EXTRA Cerebrovascular Diseases

Cerebrovasc Dis Extra 2013;3:46–54
DOI: 10.1159/000350459
Published online: April 5, 2013

1664–5456/13/0031–0046$38.00/0
www.karger.com/cee

Karger Open access

Original Paper

Fluid-Attenuated Inversion Recovery Hyperintense Vessels in Posterior Cerebral Artery Infarction

Kwon-Duk Seo[a] Kee Oog Lee[c] Young-Chul Choi[a] Won-Joo Kim[a]
Kyung-Yul Lee[a, b]

[a]Department of Neurology, Gangnam Severance Hospital, Yonsei University College of Medicine, and [b]Severance Institute for Vascular and Metabolic Research, Seoul, and [c]Department of Neurology, Konyang University College of Medicine, Daejeon, Korea

Key Words

Fluid-attenuated inversion recovery MRI · Hyperintense vessel · Posterior cerebral artery infarction

Abstract

Background: Fluid-attenuated inversion recovery hyperintense vessels (FHVs) are known to reflect stagnant or slow blood flow within the cerebral artery. FHVs are frequently observed in patients with acute cerebral infarction accompanied by arterial occlusion or significant stenosis of the anterior cerebral circulation. However, FHVs have not been studied in the context of posterior cerebral circulation. Thus, we investigated the prevalence of FHVs and its clinical significance in patients with acute posterior cerebral artery (PCA) territory infarction. ***Methods:*** In this retrospective study, consecutive patients with PCA territory infarction who underwent MRI within 1 week after symptom onset were enrolled. Two neurologists who were blinded to the angiographic findings read the images and determined the presence of FHVs. Afterwards, FHVs were graded according to the extent (subtle or prominent) and location (proximal or distal) of the hyperintense vessels. Neurologic deficits of the patients were assessed by the National Institutes of Health Stroke Scale (NIHSS) upon admission and after 5 days. The clinical outcome between patient groups based on FHVs grading was compared using the NIHSS. Among the patients with PCA occlusion, infarction volume on the diffusion-weighted image was compared between the two groups with and without distal FHVs. ***Results:*** FHVs were observed in 25 of the 87 patients (28.7%) with PCA territory infarction and in 65.7% of the 35 patients with significant arterial stenosis (10 patients) or occlusion (25 patients) in the posterior cerebral circulation. Among the 18 patients with PCA occlusion, the NIHSS score was significantly improved in patients with distal FHVs compared to the others

Kyung-Yul Lee, MD, PhD
Department of Neurology, Gangnam Severance Hospital
Yonsei University College of Medicine
211 Eonjuro, Gangnam-gu, Seoul 135-720 (Korea)
E-Mail kylee@yuhs.ac

Cerebrovascular Diseases EXTRA

Cerebrovasc Dis Extra 2013;3:46–54

DOI: 10.1159/000350459

(2.00 ± 2.18 vs. 0.56 ± 1.01, p = 0.04). The infarction volume was smaller in the distal FHV group than in the others (8.3 ± 8.7 vs. 16.8 ± 17.6 ml), but the difference was not statistically significant. ***Conclusions:*** FHVs are detected in patients with PCA territory infarction, especially in those with an occlusive lesion in the PCA. FHVs can be used as an imaging marker of PCA occlusion. Although this study showed a better clinical improvement in patients with distal FHVs, further study is needed to elucidate the clinical meaning of FHVs in PCA infarction.

Introduction

Fluid-attenuated inversion recovery hyperintense vessels (FHVs) are detected in the subarachnoid space due to suppression of the cerebrospinal fluid (CSF) signal, causing contrast between dark CSF and bright blood vessels. FHVs can be seen in ischemic stroke patients with arterial occlusion or significant stenosis [1]. Sometimes they can be observed in patients with cerebral arterial occlusion but without infarction, i.e. those with moyamoya disease [2]. FHVs have been reported in 10–97% of ischemic stroke patients [1, 3–8]. Their prevalence varies according to the arterial status; moreover, FHVs are observed more frequently in patients with middle cerebral artery (MCA) or internal carotid artery occlusion (75–80%) [5–7], in contrast to 14% of patients without arterial occlusion [8]. In most studies, FHVs are reported within the first 24 h after stroke onset, but they can be detected up to 13 days after stroke [9].

