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Letter to the Editor

Imaging Predictors for Atherosclerosis-Related Intracranial Large Artery Occlusions in Acute Anterior Circulation Stroke

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Dear Sir:

Recent randomized clinical trials have demonstrated the beneficial effects of new thrombectomy devices as an endovascular treatment for patients with intracranial large artery occlusion.[1-5] However, treatment plans may vary according to different etiologies of arterial occlusion. Arterial occlusion associated with embolism may respond well to thrombectomy devices, but can be less effective in patients with arterial occlusion due to intracranial atherosclerotic disease (IAD).[6] IAD-related occlusion is not uncommon in the Asian population.[7] Despite increased awareness of the presence of IAD occlusions in this group, routine angiographies are unable to differentiate between IAD-related and embolic occlusions.[8] The present study aimed to evaluate imaging modalities that could potentially distinguish between these two etiologies.

Consecutive patients admitted to Ajou University Hospital (Suwon, Korea) for ischemic stroke, between January 2010 and March 2014, were enrolled. Patients with intracranial large artery occlusions resulting in acute ischemic stroke who underwent the following cerebral imaging studies within 8 hours of symptom onset were included in the study: axial computed tomography (CT), CT angiography, magnetic resonance imaging (MRI), and transfemoral cerebral angiography with or without combined endovascular revascularization treatment. Exclusion criteria were as follows: (1) occlusions occurring in the posterior circulation, as the imaging characteristics for this type of occlusion are different and the sample size was small; (2) dissection, Moyamoya disease, or vasculitis; and (3) persistent occlusion or incomplete recanalization despite endovascular treatment. Informed consent was obtained from all participants, and the study protocol was approved by the local institutional review board.

On non-contrast CT, the Alberta stroke program early CT score (ASPECTS), dense clot signs, and arterial calcification in the occlusion site were evaluated. On MRI, infarct core volumes with an ADC threshold of 600×10^{-6} mm^2/s were calculated using the NordicICE software package (NordicNeuroLab, Bergen, Norway). On diffusion-weighted imaging (DWI); the stroke patterns evaluated were classified as branch occlusive, borderzone, scattered, or territorial infarcts; as previously reported elsewhere.[9] Each infarct pattern was evaluated separately, and a patient could have two or more infarct types. The susceptibility vessel sign and its clot burden score on gradient echo (GRE) or susceptibility-weighted imaging (SWI) were evaluated. Although GRE was used more often, SWI was used at the start of the study until September 2010. A 10-point scale was used to assign the clot burden score, which indirectly represented the clot length, as previously described.[10] Points were subtracted from a total of 10 and the following values were assigned: intracranial ICA involvement = 3, proximal MCA = 2, distal MCA = 2, superior division of the

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MCA = 1, inferior division of the MCA = 1, and ACA = 1; where a higher clot burden score indicated less of a clot burden.

Using transfemoral cerebral angiography, IAD was diagnosed where (1) final angiography showed a significant (> 70%) fixed focal stenosis or moderate stenosis with either flow and perfusion impairment on angiography or an evident tendency for reocclusion, (2) angioplasty or stent insertion was required to achieve full recanalization, and (3) remaining arterial stenoses were not considered to be attributable to vessel wall injury or iatrogenic dissection. An angiographic embolism was diagnosed if no or minimal stenosis was observed with sufficient blood flow and without a tendency for reocclusion after recanalization. Two experienced neurologists (KSL and HIS) who were blinded to the patients' medical histories were responsible for reading the angiographic data. In case of discrepancy, final diagnosis was based on consensus and included a third interventional neurologist (JSL).

Demographic characteristics, risk factors, and imaging characteristics were compared between the IAD and embolic groups. Statistical analyses were performed using SPSS (Version 21.0, IBM SPSS, Armonk, USA). Parameters were compared using the χ^2 and Mann-Whitney U tests for nonparametric variables and a Student's *t* test for continuous variables. In all analyses, *P* values < 0.05 were considered statistically significant.

