

# Carotid Wall Imaging with Routine Brain MRI to Facilitate Early Detection of Carotid Plaque and Intraplaque Hemorrhage

Hyo Sung Kwak, Hye Jin Yang, Seung Bae Hwang, Gyung Ho Chung

Department of Radiology of Chonbuk National University, Research Institute of Clinical Medicine of Chonbuk National University, Biomedical Research Institute of Chonbuk National University Hospital, Jeonju, Korea

Dear Sir:

Previous studies have reported stroke magnetic resonance imaging (MRI) assessments that included a carotid magnetization-prepared rapid acquisition with gradient-echo (MPRAGE) sequence. The findings of these studies showed that a carotid MPRAGE-positive signal was associated with an increased risk of territorial cerebral ischemic events, as detected by brain diffusion-weighted imaging (DWI).<sup>1</sup> This study evaluated the effectiveness of carotid MPRAGE added to standard brain MRI with contrast-enhanced MR angiography (CE-MRA) as an outpatient screening tool for detecting and evaluating carotid intraplaque hemorrhage (IPH) location.

From November 2013 to November 2015, 2,036 outpatients were enrolled for carotid wall imaging using the MPRAGE sequence and carotid contrast-enhanced MR angiography within the standard brain MRI protocol at 3.0-T (Achieva, Philips Healthcare, Best, The Netherlands). An experienced neuroradiologist excluded images with the following traits: no carotid artery suppression, poor imaging quality, internal carotid artery (ICA) total occlusion, previous stent insertion or endarterectomy, or incomplete coverage of ICA bifurcation. Carotid plaques were defined as having wall thickness greater than 2 mm in at least 2 consecutive slices on MPRAGE imaging. Carotid plaques with a high signal intensity on MPRAGE (i.e., >200% of the adjacent muscle in at least 2 consecutive slices) were defined as IPH. The locations of IPH were divided into common carotid artery, carotid bifurcation, and ICA.

Among the 1,737 subjects underwent carotid wall MR imaging, 291 carotid plaques were detected in 226 subjects (13%) and enrolled in the study. Among these, 146 carotid plaques (50.2%) of 118 subjects (52.2%) demonstrated MR-positive IPH. Patient demographics between the two groups were similar. Among the subjects with carotid plaques, 65 (28.8%) showed bilateral lesions and 28 patients (12.4%) were recorded as showing bilateral MR-positive IPH. The findings of the carotid plaque in patients are shown in Table 1. The degree of carotid stenosis was significantly higher in the MR-positive IPH group ( $P=0.001$ ). The prevalence of moderate- to high-grade stenosis (>50%) was significantly higher in the IPH-positive group. Among patients with carotid plaques, 101 (34.1%) showed normal angiographic findings on CE-MRA. Among these with normal angiographic findings, 43 (42.6%) carotid plaques with IPH were detected. The locations of IPH in the carotid artery are summarized in Table 2. Among subjects with IPH in the common carotid artery (CCA), 29 patients (90.6%) recorded normal angiographic findings on CE-MRA (Figure 1). Normal angiographic findings on CE-MRA were significantly more common in subjects with CCA IPH than in those with ICA IPH.

Prospective studies have found a relationship between the presence of IPH at baseline and ischemic stroke.<sup>1,2</sup> The presence of IPH was associated with a six-fold higher risk for stroke events and the annual event rate in subjects with detectable IPH was 17.71% as compared with 2.43% in patients without IPH.<sup>3</sup> The development of IPH also posed immediate and long-term atherosclerosis-promoting effects on plaque progression and altered

**Table 1.** Carotid plaque findings in IPH-positive and IPH-negative subjects

	IPH-positive	IPH-negative	P
Patients	118	108	
Carotid arteries	146	145	
Stenosis (NASCET criteria)	39.5 ± 33.7	22.5 ± 23.9	0.001
Normal, n (%)	43 (29.5)	58 (40.0)	0.08
Mild, n (%)	45 (30.8)	69 (47.6)	0.005
Moderate	28 (19.2)	11 (7.6)	0.007
Severe	30 (20.5)	7 (4.8)	0.001

IPH, intraplaque hemorrhage; NASCET, North American Symptomatic Carotid Endarterectomy Trial.

Degree of carotid stenosis as observed in contrast-enhanced MR angiography = normal: 0%, mild: <50%, moderate: 51–0%, and severe: > 70%.