The mechanism of FHVs is known to be related to slow or stagnant blood flow [1]. FHVs are radiological indicators of proximal arterial occlusion or severe stenosis [8, 10–12]. Furthermore, they are reported to reflect collateral circulation and diffusion-perfusion mismatch on MRI [4, 5, 13, 14]. However, controversy exists regarding the clinical implication of FHVs for acute severity of stroke and the functional outcome [5, 7, 10, 15–17].

Previous studies have mostly focused on the anterior circulation. The prevalence of FHVs in the posterior circulation is unclear, and only a few cases of FHVs in the posterior cerebral artery (PCA) have been reported [3, 8, 11]. In this study, we identified the prevalence and clinical significance of FHVs in acute PCA infarction.

Patients and Methods

Patients

We retrospectively selected patients with acute PCA territory infarction from our stroke registry between October 2008 and July 2012 including all consecutive patients admitted to our hospital. Inclusion criteria were: (1) MRI within 1 week of symptom onset, (2) ischemic changes in the PCA territory confirmed by diffusion-weighted imaging (DWI), and (3) blood vessel study with MRA or CTA. We excluded patients with infarction in multiple territories other than the PCA territory. Neurologic deficit was assessed with the National Institutes of Health Stroke Scale (NIHSS) at admission and 5 days later. The stroke mechanisms were classified based on the Trial of Org 10172 in Acute Stroke Treatment (TOAST) classification [18].

Imaging Studies

MRI examinations were performed utilizing three different 3.0T scanners (Discovery MR750 and Signa Excite, GE Medical Systems; Achieva, Philips Medical Systems). Fluid-attenuated inversion recovery (FLAIR) parameters for the three scanners, respectively, were as follows: TR/TE = 9,177/141 ms, 12,000/144 ms, 11,000/125 ms, TI = 2,200 ms, 2,519 ms,