A total of 134 patients were enrolled in this study (IAD group, n = 14; embolic group, n = 120). In the embolic group, 4 patients had extracranial ICA steno-occlusive lesions. Patients in the IAD group were younger (58 vs. 68 years, *P* = 0.011), more often male (86% vs. 52%, *P* = 0.015), and more likely to be smokers (50% vs. 13%, *P* = 0.001). Atrial fibrillation was more common in the embolic group than in the IAD group (62% vs. 0%, *P* < 0.001), although the frequency of other risk factors did not differ between the groups. The frequency of revascularization treatment used, including intravenous fibrinolysis (71% vs. 75%, *P* = 0.771) and endovascular treatment (64% vs. 78%, *P* = 0.238), did not differ between the groups. Final successful reperfusion rates (modified treatment in cerebral ischemia score 2b–3; 71% vs. 64%, *P* = 0.576) and successful recanalization rates (arterial occlusive lesion score 2–3; 86% vs. 76%, *P* = 0.399) did not differ between the groups.

The imaging findings of each group are presented in Table 1. The ASPECTS score (median: 8 vs. 7, *P* = 0.291) and frequency of a dense clot sign (43% vs. 47%, *P* = 0.766) in the occlusion site on non-contrast CT did not differ between the groups. Occlusion of the M1 segment of the MCA was more frequent in the IAD group than in the embolic group (93% vs. 42%, *P* = 0.004). The susceptibility vessel sign on GRE was observed in 71% and 84% of patients in the IAD and embolic groups, respectively (*P* = 0.239). The clot burden score was significantly higher (indicating a lower clot burden) in the IAD group than in the embolic group (8 [interquartile range: 7-9] vs. 6 [5-8], *P* = 0.009). A full territorial infarct pattern on DWI (18% vs. 55%, *P* = 0.020) was less frequent while borderzone infarcts (36% vs. 12%, *P* = 0.032) and scattered infarct patterns (55% vs. 31%, *P* = 0.110) tended to be more frequent in the IAD group than in when compared with the embolic group. The baseline infarct core volume was significantly smaller in the IAD group than in the embolic group (14 vs. 54 mL, *P* < 0.001).

Table 1. Comparison of imaging results between IAD and embolic groups

	IAD group	Embolism group	*P* value
ASPECTS score on NCCT, median (IQR)	8 (5.75-9)	7 (4.75-9)	0.291
Occlusion site			0.004
Intracranial ICA	1 (7.1%)	41 (34.2%)	
M1	13 (92.9%)	50 (41.7%)	
M2	0 (0%)	9 (7.5%)	
Other	0 (0%)	20 (16.7%)	
Dense clot sign on NCCT	6 (42.9%)	56 (47.1%)	0.766
Presence of arterial calcification on NCCT	0 (0%)	16 (13.4%)	0.144
Susceptibility vessel sign on GRE*	10 (71.4%)	90 (84.1%)	0.239
Clot burden score on GRE,* median (IQR)	8 (7-9)	6 (5-8)	0.009
DWI pattern–branch occlusive infarct	3 (27.3%)	13 (13.3%)	0.213
DWI pattern–border zone infarct	4 (36.4%)	12 (12.2%)	0.032
DWI pattern–scattered infarct	6 (54.5%)	30 (30.6%)	0.110
DWI pattern–territorial infarct	2 (18.2%)	54 (55.1%)	0.020
Baseline infarct core volume†	14 ± 12	54 ± 65	< 0.001

IAD, intracranial atherosclerotic disease; ASPECTS, Alberta stroke program early computed tomography score; NCCT, non-contrast computer tomography; IQR, interquartile range; ICA, internal carotid artery; GRE, gradient echo; DWI, diffusion-weighted imaging.
*Susceptibility-weighted imaging was used in place of GRE up to September, 2010; †A threshold of apparent diffusion coefficient $< 600 \times 10^{-6}$ mm^2/s.

We found that imaging findings may predict the presence of IAD occlusions. Occlusion in the M1 segment of the MCA, a scattered or borderzone infarct pattern on DWI, smaller infarct core volume on the ADC map, and lower clot burden on GRE were associated with IAD-related occlusions.

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