# Gadolinium contrast enhancement of carotid atherosclerotic plaque is associated with symptomatic status

**J. Cai[1], N. Balu[2], D. Xu[2], H. Ju[1], X. Xu[1], X. Zhao[1], and C. Yuan[2]**

[1]Dept of Radiology, Chinese PLA General Hospital, Beijing, Beijing, China, People's Republic of, [2]Dept of Radiology, University of Washington, Seattle, Washington, United States

**Introduction:** Stroke is the third leading cause of death in the US. A significant portion of strokes is caused by rupture of carotid atherosclerotic plaques. Thus the identification of carotid plaques vulnerable to rupture can significantly improve outcome by targeting these patients for advanced medical/surgical care. Plaque neovasculature and inflammation are associated with plaque vulnerability [1]. The blood vessels that supply the arterial wall called the vasa vasorum, are known to form a plexus around the outer boundary of the vessel in advanced atherosclerotic disease [2]. It has been suggested that contrast enhancement of the plaque may occur through the vasa vasorum. Thus measurement of contrast enhancement of the outer wall surface may help in identifying the vulnerable carotid atherosclerotic plaque.

**Aim:** 1) To determine if contrast enhancement of the outer wall surface can be observed using high resolution contrast-enhanced carotid MRI (CE-MRI) and 2) To test the hypothesis that outer wall surface enhancement differs between symptomatic and asymptomatic carotid plaques.

**Materials and Methods:**

**Subjects:** Twenty four subjects underwent CE-MRI according to institutional review board guidelines. Symptomatic status was obtained from patients' clinical history and was defined as amaurosis fugax, transient ischemic attacks or overt stroke. Twelve subjects were symptomatic and twelve subjects were asymptomatic. The side on which symptoms were experienced was considered significant for this analysis. Accordingly, bilateral carotid arteries were classified into 12 symptomatic and 36 asymptomatic arteries.

**Imaging:** Patients were positioned in a GE 3T Signa scanner using a head holder and phased array carotid coils with four-elements were applied bilaterally. Pre-contrast black-blood T1w images of bilateral carotids were obtained using a quadruple inversion recovery (QIR) [3] sequence with the following imaging parameters: TR(msec)/TE(msec)/echo train length/FOV(cm×cm)/Matrix/NEX/Slice-thickness(mm) of 800/9/11/14x14/256×256/1/2. Gadodiamide (Omniscan, GE Healthcare, Milwaukee, USA) was injected intravenously at a dose of 0.1 mmol/kg. Post-contrast T1w images were obtained using identical QIR parameters.

**Table 1:** Difference of CE measures between symptomatic and asymptomatic patients

| | Symptomatic Mean ± Std | Asymptomatic Mean ± Std | P-value |
|---|---|---|---|
| **Mean CE** | 0.02±0.03 | 0.04±0.04 | 0.254 |
| **Std** | 0.05±0.03 | 0.05±0.03 | 0.490 |
| **Skewness** | 1.44±0.74 | 2.67±1.89 | 0.002* |
| **Kurtosis** | 9.15±4.94 | 26.67±34.78 | 0.005* |

Std – Standard deviation

* Significant difference (P≤0.05)

**Image analysis:** A reader blinded to symptomatic status measured the signal intensity on the outerwall surface where surface was defined as a 3 pixel wide region (approximately 1.8mm thick). The signal intensity of adjacent sternocleidomastoid muscle was also measured. Contrast enhancement was defined as the difference in signal intensity between pre and post-contrast images. Contrast enhancement relative to the adjacent muscle was obtained by subtracting the enhancement of the muscle. Relative contrast enhancement was measured for all images and the mean value for each artery was obtained. The mean, standard deviation, kurtosis and skewness of outer wall contrast enhancement were compared between symptomatic and asymptomatic subjects by an independent sample t-test. A p-value less than 0.05 was considered significant.

**Results:** A pattern of outer wall surface enhancement could be clearly visualized using contrast enhanced MRI (figure 1). The kurtosis and skewness of outer wall surface enhancement was significantly higher in asymptomatic arteries (Table 1) compared to symptomatic arteries ($P \leq 0.05$) suggesting that the outer wall enhancement response is more homogenous in symptomatic arteries. There was no difference in mean and standard deviations of relative contrast enhancement.

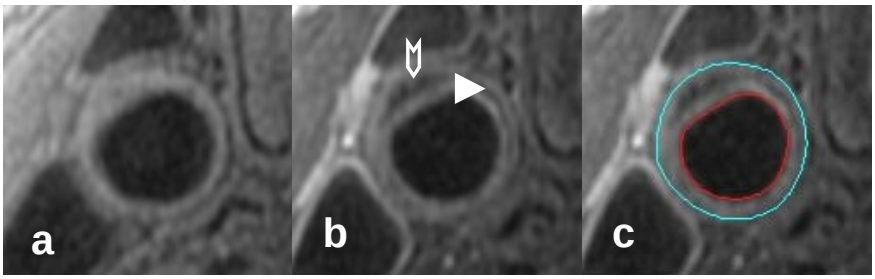


**Figure 1:** Example of outer wall contrast enhancement in the common carotid artery: (a) Pre-contrast T1w image (b) Post-contrast T1w image showing outer wall enhancement (solid arrowhead) and an overlying non-enhancing lipid/necrotic core (chevron) (c) Lumen (red) and outer wall (blue) contours delineating plaque boundaries.

**Conclusions:** Homogeneous outer wall contrast enhancement is associated with symptomatic carotid plaque. Measurement of outer wall surface contrast enhancement by black-blood carotid MRI may provide an objective quantitative measure to distinguish between symptomatic and asymptomatic patients. These results suggest that further prospective studies of quantitative measurements by CE-MRI may advance our capabilities to distinguish the vulnerable patient so that treatment can be effectively targeted, thereby greatly reducing health care expenditure.

**References:**

[1] Moulton KS, PNAS 2003. 100: 4376.

[2]Diaz-Flores L Jr, et al, Histol Histopathol. 2007 22: 1379-86.

[3] Yarnykh et al, MRM. 2002, 48:899-905