Cerebrovasc Dis Extra 2013;3:46–54
DOI: 10.1159/000350459

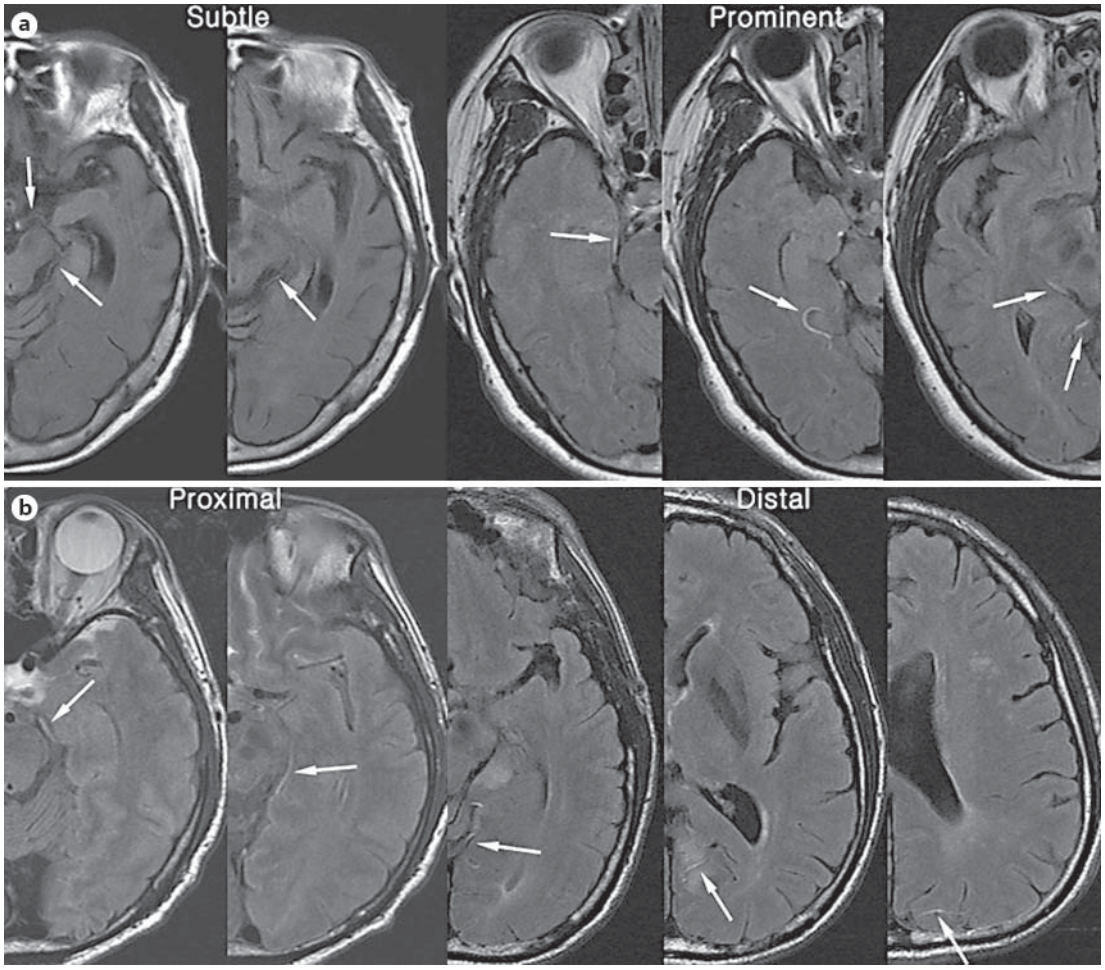

Fig. 1. Example of FHVs grading in 4 different patients. **a** Both patients have a PCA occlusion and demonstrate different extents of FHVs on FLAIR imaging. **b** Both patients have a PCA occlusion and demonstrate different locations of FHVs on FLAIR imaging.

2,800 ms, FOV = 21 × 21 cm, 21 × 21 cm, 22 × 22 cm, matrix size = 352 × 224, 352 × 224, 340 × 299, slice thickness = 4 mm, inter-slice gap = 1 mm. DWI were obtained using the following parameters, respectively: TR/TE = 9,000/79.3 ms, 8,000/71.4 ms, 3,384/75.9 ms, FOV = 23 × 23 cm, 23 × 23 cm, 24 × 24 cm, matrix size = 160 × 160, 160 × 160, 128 × 128, slice thickness = 4 mm, interslice gap = 1 mm, b value = 1,000 s/mm^2. The resulting voxel volumes of FLAIR were 2.24 mm^3 (GE Medical Systems) and 1.90 mm^3 (Philips Medical Systems), respectively. Extracranial contrast-enhanced MRA and intracranial time-of-flight MRA were performed. CTA was conducted in 3 patients at 50 and 150 min, and 24 h before the FLAIR images.

The FLAIR images were reviewed by two neurologists to determine the presence of FHVs without knowing the angiographic findings. Two readers graded the FLAIR images independently, and discordance was settled by a separate consensus reading. FHVs were defined as linear or serpentine tubular structures with a high signal intensity in the subarachnoid space and graded as subtle (observed in one or two axial slices) or prominent (observed in more than three continuous axial slices) (fig. 1a). We also divided patients with FHVs into two groups based on the location in patients with proximal PCA occlusion. Proximal FHV was

Table 1. Clinical characteristics of patients

	Patients		p value
	FHV (+)	FHV (–)	
Number of patients	25 (27.9)	62 (72.1)	
Male gender	14 (56.0)	43 (69.4)	0.236
Age, years	61.1±16.0	63.7±13.2	0.449
Hypertension	12 (48.0)	34 (54.8)	0.638
Diabetes mellitus	8 (32.0)	17 (27.9)	0.8
Time interval from symptom onset to MRI, h	29.4±38.7	39.5±37.4	0.006
TOAST classification			
LAA	9	12	
CE	8	10	
LAC	2	27	
SUE (LAA+CE)	6	1	
SUE (LAC+CE)	0	1	
SUE (negative evaluation)	0	11	

