An Improved Phased-Array Surface Coil for Carotid Vessel Wall Imaging

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Introduction Carotid atherosclerosis is a progressive inflammatory disease of the vessel wall characterized by plaque formation at the carotid bifurcation, manifest by stroke. High-resolution MRI of the carotid vessel wall can accurately measure lesion size and comprehensively assess plaque composition[1]. Phased-array (PA) surface coils have been developed to provide improved signal-to-noise ratio (SNR) at the carotids [2]. The purpose of this study is to compare a novel four-element PA coil to the present standard two-element PA coil.

Materials and Methods **PA Surface Coils** Two sets of receive-only PA coils were designed and constructed at the University of Washington to provide a high signal-to-noise ratio at a limited depth across a moderate field of view. The four-element coil array consisted of two transverse pairs of approximately square coils applied bilaterally. Overall dimensions of each coil set were $\Delta x \times \Delta z = 11 \times 6.8$ cm. The eight-element array consisted of two sets of four coils occupying points of a square, applied bilaterally (Figure 1). Overall dimensions of each coil set were $\Delta x \times \Delta z = 12.8 \times 10.3$ cm. The overlap in the transverse direction minimizes mutual inductance. The overlap along the longitudinal direction is greater than necessary to cancel the mutual inductance, in order to minimize the valley in signal peaks. Excess mutual inductance was compensated by a common capacitor to decouple the longitudinal coils. The transverse overlap minimizes coupling between both laterally adjacent and diagonally adjacent coil pairs. The pattern of conductive loops was fabricated by etching a flexible circuit board. Capacitor values were scaled to provide tuning and matching at the appropriate operating frequencies.

Imaging Images of bilateral carotid arteries were obtained from a total of five healthy subjects (four males and one female, 28-41 years old) who participated according to institutional IRB. Subjects were scanned on a Philips Achieva 3T whole-body scanner using the PA coils described above. A similar multi-contrast protocol providing T1-, T2-, and PD-weighted black-blood images was used with both coils. All scans were conducted using a 2D fast spin-echo (FSE) sequence with inversion-recovery preparation. Images were obtained with the following parameters: TR(msec)/TE(msec)/echo train length/receiver bandwidth (±khz) = 800/9/11/20.8 for T_1, 4000/52/12/31.3 for T_2, and 4000/8/12/31.3 for PD. The 4 element and 8 element standard protocols included a number of excitations (NEX) equal to 1, slice thickness of 2 mm, matrix size (readout × phase encoding) of 256 × 192, and rectangular field of view (FOV) of 16 × 12 cm providing an in-plane resolution of 0.63 mm. To assess possible improvements in resolution, the T_1-weighted black-blood images were repeated with NEX = 1, a larger matrix size of 512 × 512, and a FOV of 14 × 14 cm (in-plane resolution = 0.27 mm). Images were analyzed by an independent reader blinded to coil configuration. Images obtained with four-element and eight-element coils were matched using the carotid bifurcation as an internal reference. Inner and outer wall boundaries were identified by a semiautomated Snake algorithm implemented in custom-designed image analysis software. An analysis of the T_1-weighted images was conducted to assess for an increased SNR. SNR was calculated as SNR = S/σ, where S is the true signal intensity corrected for the noise contribution and σ is the true standard deviation (SD) of the noise. Corrected signal intensity S was obtained from the measured magnitude signal (S_m) and the measured magnitude of the background noise (S_n): $S = (S_m^2 - S_n^2)^{1/2}$. Wall and lumen SNR and wall-lumen contrast-to-noise (CNR) were compared in 10 carotid arteries by paired t-test.

Results Artery wall SNR, artery lumen SNR, and lumen-wall CNR significantly increased (Table 1) in T_1-weighted images acquired using the eight-element coil array, with gain factors of 1.5 for wall SNR, 1.5 for lumen SNR and 1.3 for lumen-wall CNR. Although a moderate increase in the residual blood signal did occur, the overall quality of black-blood imaging was significantly higher in the eight-element images, as indicated by the lumen-wall CNR. Images with a 512 × 512 matrix obtained from the eight-element coil array compare favorably to four-element images (Figure 2).

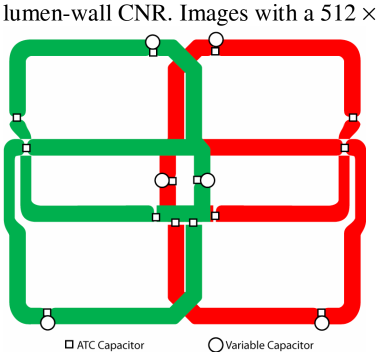

Figure 1. Structure of one four-element set from the eight-element coil array.

Table 1. Properties of T_1-weighted black-blood carotid artery images acquired with four-element and eight-element coil arrays (NEX=1, 0.63 mm in-plane resolution)

Parameter	Four-element	Eight-element	*P*
SNR_{wall}	12.3±4.2	16.5±4.6	0.004
SNR_{lumen}	3.63±1.3	5.45±1.4	0.023
CNR	8.65±3.3	11.1±3.5	0.002

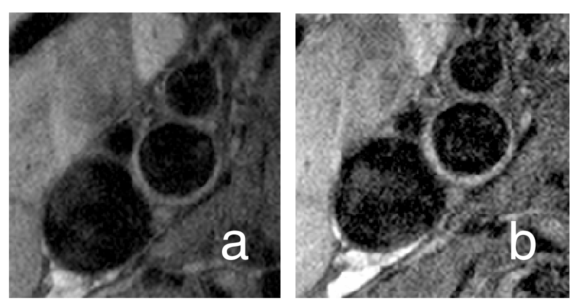

Figure 2. High-resolution (0.27 mm) T_1-weighted black-blood images of the neck from a healthy subject obtained with: (**a**) eight-element and (**b**) four-element coil arrays. Images are located superior to the carotid bifurcation. Noise levels are markedly increased in the four-element image.

Conclusions T_1-weighted black blood imaging of the carotid artery wall with a novel eight-element PA coil array provides a significant increase in SNR and CNR when compared to a conventional four-element coil design. This improvement permits an increase in spatial resolution.

Discussion Prospective epidemiological studies of carotid atherosclerosis include subjects with variable locations of the carotid bifurcation. Novel coil designs with improved SNR and CNR across the required broad coverage area may enhance large-scale carotid imaging at 3T.

References [1] Yuan C et al., *NMR Biomed.* 2006;19:636-654 [2] Hayes CE et al., *JMRI* 1996;6:109-112