastole. 1-2 pixel blur is seen anteriorly and posteriorly in the ungated images, but is not present in the gated images.

Discussion: In this study we have shown that a gating window of approximately 50% of end-diastole yields a low motion period during which one can image the carotid artery wall at high resolution (0.5x0.5mm in-plane) in a healthy volunteer. However, large variability exists in the healthy population when longer gating windows are used. This work motivates patient-specific determination of the gating window in order to minimize acquisition time, especially in the case of a diseased patient population in which larger gating windows may be acceptable because of reduced vasomotion. In addition to reducing visible blurring, the use of a low-motion gating window is particularly important for quantitative imaging applications that depend heavily on reliable spatial localization of pixels.

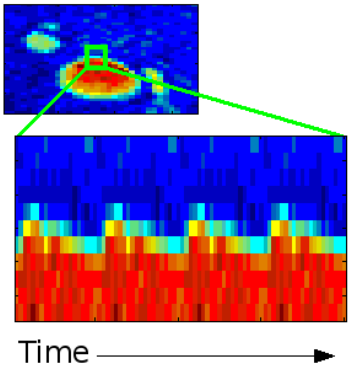

Figure 1: Lumen Boundary Motion Trace of a column of pixels over 20 acquired phases of the cardiac cycle at the lumen boundary near the carotid bifurcation of a healthy volunteer (repeated over four cycle lengths for illustration). Maximum deviation is observed early in the cycle, with relatively little boundary motion in the latter half.

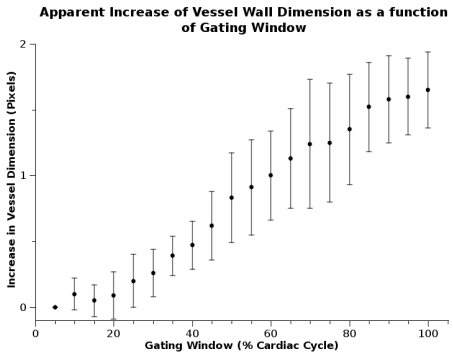

Figure 2: Increasing Gating Window As the gating window increases, apparent vessel wall size increases. Over a limited range, 50% of the end diastolic cycle, a low blur region exists for all volunteers. Above this, there is large person-to-person variation in vessel wall motion.

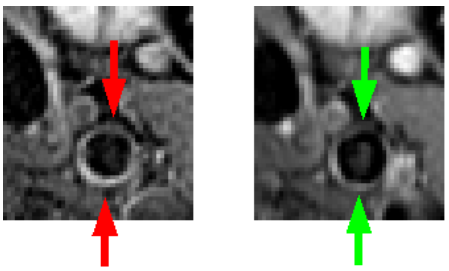

Figure 3: Non-gated vs. Gated Acquisition Representative slice from an ungated (left) black blood 3DT1 acquisition shows 1-2 pixel burring anteriorly and posteriorly (red arrows). These blurring artefacts are not present in the gated acquisition (right) using a 50% gating window during end diastole (green arrows).

References: 1. Al-Kwifi et al. MRM 52:605-611 (2004) 2. Mani et al. JMRI 22:628-633 (2005)