Data are expressed as the mean ± SD or as n (%). SUE = Stroke of undetermined etiology.

defined as FHVs seen at the level of the PCA occlusion, usually the perimesencephalic cistern. Distal FHV was present when FHVs were observed beyond the occlusion site, usually above the brainstem level on more than two continuous axial slices of FLAIR images (fig. 1b). MRA or CTA findings were classified into four categories according to the severity of stenosis: occlusion, significant stenosis (≥50%), mild stenosis (<50%), and normal. The degree of stenosis was measured as described [19, 20].

We measured the infarction size on DWI in patients with PCA occlusion to compare the characteristics of patients with the same condition. The infarction area was defined as hyperintense lesions on DWI and corresponding hypointense lesions on apparent diffusion coefficient maps. Infarction volumes were measured in 18 patients using semi-automated computerized software (Xelis; Infinitt, Korea).

Statistical Analysis

We performed all statistical analyses with SPSS 19.0 software for Windows. Interobserver agreement for the presence of FHVs was assessed by calculating the κ statistical analysis and the 95% confidence interval. We used the t test for numerical data and the χ^2 test for proportions of demographical data. In addition, the χ^2 test was performed to analyze the proportion of FHVs obtained by the three different devices. The Mann-Whitney U test was used to compare NIHSS score improvement between different groups of patients, the difference in infarction volume between the distal FHV group and the others, and the MRI time lag between patients with and without FHVs. The level of statistical significance was $p < 0.05$.

Results

Eighty-seven patients fulfilled the inclusion criteria. FHVs were detected in 25 patients (28.7%, κ = 0.748). Furthermore, FHVs were observed in 13 of the 51 patients who underwent MRI with Signa Excite, in 9 of the 23 patients with Discovery MR750 and in 3 of the 13 patients with Achieva, respectively. There was no difference in the proportion of FHVs detected by the

EXTRA Cerebrovascular Diseases

Cerebrovasc Dis Extra 2013;3:46–54

DOI: 10.1159/000350459

Table 2. Relationship between FHVs and artery status

	Total	FHV (+)	FHV (–)
Occlusion			
VA	3	0	3
BA	4	4	0
PCA P1	8	7	1
PCA P2	10	9	1
Significant stenosis (>50%)			
BA	5	2	3
PCA	5	1	4
Mild stenosis (<50%)	12	0	12
No stenosis	40	2	38

VA = Vertebral artery; BA = basilar artery.

Table 3. Comparisons of NIHSS scores between groups of patients

	FHV (+)	FHV (–)	p value	Prominent FHV	Subtle FHV	p value
Number	25	62		19	6	
Initial NIHSS	5.76±7.71	1.98±2.44	0.001	6.95±8.52	2.00±1.41	0.069
Follow-up NIHSS	4.32±6.92	1.52±2.54	0.003	5.21±7.75	1.50±1.05	0.198
Difference in NIHSS	1.44±2.93	0.47±0.90	0.022	1.74±3.26	0.50±1.23	0.08

Data are expressed as the mean ± SD or as number.

