Quantitative Comparison of Carotid Plaque Composition between 1.5 and 3.0T Field-Strengths

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Introduction

Developments in RF coil and pulse sequence design have provided high spatial resolution images at 1.5T for the *in vivo*, quantitative evaluation of carotid wall morphology and plaque composition. In a recent investigation[1] comparing multi-contrast black-blood MRI at 1.5 and 3.0T, significant increases in carotid wall signal-to-noise ratio (SNR) and lumen/wall contrast-to-noise ratio (CNR) were observed at the higher field-strength. However, the performance of high-field imaging in visualization of the carotid plaque tissue composition has not been studied to date. The purpose of our study was to assess the effects of field-strength on the quantification of the carotid atherosclerotic plaque.

Methods

Imaging protocol: 20 asymptomatic participants (mean ± SD age: 69.8 ± 10.5 years; male: 75%) with 16-79% carotid stenosis as determined by duplex ultrasound underwent high spatial resolution carotid MRI at both 1.5T (GE Signa Horizon EchoSpeed) and 3.0T (Philips Achieva) using bilateral, four-element, phased-array surface coils. A multi-contrast protocol for carotid MRI was used to obtain 2D T1-weighted, proton density, and T2-weighted black-blood images and 3D time-of-flight (TOF) angiography. In addition, a contrast-enhanced black-blood T1W (CE-T1W) sequence was acquired five minutes after intravenous infusion of 0.1 mmol/kg Gadolinium-DTPA-BMA (Omniscan, GE Healthcare). Black-blood imaging for PD and T2-weighted scans was achieved using a time-efficient multi-slice DIR technique[2]. For pre- and post-contrast T1-weighted imaging, T1-insensitive QIR[3] black-blood preparation was used. The protocols for each field-strength had identical in-plane resolution (0.6x0.6 mm) and slice thickness (2 mm). Based on an expected increase in SNR at 3.0T,[1] one signal acquisition was used instead of the two signal averages at 1.5T. To avoid unwanted T1-weighting, PD and T2-weighted scans at 3.0T were obtained with a longer TR (4000 vs. 3000 ms). No TR adjustment was performed for T1-weighted (TR=800 ms) and 3D TOF (TR=20 ms) images.

Image analysis: Area measurements of the lumen, arterial wall, and plaque components were acquired using semi-automated processing software (CASCADE[4]) by three readers blinded to field strength. Plaque components were defined according to previously published histology-based criteria[5]. Cohen's kappa (κ) was used to determine agreement between detection of plaque components. Agreement in area measurements was done with the intra-class correlation coefficient (ICC) and bias was assessed with linear mixed modeling to control for intra-subject correlations.

Results

Gross morphological characteristics of the carotid arteries (lumen, wall, and total vessel area) were not significantly different between 1.5T and 3.0T (Table 1). There was strong agreement between field-strengths in the detection of plaque components (Table 1, κ), however, hemorrhage was more prevalent at 1.5T than 3.0T (14.7% vs. 7.8%, respectively). While there was no significant difference in size of lipid-rich necrotic core (Fig. 1) and hemorrhage at matched locations between field-strengths, calcified regions appeared significantly larger at 3.0T (Table 1). To explore the differences in hemorrhage detection, we compared the normalized mean (±SD) signal intensity of hemorrhage in each contrast weighting. Hemorrhage had a higher intensity at 1.5T compared to 3.0T on both TOF (1.81±0.57 vs. 1.46±0.44; p=0.003) and T1W (1.34±0.23 vs. 1.08±0.40; p=0.02) – the two weightings used for hemorrhage identification (Fig. 2).

Table 1. Agreement and quantitative comparison of plaque metrics.

	ICC	Cohen's κ	Area Difference* (mm²)	*p-value*
Lumen Area	0.96	–	-0.32 (-1.11, 0.46)	0.42
Wall Area	0.91	–	0.28 (-0.77, 1.32)	0.60
Total Vessel Area	0.96	–	-0.08 (-1.28, 1.12)	0.90
Calcification	0.79	0.72	**1.60 (0.18, 3.02)**	**0.03**
LRNC	0.83	0.73	-1.39 (-3.83, 1.06)	0.26
Hemorrhage	0.62	0.66	-3.29 (-8.20, 1.61)	0.17

*Difference: 3.0T – 1.5T expressed as mean (95% CI)
ICC = intra-class correlation coefficient; LRNC = lipid-rich necrotic core

Discussion and Conclusions

3.0T imaging provides consistent measurements of plaque morphology and the necrotic core size but may introduce bias in detection and measurements of calcification and hemorrhage, as compared to 1.5T. This disagreement is likely related to the increased magnetic susceptibility of calcification and a stronger effect of paramagnetic ferric iron in hemorrhage at higher field-strengths. As such, 3.0T imaging may improve the detection of calcification, but more sensitive imaging techniques[6] may need to be used for hemorrhage evaluation at 3.0T.

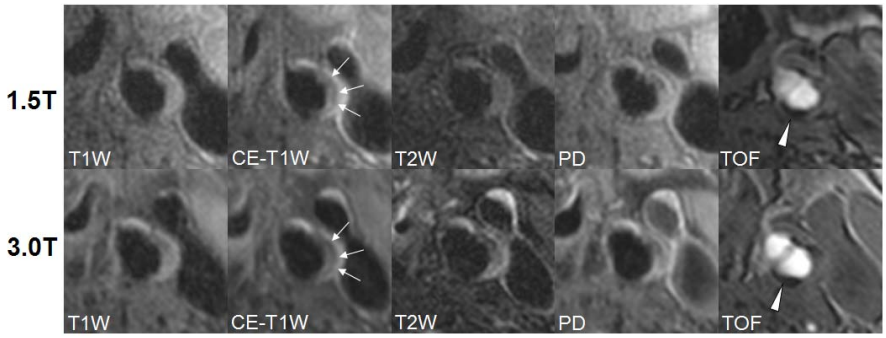

Figure 1. Matched cross-sectional images of the left carotid bifurcation. A lipid-rich necrotic core of similar size is apparent on the CE-T1W images (arrows). Calcification is also present on TOF (arrowheads). Notice the increase in size of calcification at 3.0T.

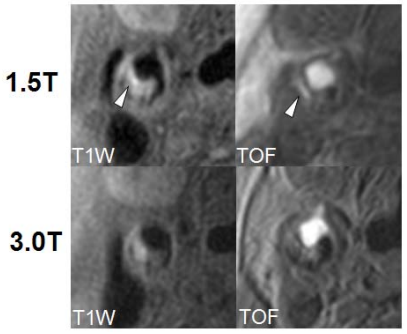

Figure 2. The signal for hemorrhage (hyperintense on T1W and TOF) is present at 1.5T (arrowhead), but not at 3.0T

References

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