Arterial Wall Enhancement Overlying Carotid Plaque on CT Angiography Correlates With Symptoms in Patients With High Grade Stenosis

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Background and Purpose—The degree of internal carotid artery (ICA) stenosis is an established primary risk factor for embolic stroke. Recent publications suggest that inflammatory features may also play an important role. Our purpose was to correlate acute neurological symptoms with either carotid wall enhancement or plaque calcification, on axial CT angiographic source images (CTA-SI) of patients with severe (≥70%) ICA stenosis.

Methods—75 consecutive patients with ≥70% ICA stenosis on CTA-SI were identified. Each case was classified as symptomatic (n=37) or asymptomatic (n=38), and as having either calcified or noncalcified plaque. The latter group was stratified into those with versus without arterial wall enhancement, measured in absolute and relative Hounsfield Units (HU).

Results—Calcified plaque was present in 39% (15/38) of the symptomatic patients and in 62% (23/37) of the asymptomatic patients (P=0.065). Of the 37 patients without calcified plaque, carotid wall enhancement was observed in 83% (19/23) of the symptomatic, but only in 57% (8/14) of the asymptomatic patients (P=0.041). When the “calcified plaque” and “no carotid wall enhancement” groups were pooled, versus the “carotid wall enhancement” group, enhancement was more likely in symptomatic patients (OR 3.625, CI 95% 1.3229 to 9.93, P=0.01 Fisher Exact test).

Conclusions—In patients with severe ICA stenosis, additional stratification of stroke risk may be possible based on the presence of carotid wall enhancement on CTA-SI. Patients with carotid wall enhancement are more likely to be symptomatic, compared to those with either calcified plaque or no enhancement. (Stroke. 2009;40:1894-1896.)

Key Words: cerebrovascular disease ■ CT ■ risk factors ■ carotid artery

With increasing evidence that plaque characteristics have an impact on thrombogenesis, there is marked interest in imaging components of carotid artery atherosclerotic lesions. Specifically, enhancement of the vasa vasorum overlying a carotid plaque may be a marker of local inflammatory change.1-2 Fleiner et al have demonstrated increased density of vasa vasorum neovascularization in the carotid, iliac, and renal arteries in patients with vascular events.2 Carotid wall enhancement in diseased vessels has been detected on angiography.3,4 Our purpose was to explore the relationship between acute stroke or TIA, carotid wall enhancement and plaque calcification, in a cohort of patients with severe (≥70%) ICA stenosis.

Materials and Methods

Patient Selection

75 patients with ≥70% ICA stenosis on CTA were retrospectively included in this study. We defined “symptomatic” as patients who had an anterior circulation stroke or transient ischemic attack (TIA), ipsilateral to the ≥70% stenosed carotid artery, within 1 month of CTA. The diagnosis of stroke was based on admission clinical presentation and positive diffusion-weighted imaging or CT findings at follow-up. We defined “asymptomatic” as those patients without a stroke or TIA indication for the CTA examination, or patients with a stroke or TIA more than a month old, not referable to the target artery. Cardiovascular risk factors were compared for both groups with Fisher Exact test.

Imaging Analysis

CTA was performed on General Electric 16 slice helical scanners as previously described.3 Percent stenosis was confirmed on CTA-SI and maximum intensity projection by a neuroradiologist, according to the NASCET method.6 Two readers visually rated and measured with free hand segmentation region-of-interest analysis (ROI) each carotid plaque for calcification and carotid wall enhancement. During image review, center level was set at 200 HU and window width at 750 to 760 HU, which allowed for optimal plaque component distinction.7 Plaque was considered calcified if it measured >130 HU and comprised >50% of the plaque volume.7-9 Carotid wall enhancement was considered present if >50% of the carotid wall circumference enhanced, at the level of maximum stenosis (Figure 1A and 1B). Subsequent to visual assessment, ROI (Analyze 6.0, Mayo Clinic) analysis included the enhancing 50% of the target ICA wall circumference and compared to the contralateral ICA wall. A minimum mean difference of >10 HU was considered enhancing tissue. Visual and quantitative ratings were compared using Fisher Exact test. Interobserver agreement was calculated using chance adjusted (kappa) statistics. SAS version 9.0 was used for statistical analysis (SAS Institute).

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Additionally, the “no carotid wall enhancement” and “calcified plaque” groups were pooled, and compared to the “carotid wall enhancement” group using Fisher’s Exact test.

**Results**

Cardiovascular risk factors such as hypertension, diabetes, hypercholesterolemia, atrial fibrillation, coronary disease, and medical treatments of the 2 groups were compared. Only diabetes was statistically more common in the asymptomatic group. The mean ICA stenosis was 82% (SD=5) for the symptomatic and 80% (SD=6) for the asymptomatic group (P=0.1093).

Calcified plaque was present in 15 of the symptomatic and in 23 of the asymptomatic patients (P=0.0657). In noncalcified plaques, carotid wall enhancement was observed in 19 of 23 symptomatic patients (82%), but in only 8 of 14 asymptomatic patients (57%; P=0.0144; Figure 2). Mean density of

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**Figure 1.** A, Precontrast Axial CT of the proximal right ICA (solid arrow). B, Postcontrast Axial CTA demonstrates linear enhancement of the ICA wall (solid arrow).

**Figure 2.** Flow diagram. As part of the analysis, the results of groups A and B were pooled for comparison to group C.
the 27 carotid walls with visual enhancement was 79.3 HU (SD = 13), versus 38.3 HU (SD = 7.1) for the 10 carotid walls without visual enhancement (P = 0.041). Excellent interobserver agreement (Kappa: 0.9, agreement: 0.96) was achieved for visual assessment of carotid wall enhancement. When the calcified plaque and the no carotid wall enhancement groups’ data were pooled and compared to that of the carotid wall enhancement group, carotid wall enhancement was statistically more likely present in the symptomatic cohort. (P = 0.01, OR = 3.63, CI 95% 1.32 to 9.93, Fisher Exact test).

Discussion
We report that CTA enhancement of the ICA wall is significantly more common in symptomatic than in asymptomatic patients with ≥70% ICA stenosis. This is consistent with previous histological studies that have demonstrated the presence of neovascularization of the adventitial vasa vasorum in symptomatic ICA walls.2

CTA detected carotid wall enhancement may represent vasa vasorum neovascularization, based on both its anatomic localization and rapid enhancing time course. Strong correlation between the visual determination of carotid wall enhancement and the quantitative ROI analysis was noted; visual assessment may not only be practical but is sufficient.

Our study has several limitations. We only included patients with severe (>70%) ICA stenosis. This was unavoidable with our retrospective study design, as few patients with moderate (50% to 69%) stenosis were imaged with CTA. Furthermore, a confounding factor in the interpretation of CTA-SI is that dense calcifications may obscure subtle wall enhancement.

Conclusion
In patients with severe ICA stenosis, additional stratification of stroke risk may be possible based on the presence of carotid wall enhancement on CTA. Patients with carotid artery wall enhancement are more likely to be symptomatic, versus those with either calcified plaque or no carotid artery wall enhancement.

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Disclosures
None.

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