Improvements in spatial resolution using a novel 8-element carotid phased array coil at 3T

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Carotid atherosclerotic plaque imaging demands high SNR and high resolution simultaneously. These competing demands lead to prolonged scan times that are limiting for clinical studies. Although current four-element phased array (PA) coils provide images of adequate SNR over a limited FOV, PA coils with additional elements can improve SNR and coverage. The most widely used design consists of a four-element design [1]. Recently a new coil design with eight-elements has been proposed [2]. The improvement in SNR by moving to an eight-element PA coil can be used to improve resolution for better visualization of the carotid artery wall.

Aim: To quantify the improvement in SNR for high spatial resolution multi-contrast black-blood (BB) carotid MRI by the use of an eight-element PA coil.

Methods: 1) Phased array coils: Two sets of bilateral receive-only PA coils with 4 and 8 elements were compared. The four-element coil (4PA) array consisted of two transverse pairs of approximately square coils (dimensions of each coil set were $\Delta x \times \Delta z = 11 \times 6.8$ cm) applied bilaterally. The eight-element array (8PA) consisted of two sets of four coils occupying points of a square (dimensions of each coil set were $\Delta x \times \Delta z = 12.8 \times 10.3$ cm), applied bilaterally. The elements were overlapped in the transverse direction to minimize mutual inductance. In order to minimize the valley in signal peaks, the overlap in the longitudinal direction was made greater and the excess mutual inductance was compensated by a common capacitor for decoupling.

2) Imaging Protocol: Bilateral carotid arteries of five healthy subjects (four males and one female, 28-41 years old) were scanned on a Philips Acheiva 3T with institutional IRB approval. All subjects were scanned with both 4PA and 8PA coils using the same protocol. BB images were obtained using multi-slice double inversion recovery [3] turbo spin-echo with the following parameters [TR(msec)/TE(msec)/echo train length/FOV(cmxcm)/Matrix/NEX/Slice-thickness(mm)/receiver-bandwidth(±khz)] for T2: 4000/52/12/16x12/256x192/1/2/31.3 and 4000/8/12/16x12/256x192/1/2/31.3 for PD. A quadruple inversion recovery [4] (QIR) black-blood sequence with 0.63mm in-plane resolution was implemented for T1: 800/9/11/16x12/256x192/1/2/20.8. Additionally an ultra-high resolution QIR T1 sequence with an in-plane resolution of 0.27mm (FOV/matrix 14x14/512x512) was used to assess resolution improvements made possible by using the 8PA coil.

3) Image Analysis: Image assessment was done blinded to coil configuration. Lumen and outer wall contours were drawn on bilateral carotids using a semi-automated snake algorithm. T1, T2 and PD images were matched using the carotid bifurcation. Lumen SNR (SNR_l), Wall SNR (SNR_w) and wall-lumen contrast-to-noise ratio (CNR) were compared on all three image weightings. SNR was defined as S/σ, where S was measured as $(S_s^2 - S_n^2)^{1/2}$ with S_s being the mean signal and S_n the mean background noise. σ was obtained from the relation for the measured standard deviation of noise (SD_{noise}) and the number of receivers: $SD_{noise} = 0.695\sigma$ (for 4 receivers). Correction factor for 8 receivers is not available in current literature and hence SD_{noise} for 8 receivers was calculated similar to the 4 receiver case. CNR was defined as $SNR_w - SNR_l$. S_s was measured for all pixels contained between lumen and outer wall boundaries. S_n and SD_{noise} were measured from a region of interest placed in an area of background noise free from signal and artifacts. SNR_l, SNR_w and CNR measured from individual image locations were averaged to obtain mean SNR and CNR values for each artery. SNR and CNR were compared between 4PA and 8PA coils using paired student t-test and Pearson correlation coefficient. A similar procedure was carried out for the ultra-high resolution T1 images.