three different devices (p = 0.448). Demographic characteristics are shown in table 1. There was no difference in gender, age, or prevalence of diabetes mellitus and hypertension between the two groups. One patient with PCA occlusion received intra-arterial thrombolysis and 2 patients with basilar artery occlusion received intravenous and mechanical thrombolysis, respectively. Of the 25 patients with FHVs, 23 had etiologies such as large artery atherosclerosis (LAA) or cardioembolism (CE) classified by the TOAST classification. Only 2 of the 29 patients with lacunar infarction (LAC) classified by the TOAST classification showed FHVs. MRI was performed at a mean time of 36.6 ± 37.8 h (range, 4 to 160) after symptom onset. Nineteen patients (76%) with FHVs and 26 patients (42%) without FHVs underwent MRI within 24 h after symptom onset. The time lag from stroke onset to MRI was shorter in patients with FHVs (29.4 ± 38.7 h) than in patients without FHVs (39.5 ± 37.4 h) (p = 0.006). Twenty-five patients had occlusion in the posterior circulation (vertebral artery = 3, basilar artery = 4, and PCA = 18), and 10 patients had severe stenosis in the posterior circulation. Twelve patients had mild stenosis in the PCA, and the remaining 40 patients had no occlusion or stenosis. FHVs were detected in 20 of the 22 patients (90.5%) with occlusion of the PCA or basilar artery, and 3 of 10 patients (30%) showed significant stenosis (table 2). Initial and follow-up NIHSS scores were significantly higher in patients with FHVs (5.76 ± 7.71 and 4.32 ± 6.92) than in those without FHVs (1.98 ± 2.44 and 1.52 ± 2.54) (p = 0.001, p = 0.003, respectively). The improvement in NIHSS scores from baseline to 5 days was significantly greater in patients with FHVs than in patients without FHVs. Among the patients with FHVs, 19 patients were classified as having prominent FHV, and 6 patients had subtle FHV. Initial and follow-up NIHSS scores were similar in both groups. There was no significant difference in the improvement in NIHSS scores between the two groups (table 3). Eighteen patients with PCA occlusion were divided into two groups of 9 patients with distal FHVs and 9 others (7 with

