Association of carotid atherosclerosis eccentricity with high risk plaque features: An MRI study

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Introduction

Identifying patients with carotid atherosclerosis at risk for ischemic stoke would greatly benefit patient outcomes. Recently, high-resolution methods have enabled MRI to noninvasively image the fine internal structure of the carotid plaque [1]. Some carotid plaque features, such as the presence of intraplaque hemorrhage (IPH) and thin or ruptured fibrous cap on multi-contrast weighted MR imaging, have been reported to be predictors of subsequent stroke [2]. However, multi-contrast weighted MRI requires a long scan time. On the other hand, some simple morphology characteristics of carotid atherosclerosis are believed to be indicators of high risk plaque. Among those characteristics, plaque eccentricity of carotid artery has recently been found to be associated with ipsilateral cerebrovascular events in an ultrasonography study [3]. In this study, we sought to explore the contribution of plaque eccentricity to identify high-risk plaque features in carotid artery by MRI.

Purpose

To assess the association between plaque shape and high risk plaque features in carotid artery, a novel eccentricity index (EI) of plaque using MR imaging was established. We hypothesized that plaques with high risk features would have different degree of eccentricity from plaques without these features.

Methods and Materials

Population In this study, 66 patients (age range: 47–83 years, mean age: 67±9.9 years) with >50% stenosis in at least one carotid artery were evaluated using multi-contrast magnetic resonance imaging.

MR Imaging All images were acquired on a clinical 3T scanner (Signa, GE Healthcare). A standardized protocol was used to obtain 5 image contrast-weightings of bilateral carotid arteries in the transverse plane [4, 5]: Pre-contrast T1-weighted (T1W), contrast enhanced T1-weighted (CET1W), proton density weighted (PDW), T2-weighted (T2W), and 3-dimensional time-of-flight (3D TOF) MR angiography. Parameters for the imaging sequences were as follows. T1W: quadruple inversion-recovery (QIR) [5], black-blood, 2D fast spin-echo, repetition time (TR)/effective echo time (TE)=800/10.45 ms; T2W: double echo, TR/TE=3500/70.38 ms; PDW: double echo, TR/TE=3500/12.42 ms; and 3D TOF: TR/TE=21/2.9 ms. All images were obtained with a slice thickness of 2 mm and a field of view of 14 cm. Except for TOF images with inter-slice spacing of -1mm, the inter-slice spacing of all other weightings was 0 mm.

Image analysis Both sides of carotid arteries in all patients were analyzed with semi-automated analysis software CASCADE [6]. For each location, the plaque EI was obtained as follows: first, a reviewer identified the lumen and outer wall boundaries based on the T1W image; next, the centers of the lumen boundary and outer wall boundary were calculated automatically, together with the areas of the lumen (La) and wall (Wa); EI for each location was then evaluated by calculating the distance between lumen center (Lc) and outer wall center (Wc). To minimize the influence of variability of the carotid artery size in different patients, the normalization of EI was realized by dividing the distance of Lc and Wc with the square root of the total vessel area (Wa+La), given by: $EI = 100 * \left| Lc - Wc \right| / \sqrt{Wa + La}$ (Fig. 1). The EI of each artery was then acquired using the mean EI of every location in this artery. Plaque feature measurements were acquired as follows: the reviewer identified plaque components (intraplaque hemorrhage, lipid rich/necrotic core, and calcification) based on a established criteria with multi-contrast MRI [7]; Fibrous caps status was then categorized as thick, thin, or ruptured using previously published, histologically validated criteria [8].

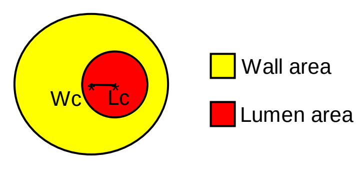

Fig. 1. Calculation of eccentricity index $EI = 100 * \left| Wc - Lc \right| / \sqrt{Wa + La}$

Data analysis The presence of IPH and thin or ruptured fibrous cap were considered as high risk features of carotid plaques. We compared the difference of continuous eccentricity index value between arteries with IPH present and arteries with IPH absent, and between arteries with thin or ruptured fibrous cap and thick fibrous cap. The EI value was described as mean value ± 95% confidence interval and independent T-tests were used for comparing the difference between groups, P-values below 0.05 were considered significant.

Results

Out of the total 132 arteries, three were excluded due to poor image quality, twelve were excluded due to carotid artery occlusion, and three were excluded due to calcification nodules near the lumen boundary. In the remaining 114 arteries, 15 arteries had presence of IPH, and 99 arteries were without IPH. In the 89 arteries with lipid rich/necrotic core, 38 arteries had thick fibrous cap and 51 arteries had thin or ruptured fibrous cap. The mean EI value of the arteries with IPH was higher than arteries without IPH (Fig. 2 (a)). An independent T-test showed that there was significant difference (p<0.001) between these two groups. Arteries with thin or ruptured fibrous cap had higher mean EI than the arteries with a thick fibrous cap (fig. 2 (b)), and also there was a statistically significant difference (p<0.001) between the two groups.

Conclusion

This study demonstrates that the plaques with high risk features (presence of IPH and thin or ruptured fibrous cap) have relatively high eccentricity index (EI), which suggests the proposed EI from carotid MRI could be a potential predictor of high risk plaque.

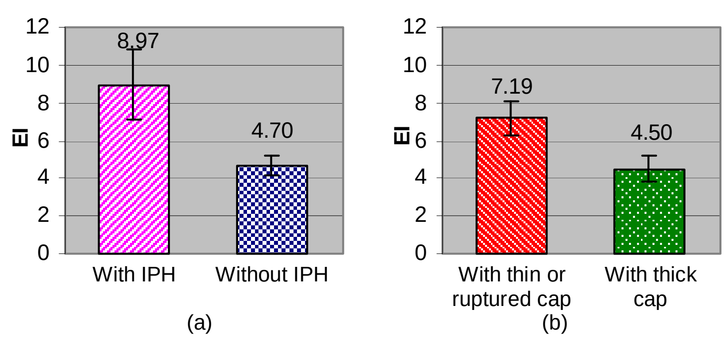

Fig. 2. (a) Comparison of EI between arteries with and without IPH; (b) comparison of EI between arteries with thin or ruptured fibrous cap and with thick fibrous cap. The bar on each column shows the 95% confidence interval.

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