Table 1: Improvement in SNR/CNR between 8PA and 4PA using standard (0.63mm in-plane) protocol

	Four-element coil Mean ± SD	Eight-element coil Mean ± SD	Ratio
Wall SNR			
T1	31.99 ± 12.60	52.35 ± 19.21	1.66
T2	31.45 ± 3.77	49.57 ± 5.71	1.61
PD	53.69 ± 18.69	90.97 ± 20.41	1.72
CNR			
T1	24.02 ± 10.21	36.62 ± 12.29	1.57
T2	22.93 ± 8.52	34.35 ± 14.86	1.51
PD	37.76 ± 13.62	63.61 ± 24.42	1.70

* All P values ≤ 0.002

Results: The 8PA coil showed a 1.5-1.9 times improvement in CNR (Table 1) compared to 4PA coil. Wall SNR was improved by roughly 60% in all three black-blood sequences. Although signal inside the lumen was also increased on 8PA, the CNR was improved by 50% using the 8PA. Ultra-high resolution T1 (0.27mm in-plane) showed better delineation of vessel boundaries using 8PA with lesser noise (figure 2). SNR_w was significantly greater (1.35 times) using 8PA on ultra-high resolution images ($P \leq 0.001$). CNR was also improved over 4PA (($P \leq 0.0001$).

Conclusions: The 8PA coil provides substantially improved CNR and thus better delineation of the carotid arterial wall. The improved SNR enables ultra-high resolution carotid imaging and will allow fine plaque structure to be resolved. Carotid MR imaging studies will benefit by use of the 8PA coil by virtue of improved SNR and CNR.

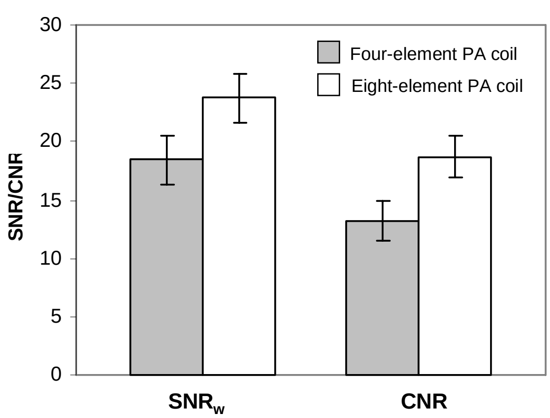

Figure 1: Improvement in SNR and CNR of eight-element PA coil over four-element PA coil on ultra-high resolution (0.27m in-plane) T1 images

References:
[1] Hayes et al, JMRI. 1996, 6:102-111.
[2] Scholnick et al, ISMRM. 2007.
[3] Yarnykh et al, JMRI. 2003, 17:478-83.
[4] Yarnykh et al, MRM. 2002, 48:899-905

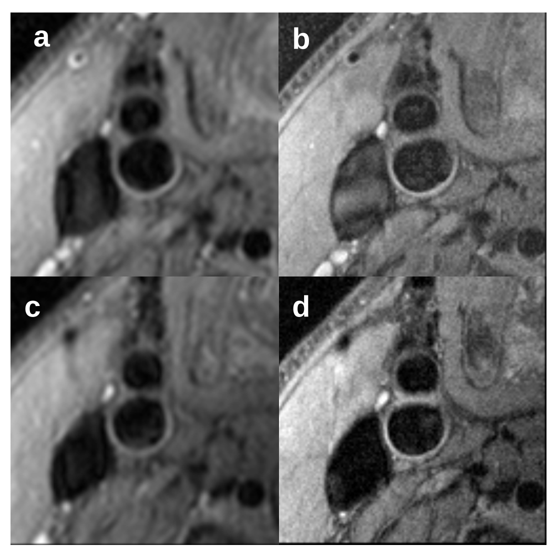

Figure 2: Matched representative images just distal to carotid bifurcation (a) 4PA T1 (b) 4PA T1 (0.27mm) (c) 8PA T1 (d) 8PA T1 (0.27mm)