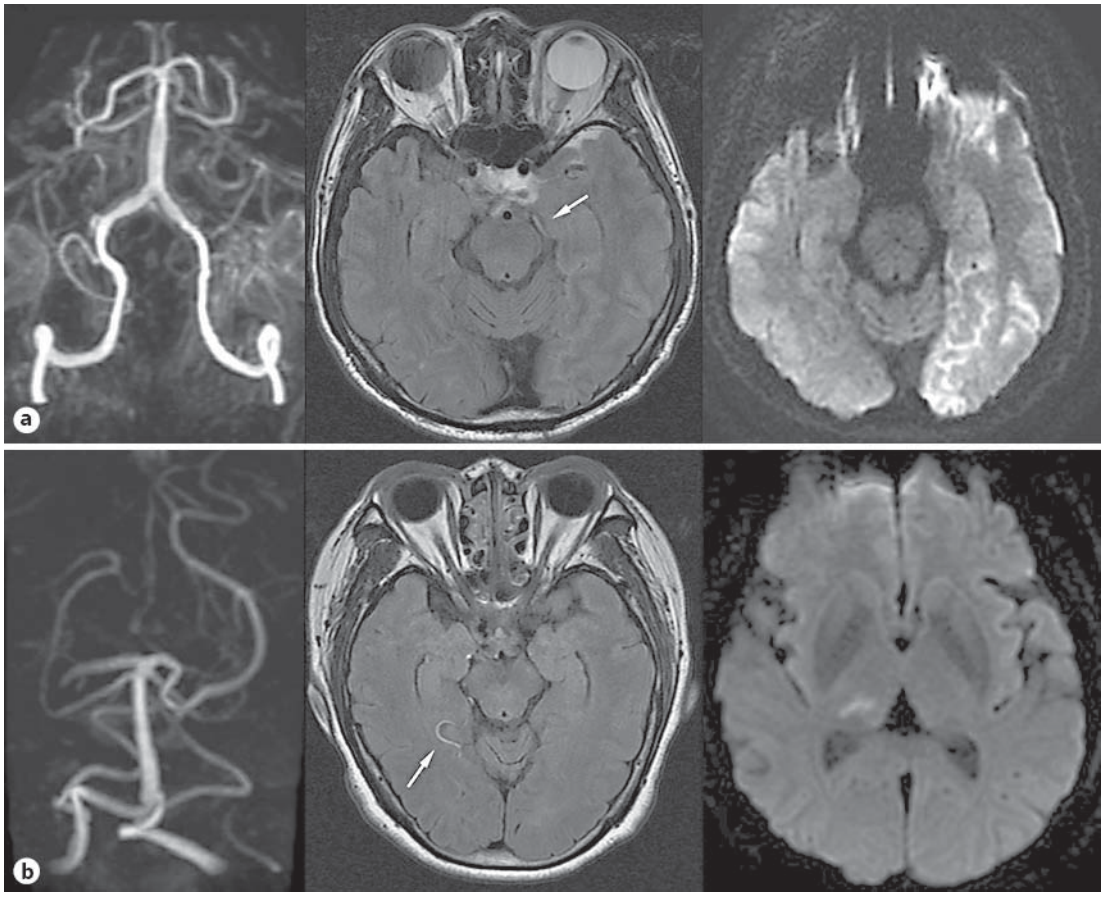

Fig. 2. a MRA shows P2 occlusion and DWI reveals large left PCA territorial infarction in the patient with proximal FHVs. This patient has no distal FHVs. **b** MRA shows P2 occlusion and DWI reveals small right thalamic infarction in the patient with distal FHVs.

proximal FHVs and 2 with none). Both groups had an equal number of patients with P1 segment of PCA (4 patients) and P2 segment occlusion (5 patients). Initial and follow-up NIHSS scores were similar in both groups. The NIHSS score was significantly improved in patients with distal FHVs compared to the others. The infarction volume in the distal FHV group (8.3 ± 8.7 ml) was smaller than in the other group (16.8 ± 17.6 ml) (fig. 2), but the difference was not statistically significant (p = 0.387) (table 4).

Discussion

Detecting FHVs within the PCA is difficult because of the small number of patients with infarction in the PCA territory compared to infarction in the MCA territory and the anatomical characteristics of the PCA that include a short and tortuous pathway compared to that of the MCA. The diameter of the PCA vessel is also smaller than that of the MCA vessel. Moreover, the cerebral blood flow distribution of the PCA is smaller than that of the MCA. In this study, FHVs were detected in 28% of patients with acute PCA territory infarction. Patients with FHVs reportedly demonstrated large arterial occlusions in a previous study [3]. FHVs were detected in most patients with PCA (89%) or basilar artery (100%) occlusion in this study as

Table 4. Comparisons of clinical characteristics, NIHSS scores and infarction volume between the distal FHV group and other groups with PCA occlusion

	Distal FHV	Proximal FHV and others	p value
Number	9	9	
Male gender	6 (66.7)	3 (33.3)	0.346
Age, years	60.6±13.9	61.6±19.3	0.901
Hypertension	4 (44.4)	6 (66.7)	0.637
Diabetes mellitus	3 (33.3)	3 (33.3)	1.00
Initial NIHSS	5.89±6.27	3.00±2.00	0.395
Follow-up NIHSS	3.89±5.49	2.44±1.67	0.892
Difference in NIHSS	2.00±2.18	0.56±1.01	0.04
Infarction volume, ml	8.3±8.7	16.8±17.6	0.387

Data are expressed as the mean ± SD or as number (%).

well. However, FHVs were not detected in patients with vertebral artery occlusion. We speculate that sufficient blood flow to the basilar artery and PCA from another vertebral artery are the main causes of the absence of FHVs in vertebral artery occlusion.

FHVs were detected in 2 patients without a steno-occlusive lesion in the PCA. This observation is contradictory to the suggested mechanism of FHVs, which is slow or stagnant arterial blood flow [1]. Similar to our study, Cheng et al. [8] reported that FHVs are observed in 2% of LAC patients. Although we interpreted our images as FHVs because the tubular signal on FLAIR was matched with the PCA on contrast-enhanced T1-weighted images, it is possible that we misidentified a CSF flow artifact or other structures such as cranial nerves and venous structures.

The imaging time from symptom onset was short in patients with FHVs compared to the other group in our study. This time-dependent appearance of FHVs in ischemic stroke can be explained by spontaneous recanalization of the occluded artery during the late period of ischemic stroke [9]. In addition, parenchymal ischemic changes with brain edema prevent discrimination between FHVs and ischemic brain tissue in the late period. In a previous study [9], FHVs disappeared after recanalization of the intracranial artery.