**Table 2.** Location of intraplaque hemorrhage in carotid artery

	CCA (n = 32)	Bifurcation (n = 15)	ICA (n = 99)
Degree of stenosis			
Normal	29 (90.6%)*	7 (46.7%)	7 (7.1%)
Mild	3 (9.4%)	5 (33.3%)	37 (37.4%)
Moderate	0	2 (13.3%)	26 (26.2%)
Severe	0	1 (6.7%)	29 (29.3%)

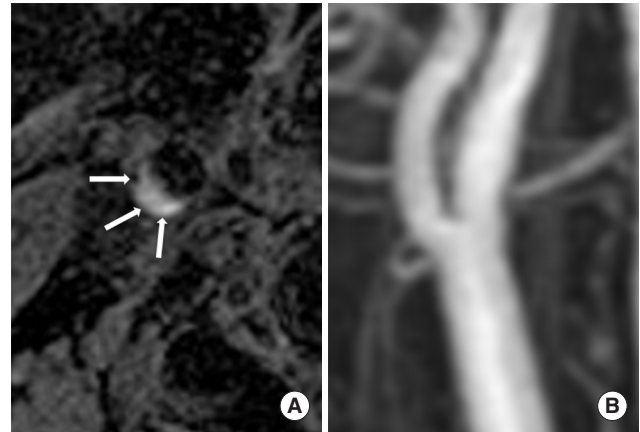
CCA, common carotid artery; ICA, internal carotid artery.

\*Significant difference in the location of intraplaque hemorrhage between common and internal carotid arteries ( $P < 0.00$ ).

the biology and natural history of carotid atherosclerosis.<sup>4,5</sup> Among patients with CCA plaques with IPH, 29 (90.6%) demonstrated normal angiographic findings, which suggest that most CCA plaques with IPH are not identified on CE-MRA. Therefore, CE-MRA might play a limited role in detecting small plaques and IPH in accordance with the North American Symptomatic Carotid Endarterectomy Trial criteria. Although normal angiographic findings were seen in carotid CE-MRA, one-step vessel wall imaging using MPRAGE and luminal imaging using CE-MRA would be useful in early identification of carotid plaque and IPH. In conclusion, the inclusion of carotid wall imaging using MPRAGE sequence and CE-MRA to routine brain MR studies is a useful tool in screening for early detection of carotid plaque and IPH.

## References

1. Takaya N, Yuan C, Chu B, Saam T, Underhill H, Cai J, et al. Association between carotid plaque characteristics and subsequent ischemic cerebrovascular events: A prospective assessment with MRI—initial results. *Stroke* 2006;37:818–823.
2. Yamada N, Higashi M, Otsubo R, Sakuma T, Oyama N, Tanaka R, et al. Association between signal hyperintensity on T1-weighted MR imaging of carotid plaques and ipsilateral isch-



**Figure 1.** Carotid plaque in a 69-year-old man. (A) MPRAGE image shows high-signal intensity in the right carotid plaque (arrows), suggesting intraplaque hemorrhage in the common carotid artery. (B) Maximum intensity-projection of contrast-enhanced MR angiography shows normal angiographic findings for the right carotid artery.

emic events. *AJNR Am J N* 2007;28:287–292.

3. Saam T, Hetterich H, Hoffmann V, Yuan C, Dichgans M, Poppert H, et al. Meta-analysis and systematic review of the predictive value of carotid plaque hemorrhage on cerebrovascular events by magnetic resonance imaging. *JACC Cardiovasc Interv* 2013;62:1081–1091.
4. Sun J, Underhill HR, Hippe DS, Xue Y, Yuan C, Hatsukami TS. Sustained acceleration in carotid atherosclerotic plaque progression with intraplaque hemorrhage: A long-term time course study. *JACC Cardiovasc Imaging* 2012;5:798–804.
5. Sun J, Balu N, Hippe DS, Xue Y, Dong L, Zhao X, et al. Subclinical carotid atherosclerosis: Short-term natural history of lipid-rich necrotic core—A multicenter study with MR imaging. *Radiology* 2013;268:61–68.

### Correspondence:

Seung Bae Hwang  
Radiology and Research Institute of Clinical Medicine of Chonbuk National University-Biomedical Research Institute of Chonbuk National University Hospital, 567 Baekje-daero, Deokjin-gu, Jeonju 54896, Korea

Tel: +82-63-250-2582, Fax: +82-63-272-0481  
E-mail: sbh1010@jbnu.ac.kr

Received: October 17, 2016  
Revised: December 7, 2016  
Accepted: December 11, 2016

This paper was supported by the funding from Biomedical Research Institute, Chonbuk National University Hospital, Jeollabuk-do, Republic of Korea.

The authors declare there are no conflicts of interest towards this manuscript.