

Carotid Artery Plaque Burden as Measured by Magnetic Resonance Imaging: A Potential Imaging Indicator for Acute Cerebral Ischemic Lesion Volume

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Introduction: The heterogeneity origin of stroke makes its risk prediction clinically challenging. Recently, the volume of infarction and the ischemic lesion patterns have been increasingly assumed to play an important role in investigation of stroke mechanisms and outcomes [1-2]. Atherosclerotic diseases occurring in carotid arteries have been demonstrated to be associated with transient ischemic attack (TIA) and stroke [3-4]. Thus, a comprehensive assessment of carotid atherosclerosis is believed to be helpful for predicting neurovascular events and potentially improving the prognosis. Black-blood magnetic resonance imaging (MRI) has been proven to be an effective tool for the quantification of carotid atherosclerotic plaque burden and compositions [5-6]. However, the correlation between carotid artery plaque burden as measured by black-blood MRI and cerebral ischemic lesion volume is unknown.

Purpose: To determine the association between carotid plaque burden and the size of cerebral ischemic lesion volume by MR imaging.

Methods: Forty-three patients (mean age 64.5 years, 36 males) with TIA or stroke underwent carotid artery and brain MR imaging on a 3.0T whole-body scanner (Philips Achieva, Best, the Netherlands) within 1 week after neurovascular symptoms onset. *Imaging protocol:* Brain MRI protocol: T1w: TR/TE 151/2.3ms; T2w TR/TE 2123/80ms; T2w FLAIR TR/TE 11000/120ms; DWI TR/TE 1598/46ms; acquisition matrix 256×256; slice thickness 6mm; FOV 24cm×24cm. A multi-contrast protocol was used to acquire cross-sectional carotid MR images with the following parameters: 3D TOF: TR/TE 20/4ms, flip angle 20°; T1w: quadruple inversion-recovery (QIR) [7], black-blood, 2D TSE, TR/TE 800/10ms; T2w: Multi-slice Double IR (MDIR), TR/TE 4000/50ms; MP-RAGE: IR TFE, TR/TE 13.4ms, flip angle 15°; FOV 14cm x 14cm; acquisition matrix 256x256; in-plane resolution 0.55mmx0.55mm. A longitudinal coverage of 32 mm was used for bilateral carotid MR images acquisition. *Image interpretation:* Acute ischemic lesions on DWI were diagnosed when these lesions were shown to be hyperintense on the DWI integrated for the 3 diffusion sensitivity directions and hypointense on the apparent diffusion coefficient map. The cerebral hemisphere (CH) ischemic lesion volume (ILV) was measured by an experienced radiologist blinded to carotid MR images. The ischemic lesions in internal carotid artery (ICA) blood supplying territories (frontal lobe, temporal lobe, parietal lobe, occipital lobe, and basal ganglia) were also evaluated. Carotid MR images were interpreted separately by two trained reviewers with consensus using custom designed soft ware (CASCADE[®], Seattle, WA, USA). The lumen area (LA), wall area (WA), total vessel area (TVA), mean and maximum wall thickness (Mean/MaxWT), and normalized wall index (NWI=WA/TVA) were measured for each axial location. Carotid plaque burden measurements including mean LA, WA, MeanWT, MaxWT, and Mean NWI for each artery were determined.

Results: Of 43 subjects, 21 had ischemic lesions in left cerebral hemisphere, 14 of them were located in the left ICA supplying territories, 19 had ischemic lesions in right cerebral hemisphere, and 15 of them were located in the right ICA supplying territories. No significant difference of carotid plaque burden was found between both sides ($P>0.05$, Table 1). The left cerebral hemisphere showed larger but not statistically significant acute DWI lesion volume than that of the right side (Table 1). For subjects with left cerebral ischemic lesions, strong positive correlations were found between left carotid plaque burden measurements and the volume of left cerebral ischemic lesions (r ranging from 0.641 to 0.807, $P<0.05$, Table 2 and Fig). In addition, left carotid LA was negatively correlated with left cerebral ischemic lesion volume $P<0.05$, Table 2). In contrast, there were no significant correlations of right carotid plaque burden with ischemic lesion volume in right cerebral hemisphere ($P>0.05$, Table 2).

Discussion and conclusions: In this study, we found that left carotid artery plaque burden was significantly correlated with the volumes of ipsilateral cerebral hemisphere ischemic lesions. This finding suggests that the carotid plaque burden may be an effective predictor for the severity of ischemic stroke. We also noticed the unbalanced correlation of bilateral carotid arteries plaque burden with brain ischemic lesions and the asymmetry of ischemic lesion volume in this group, which is hypothesized to be caused by small sample size or affected by other risk factors. Upon the availability of larger patient pool, we are planning to further study the correlation between carotid plaque compositions and intracranial ischemic lesion patterns in this population.

Table 1. Characteristics in carotid artery and brain.

Characteristics	Left side (Mean±SD)	Right side (Mean±SD)	P value
ILV (CH), cm ³	6.05±10.88	1.99±1.85	0.107
ILV (ICA), cm ³	5.69±11.05	1.89±1.94	0.073
Mean LA, mm ²	48.18±14.39	42.83±12.23	0.216
Mean WA, mm ²	28.34±8.11	28.90±14.20	0.879
MeanWT, mm	1.03±0.35	1.12±0.62	0.552
MaxWT, mm	2.52±1.66	2.56±2.27	0.564
Mean NWI	0.38±0.09	0.41±0.13	0.393

Table 2. Correlation of carotid plaque burden with cerebral ischemic lesion volume.

Carotid Plaque burden	Left cerebral hemisphere lesions (N=21)				Right cerebral hemisphere lesions (N=19)			
	Total volume		Volume (ICA, N= 14)		Total volume		Volume (ICA, N=15)	
	r	P	r	P	r	P	r	P
Mean LA	-0.515	0.017	-0.641	0.014	0.296	0.233	0.244	0.381
Mean WA	0.654	0.001	0.645	0.013	-0.167	0.509	0.008	0.977
MeanWT	0.723	<0.001	0.709	0.004	-0.215	0.392	-0.110	0.695
MaxWT	0.369	0.990	0.384	0.175	-0.068	0.790	0.029	0.917
Mean NWI	0.793	<0.001	0.807	<0.001	-0.173	0.492	-0.079	0.779

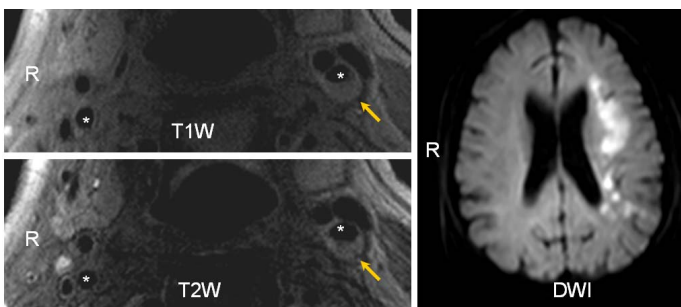


Fig. Eccentric atherosclerotic plaque (arrow) at left carotid artery (star) and a large territorial hyperintense area in left cerebral hemisphere were found on DWI in a 67 year old male patient.

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