There is a correlation between stroke mechanisms according to the TOAST classification and FHVs. FHVs were observed more frequently in the LAA and CE group than in patients with LAC. This phenomenon is comparable to a previous study and reasonable when considering the known mechanism of FHVs [8].

With regard to the clinical meaning of FHVs, we must consider the arterial occlusion status. The difference in initial and follow-up NIHSS scores depends on the presence or absence of FHV, which is a radiological indicator of large arterial occlusion. If we only compare the clinical severity in patients with FHVs and those without FHVs, an important bias emerges when adding the meaning of arterial occlusion to the FHV group. Therefore, in this study, we investigated the clinical significance of FHVs in a homogeneous group of patients with PCA occlusion. In addition, we used distal FHVs as a marker of clinical significance because we believe that proximal FHVs are simply a marker of arterial occlusion [5, 7]. The number of patients with different PCA occlusion sites was identical in the two groups. In 3 patients of the prominent FHV group, FHVs were limited to the area around the perimesencephalic cistern or were observed in one slice of FLAIR imaging beyond the brainstem level. These patients were classified into the proximal FHV group. The NIHSS scores of the distal FHV group were significantly decreased compared to the other group. Although nonsignificant, the infarction volume was small in the distal FHV group compared to the other group. This

result suggests a possible clinical meaning of FHVs as a prognostic factor. It corresponds to a previous study showing that distal FHVs appear to reflect the collateral circulation and that their outcome is good [5].

There are limitations to our study. First, the number of patients with PCA infarction was not sufficient to obtain statistically significant differences. As a result, we could not demonstrate infarction volume differences between the patients with distal FHVs and those without. Second, the imaging protocol varied due to the retrospective study design. The time lag from stroke onset to MRI was not constant, and FLAIR images from three different MRI scanners were used.

Conclusions

This study showed that FHVs could be detected in a substantial portion of patients with PCA infarction, especially in the case of arterial occlusion or significant stenosis, as already reported for MCA infarction. The finding of better improvement in the initial neurologic deficit in patients with distal FHVs suggests the possibility that FHVs will be a good prognostic indicator. Further large clinical studies are needed to confirm our findings.

Disclosure Statement

The authors have nothing to disclose.

References

1 Kamran S, Bates V, Bakshi R, Wright P, Kinkel W, Miletich R: Significance of hyperintense vessels on FLAIR MRI in acute stroke. Neurology 2000;55:265–269.
2 Maeda M, Tsuchida C: 'Ivy sign' on fluid-attenuated inversion-recovery images in childhood moyamoya disease. AJNR Am J Neuroradiol 1999;20:1836–1838.
3 Toyoda K, Ida M, Fukuda K: Fluid-attenuated inversion recovery intraarterial signal: an early sign of hyperacute cerebral ischemia. AJNR Am J Neuroradiol 2001;22:1021–1029.
4 Liu W, Xu G, Yue X, Wang X, Ma M, Zhang R, Wang H, Zhou C, Liu X: Hyperintense vessels on FLAIR: a useful non-invasive method for assessing intracerebral collaterals. Eur J Radiol 2011;80:786–791.
5 Lee KY, Latour LL, Luby M, Hsia AW, Merino JG, Warach S: Distal hyperintense vessels on FLAIR: an MRI marker for collateral circulation in acute stroke? Neurology 2009;72:1134–1139.
6 Kim SJ, Ha YS, Ryoo S, Noh HJ, Ha SY, Bang OY, Kim GM, Chung CS, Lee KH: Sulcal effacement on fluid attenuation inversion recovery magnetic resonance imaging in hyperacute stroke: association with collateral flow and clinical outcomes. Stroke 2012;43:386–392.
7 Huang X, Liu W, Zhu W, Ni G, Sun W, Ma M, Zhou Z, Wang Q, Xu G, Liu X: Distal hyperintense vessels on FLAIR: a prognostic indicator of acute ischemic stroke. Eur Neurol 2012;68:214–220.
8 Cheng B, Ebinger M, Kufner A, Kohrmann M, Wu O, Kang DW, Liebeskind D, Tourdias T, Singer OC, Christensen S, Warach S, Luby M, Fiebach JB, Fiehler J, Gerloff C, Thomalla G: Hyperintense vessels on acute stroke fluid-attenuated inversion recovery imaging: associations with clinical and other MRI findings. Stroke 2012;43:2957–2961.
9 Maeda M, Koshimoto Y, Uematsu H, Yamada H, Kimura H, Kawamura Y, Itoh H, Sakuma H, Takeda K: Time course of arterial hyperintensity with fast fluid-attenuated inversion-recovery imaging in acute and subacute middle cerebral arterial infarction. J Magn Reson Imaging 2001;13:987–990.
10 Schellinger PD, Chalela JA, Kang DW, Latour LL, Warach S: Diagnostic and prognostic value of early MR Imaging vessel signs in hyperacute stroke patients imaged <3 hours and treated with recombinant tissue plasminogen activator. AJNR Am J Neuroradiol 2005;26:618–624.
11 Iancu-Gontard D, Oppenheim C, Touze E, Meary E, Zuber M, Mas JL, Fredy D, Meder JF: Evaluation of hyperintense vessels on FLAIR MRI for the diagnosis of multiple intracerebral arterial stenoses. Stroke 2003;34:1886–1891.
12 Lee JY, Lee KY, Suh SH: Different meaning of vessel signs in acute cerebral infarction. Neurology 2010;75:668.

