# Optimal T1-weighted MR plaque imaging for cervical carotid artery stenosis in predicting development of microembolic signals during carotid dissection in endarterectomy.

Yuiko Sato[1], Kuniaki Ogasawara[1], Shinsuke Narumi[2], Makoto Sasaki[3], Ayumi Saito[2], Takamasa Namba[1], Masakazu Kobayasi[1], Kenji Yoshida[1], Yasuo Terayama[2], and Akira Ogawa[1]

*[1]Department of Neurosurgery, Iwate Medical Univercity, Morioka, Iwate, Japan, [2]Department of Neurology and Gerontology, Iwate Medical Univercity, Morioka, Iwate, Japan, [3]Division of Ultra-High Field MRI and Department of Radiology, Iwate Medical Univercity, Mrioka, Iwate, Japan*

**Target audience**: Researchers and clinicians interested in plaque imaging and stroke.

**Purpose**: Intraplaque characteristics assessed by preoperative magnetic resonance (MR) carotid plaque imaging may be associated with development of microembolic signals (MES) during carotid dissection in carotid endarterectomy (CEA)[1]. However, findings of the vulnerable plaques on the MR imaging vary because of differences in imaging techniques. The purpose of the present study was to determine which plaque imaging technique predicts more accurately development of MES during carotid dissection in CEA.

**Methods**: The present study included 60 patients (57 men, 3 women) was 69 ± 7 years (range, 51–85 years) with ipsilateral ICA stenosis ≥70% and useful residual function who underwent CEA of the carotid bifurcation in our institution. The following four MR plaque imaging techniques were compared: cardiac-gated black-blood fast spin echo (BB-FSE), magnetization-prepared rapid acquisition with gradient echo (MPRAGE), source image of three-dimensional time-of-flight MR angiography (SI-MRA) and non cardiac-gated SE[2]. Those MR plaque imaging techniques in the affected carotid bifurcation was simultaneously performed within 1 week prior to CEA using a 1.5-tesla MR scanner (Echelon Vega, Hitachi Medical Corporation, Tokyo, Japan) and an eight-channel neurovascular coil. The section direction was carefully set as perpendicular to the long axis of carotid bifurcation on the sagittal two-dimensional phase-contrast MR angiography, the section of BB-FSE was set at the location in which the stenosis was most severe, and the midsections of MPRAGE, SI-MRA, and non-gated SE were set at the identical location as that of BB-FSE. For the quantitative comparison in four techniques, the signal intensities of the carotid plaque ($S_p$) and the adjacent sternomastoid muscle ($S_m$) were measured at the section at which the four kinds of images were obtained. The regions of interest were manually located on the images by a free software package (zioTerm2009, Ziosoft, Tokyo, Japan). Each signal intensity value was obtained, and the contrast ratio (CR) of the carotid plaque was calculated by $CR = S_p/S_m$. In addition, for assessing intraplaque characteristics, the three color-coded component map on the same section of the best plaque imaging technique determined in the first study was created by the plaque analysis software package (PlaqueViewer, Hitachi Medical, Tokyo, Japan). In the side in which CEA was performed, the software automatically divided internal areas of the plaques into three color-coded components (fibrous tissue: Fib, lipid/necrosis: LRNC, hemorrhage: IPH) according to the CRs of the plaques. Next, the percentage areas of each component were automatically calculated (IPH + LRNC + Fib = 100%). Intraoperative transcranial doppler (TCD) was performed to detect MES using a PIONEER TC2020 system for insonation of the middle cerebral artery ipsilateral to the carotid artery undergoing CEA. The relationship between CR in each MR plaque imaging or percentage area of each component and development of MES during carotid dissection was evaluated using the Mann-Whitney U-test. The accuracy of the CR or the percentage area to predict development of the MES was determined using a receiver operating characteristic (ROC) curve, and the ability to discriminate between presence and absence of the MES was estimated using the area under the ROC curve (AUC). The pairwise comparison of the AUCs was performed for the CR or the percentage area of each component. For all statistical analyses, significance was set at the $p<0.05$ level.

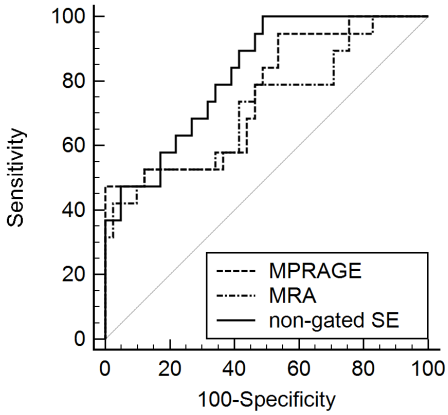


**Figure 1** ROC curves used to compare accuracy among CR in three MR plaque imaging techniques.

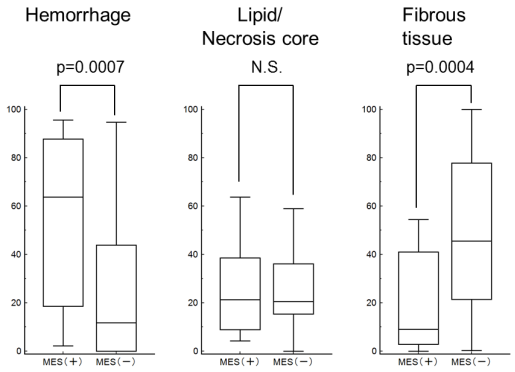


**Figure 2** Relationship between percentage area of each component in quantitative color-coded MR plaque imaging and development of MES during carotid dissection.

**Results**: While the CR in patients with MES was significantly higher than that in patients without MES in MPRAGE ($p$=0.0014), SI-MRA ($p$=0.0064) and non-gated SE ($p$=0.0001), the CR in BB-FSE did not differ between patients with and without MES. The AUC of non-gated SE was significantly greater than that of MPRAGE (difference between areas, 0.0668; $p$=0.0312) or SI-MRA (difference between areas, 0.104; $p$=0.0130)(Fig. 1). Therefore, we employed the non-gated SE for the three component color-coded map with the cutoff values of 1.17 (Fib/LRNC) and 1.55 (LRNC/IPH) that were established in a previous study[3]. While the percentage area of hemorrhage (55.5 ± 34.9% for patients with MES versus 25.0 ± 30.5% for patients without MES; p=0.0007) or fibrous tissue (19.9 ± 20.0% for patients with MES versus 49.9 ± 31.9% for patients without MES; p=0.0004) was significantly greater or less in patients with MES than in those without MES, respectively, the percentage area of lipid/necrosis did not differ between patients with (25.2 ± 17.8%) and without MES (25.0 ± 16.5%) (p=0.9083)(Fig. 2). Sensitivity, specificity, positive- and negative-predictive values for percentage areas of hemorrhage or fibrous tissue at the cut-off point lying closest to the left upper corner of the ROC curve in predicting development of MES during carotid dissection were 63%, 76%, 55% and 82% (cut-off point = 40.7%), or 53%, 88%, 67% and 80% (cut-off point = 9.0%), respectively.

**Conclusion and Discussion:** The present study demonstrated that the CR and the three color-code component map of non-gated SE, which can discriminate the intraplaque characteristics, predict more accurately development of MES during carotid dissection in CEA than other MR plaque imaging techniques.

**References**

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