Carotid Contrast Enhanced MRA as a measurement of atherosclerosis severity: direct comparison with high-resolution vessel wall imaging

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Background: MRI identified plaque features, such as intraplaque hemorrhage (IPH) and thin or disrupted fibrous caps (T/R FC) have been shown to be associated with an increased risk for future transient ischemic attack and stroke [1-2]. Although angiographically measured carotid stenosis is the standard clinical approach for assessing risk of stroke from carotid atherosclerosis, vessel wall imaging by multi-contrast MRI has been shown to accurately quantify atherosclerotic vessel wall dimensions and plaque features such as IPH, thin or disrupted FC, lipid-rich necrotic core (LRNC) and calcification [3-5].

Purpose: The goal of this study was to identify correlations between contrast-enhanced MR angiography (CE MRA) and high-risk plaque features assessed by vessel wall MRI.

Methods: A total of 132 arteries from 66 consecutive subjects with more than 50% carotid stenosis on at least one side (as measured by ultrasound) underwent bilateral carotid MRA and MRI scans. All images were acquired on a 3.0T (Signa Excite; General Electronic Healthcare) with 8 channel surface coil using a standardized MRI protocol [6] and centered at the bifurcation. All images were obtained with a slice thickness of 2 mm; inter-slice spacing of 0 mm, and in-plane resolution 0.6 mm. The plaque imaging protocol included pre- and post-contrast 2D quadruple IR [7] T1-weighted FSE (TR/TE: 800/11 ms), 2D T2-weighted and proton-density-weighted FSE (TR/TE: 3500/70 and 12 ms, respectively), and 3D TOF (TR/TE: 21/2.9 ms; Flip angle: 15°) sequences. 3D CE MRA images were acquired in the same imaging session in the coronal plane with a 3DI fast spoiled gradient echo (FSPGR) sequence (TR/TE: 2.5/1.2 ms; slice thickness: 2 mm; partitions per 3D slab: 36; matrix: 192 X 320; field of view: 320 mm; number of excitations=1). CE MRA and MRI were reviewed separately and blinded to each other. Luminal stenosis was quantified in both carotid arteries using NASCET criteria. Normalized Wall Index (NWI = wall area / [lumen area + wall area]), which provides a quantitative measurement of plaque burden [8], was calculated after lumen and vessel wall areas were outlined using custom software (CASCADE [9]). Presence of plaque composition, including LRNC and IPH, were determined using previously published criteria [2]. Fibrous cap status was determined for arteries with a LRNC. Statistical analysis was performed using SSPS software version 12.0 (SPSS Inc., Chicago, IL). Categorical data were presented as frequencies and percentages, and continuous data were presented as mean ± standard deviations. Spearman correlation coefficient with the artery as the unit of analysis was used to assess associations between stenosis measurements and NWI measurements or the occurrence of plaque features. Receiver-operator-characteristics (ROC) analyses were performed for the detection of plaque features.

Results: The finial study sample consisted of 117 evaluated arteries after 15 arteries were excluded due to poor image quality [n=3] and total occlusion [n=12]. Stenosis ranged from 0% to 99% in this population. Stenosis had a moderate positive correlation with plaque burden (r=0.59, p<0.001; Fig 1), but weak correlation with plaque features (r=0.20, p=0.03 for LRNC, r=0.25, p=0.007 for IPH, r=0.36, p=0.001 for thin or ruptured FC). The diagnostic AUC performance of stenosis measurement for the detection of plaque features was 0.64 for LRNC (p=0.03), 0.70 for IPH (p=0.01), and 0.70 for thin or ruptured fibrous cap (T/R FC; p=0.001), respectively (Fig 2).

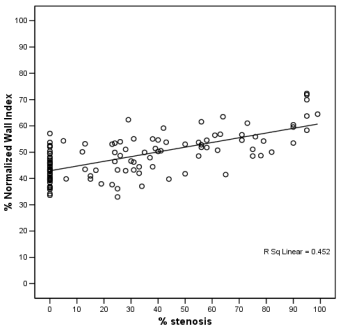

Fig 1. Scattergram of correlation between stenosis and NWI measurements (r=0.59, *p*<0.001).

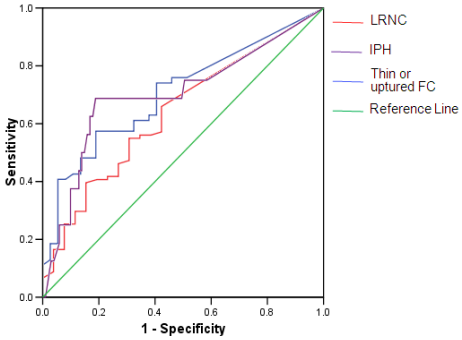

Fig 2. ROC curves of stenosis measurement for identifying plaque features.

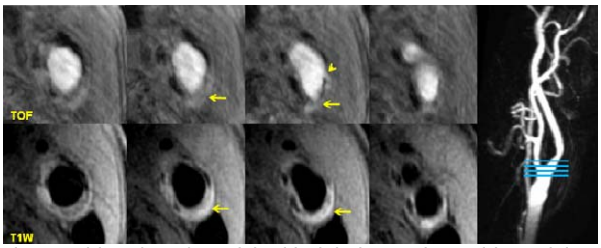

Fig 3. Subject (73 y/o male) with right internal carotid arterial stenosis = 15% seen on the CE MRA MIP (right side); while hemorrhage (arrow) and ruptured fibrous cap (arrowhead) were identified on the TOF and T1W images. Four continuous cross-sectional images are shown.

Table 1. Prevalence of NWI and plaque features stenosis categories

	0% (n = 46)	1-30% (n =27)	31-69% (n = 27)	70-99% (n = 17)
NWI	0.44 ± 0.06	0.47 ± 0.07	0.52 ± 0.07	0.61 ± 0.09
LRNC	67.4% (31/46)	81.5% (22/27)	81.5% (22/27)	94.1% (16/17)
IPH	8.7% (4/46)	3.7% (1/27)	18.5% (5/27)	35.3% (6/17)
T/R FC	41.9% (13/31)	45.5% (10/22)	72.3% (17/22)	81.3% (13/16)

The prevalence of plaque features for each stenosis category is reported in Table 1. Although there was a higher prevalence of plaque features in high-grade stenosis (stenosis = 70-99%; 94.1% for LRNC, 35.3% for IPH, and 81.3% for thin or ruptured FC), there still was a high prevalence of LRNC, thin or ruptured FC in the zero- and low grade stenosis categories (Table 1, Fig 3).

Discussion

In this investigation, we found substantial plaque burden in carotid arteries that were angiographically normal or with minimal stenosis. This finding is consistent with results of the previous study [10]. Furthermore, high-risk plaque features were commonly observed in arteries with 0-69% stenosis, as measured by contrast-enhanced MRA using NASCET criteria. The underestimation of plaque burden and complexity is likely related to the unique geometry of the carotid bulb and expansive remodeling.

Conclusion

Stenosis, as measured by MRA, underestimates plaque burden and the presence of high-risk plaque features, including arteries considered to be angiographically normal. These findings highlight the need for vessel wall imaging to accurately grade the severity and stage of carotid atherosclerosis, and may provide a critical tool for assessing risk for future carotid-related ischemic events.

Reference

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