

3D Features of Disrupted Carotid Plaque: A Multi-Plane, Multi-Contrast in vivo High Resolution MRI Study

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Introduction:

Studies of excised atherosclerotic coronary and carotid lesions have shown a strong association between plaque disruption and the occurrence of ischemic events. Analysis of axial, two-dimensional (2D) histology has shown that disrupted plaques typically have larger lipid-rich necrotic cores (LR/NC), intraplaque hemorrhage, and thin fibrous caps.

Multi-contrast high resolution magnetic resonance imaging (MRI) is capable of identifying key morphological and compositional features of advanced carotid plaque on 2D axial images. This study combined analysis of axial and longitudinal MR in a 3 dimensional assessment to test the hypothesis that plaque disruption is associated not only with plaque components but also with component distribution on the long axis.

Methods: MR imaging: 43 subjects (mean (SD) age: 67.5 (9.5) yrs, 94% male) with duplex ultrasound evidence of 50% to 99% stenosis were recruited from the clinical vascular diagnostic laboratories at the University of Washington and VA Puget Sound Health Care System after obtaining informed consent. Subjects were imaged with axial high-resolution multi-contrast weighted and longitudinal oblique carotid MRI (Axial: T1W, PD, T2W, 3D TOF; longitudinal: PD) on a 1.5T GE Signa scanner. Image review: Plaques were categorized as disrupted if there was MRI evidence of fibrous cap rupture using previously published criteria (Circulation 2000; 102:959) or ulceration. Ulceration was defined as an irregular lumen surface with an invagination extending below the surface on the multi-contrast weighted images and a disorganized flow pattern on TOF. Two experienced reviewers reached a consensus interpretation of each scan. A custom designed semi-automated image analysis tool (CASCADE) was used to measure areas of the lumen (LA), wall (WA), calcification, LR/NC, intraplaque hemorrhage (IPH) or thrombus. The morphological parameters used were: total vessel area, normalized wall index (NWI= WA / [WA + LA]), eccentricity index (EI = maximum wall thickness/ minimum wall thickness). Statistical analysis: To construct a reasonable representation of ruptured lesions prior to surface disruption, areas of ulceration were included in LR/NC measurements and considered part of the wall (Fig. 1). The mean value of the morphological parameters, mean area and the prevalence of plaque components and the length of large LR/NC's were compared between disrupted and undisrupted plaques with an un-paired t test or chi-square test where appropriate using SPSS (v. 12.0). Large LR/NC's were defined as those where the proportion of the wall occupied by the LR/NC on any given cross-section was greater than or equal to 30%.

Results: There were 17 disrupted and 26 undisrupted lesions identified for comparison. There were no significant differences in demographics and clinical characteristics between the 2 groups. Differences between morphology and composition of disrupted plaques compared to undisrupted lesions are presented in Table 1. Disrupted plaques showed a predominance of longer longitudinal length of large LR/NC along the vessel wall (p=0.016), a large mean percent LR/NC (p=0.001), a large plaque burden (NWI; p=0.002), and high prevalence of IPH or thrombus (p=0.009). In addition, disrupted plaques showed a different pattern of plaque distribution, having a more eccentric position of the lumen (mean EI; p=0.036) and a longer segment of stenosis (mean lumen area; p=0.025) when compared with the intact plaques.

Conclusion: Amongst patients with 50-99% carotid stenosis, multi-plane/multi-contrast MRI demonstrated that disrupted plaques had significantly different characteristics than non-disrupted plaques in terms of both axial and longitudinal distribution. A combination of multi-plane and multi-contrast high resolution MRI may provide valuable information about overall lesion morphology and its association to vulnerability.

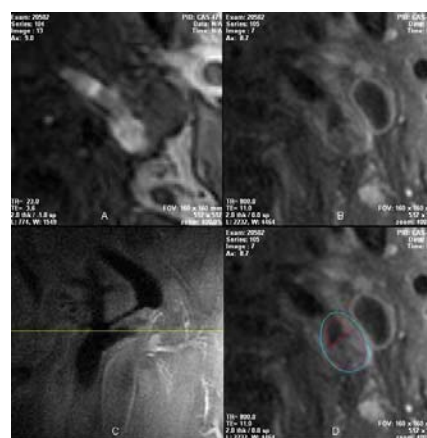


Figure 1. Axial TOF (A) and T1W (B) images of an ulceration as seen on the longitudinal image (C). In D, color contours of each feature are drawn over image B. Red = Lumen; Green = outer-wall; Purple = ulceration.

Table 1. Differences in Plaque Morphology and Composition

	Undisrupted (n=26)	Disrupted (n=17)	P value
MRI morphology measurements			
Minimum lumen area, mm ²	10.4 (9.9)	5.8 (4.9)	NS
Mean lumen area, mm ²	32.5 (12.3)	24.7 (7.9)	0.025
Mean wall area, mm ²	42.9(9.8)	46.8 (8.1)	NS
Mean total vessel wall area, mm ²	75.4 (17.2)	71.49 (13.8)	NS
Mean normalized wall index	0.59 (0.09)	0.68 (0.07)	0.02
Mean eccentric index	3.13 (1.03)	3.81 (0.94)	0.036
MRI component measurements			
Mean percent Calcification, %	4.26 (7.03)	2.09 (2.44)	NS
Mean percent IPH, %	2.60 (5.77)	5.01 (6.59)	NS
Mean percent LR/NC, %	10.71 (10.22)	22.14 (8.62)	0.001
Length of Large LR/NC, mm	2.46 (3.8)	5.75 (4.1)	0.016
Prevalence of IPH / Thrombus, %	42.3	82.4	0.009

Values represent % or mean (SD)