▶13 Azizyan A, Sanossian N, Mogensen MA, Liebeskind DS: Fluid-attenuated inversion recovery vascular hyperintensities: an important imaging marker for cerebrovascular disease. AJNR Am J Neuroradiol 2011;32:1771–1775.

▶14 Hohenhaus M, Schmidt WU, Brunecker P, Xu C, Hotter B, Rozanski M, Fiebach JB, Jungehulsing GJ: FLAIR vascular hyperintensities in acute ICA and MCA infarction: a marker for mismatch and stroke severity? Cerebrovasc Dis 2012;34:63–69.

▶15 Ebinger M, Kufner A, Galinovic I, Brunecker P, Malzahn U, Nolte CH, Endres M, Fiebach JB: Fluid-attenuated inversion recovery images and stroke outcome after thrombolysis. Stroke 2012;43:539–542.

▶16 Girot M, Gauvrit JY, Cordonnier C, Pruvo JP, Verdelho A, Leys D, Leclerc X: Prognostic value of hyperintense vessel signals on fluid-attenuated inversion recovery sequences in acute cerebral ischemia. Eur Neurol 2007;57:75–79.

▶17 Perez de la Ossa N, Hernandez-Perez M, Domenech S, Cuadras P, Massuet A, Millan M, Gomis M, Lopez-Cancio E, Dorado L, Davalos A: Hyperintensity of distal vessels on FLAIR is associated with slow progression of the infarction in acute ischemic stroke. Cerebrovasc Dis 2012;34:376–384.

▶18 Adams HP Jr, Bendixen BH, Kappelle LJ, Biller J, Love BB, Gordon DL, Marsh EE 3rd: Classification of subtype of acute ischemic stroke. Definitions for use in a multicenter clinical trial. TOAST. Trial of Org 10172 in Acute Stroke Treatment. Stroke 1993;24:35–41.

▶19 Samuels OB, Joseph GJ, Lynn MJ, Smith HA, Chimowitz MI: A standardized method for measuring intracranial arterial stenosis. AJNR Am J Neuroradiol 2000;21:643–646.

▶20 Schumacher HC, Meyers PM, Higashida RT, Derdeyn CP, Lavine SD, Nesbit GM, Sacks D, Rasmussen P, Wechsler LR: Reporting standards for angioplasty and stent-assisted angioplasty for intracranial atherosclerosis. Stroke 2009;40:e348–e365.