Hyperintense Vessels on Acute Stroke Fluid-Attenuated Inversion Recovery Imaging

Associations With Clinical and Other MRI Findings

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Background and Purpose—Hyperintense vessels (HVs) have been observed in fluid-attenuated inversion recovery imaging of patients with acute ischemic stroke and been linked to slow flow in collateral arterial circulation. Given the potential importance of HV, we used a large, multicenter data set of patients with stroke to clarify which clinical and imaging factors play a role in HV.

Methods—We analyzed data of 516 patients from the previously published PRE-FLAIR study (PREdictive value of FLAIR and DWI for the identification of acute ischemic stroke patients ≤3 and ≤4.5 hours of symptom onset—a multicenter study) study. Patients were studied by MRI within 12 hours of symptom onset. HV were defined as hyperintensities in fluid-attenuated inversion recovery corresponding to the typical course of a blood vessel that was not considered the proximal, occluded main artery ipsilateral to the diffusion restriction. Presence of HV was rated by 2 observers and related to clinical and imaging findings.

Results—Presence of HV was identified in 240 of all 516 patients (47%). Patients with HV showed larger initial ischemic lesion volumes (median, 12.3 versus 4.9 mL; P<0.001) and a more severe clinical impairment (median National Institutes of Health Stroke Scale 10.5 versus 6; P<0.001). In 198 patients with MR angiography, HVs were found in 80% of patients with vessel occlusion and in 17% without vessel occlusion. In a multivariable logistic regression model, vessel occlusion was associated with HV (OR, 21.7%; 95% CI, 9.6–49.9; P<0.001). HV detected vessel occlusion with a specificity of 0.86 (95% CI, 0.80–0.90) and sensitivity of 0.76 (95% CI, 0.69–0.83).

Conclusions—HVs are a common finding associated with proximal arterial occlusions and more severe strokes. HVs predict arterial occlusion with high diagnostic accuracy. (Stroke. 2012;43:2957-2961.)

Key Words: acute stroke ■ diffusion-weighted ■ fluid-attenuated inversion recovery ■ magnetic resonance imaging ■ stroke

In MRI of patients with acute ischemic stroke, use of fluid-attenuated inversion recovery (FLAIR) sequences has recently gained importance as a tool to assess lesion age.1 A separate finding on FLAIR images has been termed “hyperintense vessels” (HVs) and describes hyperintensities corresponding to an arterial course most conspicuous in the sylvian fissure and cortical sulci.2–4 Most likely, HVs result from retrograde flow through collateral arterial circulation, as has been shown by concurrent angiographic examinations.2–4 Pathophysiologically, sluggish blood flow is thought to result in an absence of flow void in these arteries causing increased signal intensities. We investigated whether clinical and...
imaging characteristics would support this hypothesis in a representative, large and multicenter group of patients with acute stroke.

Methods

MR and clinical data from patients included for final analysis in the previously published PRE-FLAIR study (PREdictive value of FLAIR and DWI for the identification of acute ischemic stroke patients ≤3 and ≤4.5 hours of symptom onset—a multicenter study) were reviewed according to the presence of HV.1 In this multicenter observational study, we analyzed clinical and MRI data from patients with acute stroke studied by MRI including diffusion-weighted imaging (DWI) and FLAIR within 12 hours of observed symptom onset. The study was performed by an international consortium of researchers within the Stroke Imaging Repository (STIR) and Virtual International Stroke Trials Archive (VISTA) research groups. PRE-FLAIR included individual data sets from 7 participating stroke centers and 3 studies: Echoplanar Imaging Thrombolysis Evaluation Trial (EPITHET), which was a Phase 3 prospective, randomized, double-blinded, placebo-controlled, multinational trial,6 Valeur predictive des paramètres IRM à la phase aigue de l’accident vasculaire cerebral: application à la gestion des essais thérapeutiques (VIRAGE), which was a national multicenter study,6 and the 1000Plus study, a prospective study on the mismatch concept in patients with acute stroke within the first 24 hours after symptom onset.7 Patients presented during different time periods between January 1, 2001, and May 31, 2009. Patients were enrolled if they had well-defined symptom onset (ie, exact time of symptom onset was recorded and reported by either the patient or somebody who witnessed their symptom onset). Details of imaging parameters and postprocessing have been reported.1 Patients received no contrast agents before imaging with FLAIR sequences. All patients were studied within 12 hours of stroke onset. Patient age, time from symptom onset to MRI, severity of neurological deficit on admission (National Institutes of Health Stroke Scale), and stroke cause (according to Trial of ORG 10172 in Acute Stroke Treatment8) were recorded.1 Visibility of FLAIR lesions corresponding to DWI lesions was rated as described previously.1 Additionally, one observer (B.C.) assessed the affected vascular territory and pattern of ischemic lesions on DWI images regarding the assumed etiology (territorial, lacunar, hemodynamic, and multiple embolic distribution). HVs were defined as hyperintensities in FLAIR corresponding to the typical course of a blood vessel that was not considered the proximal, occluded main artery ipsilateral to the diffusion restriction (see the Figure). Presence of HV was rated by 2 observers (B.C. and M.E.) and consensus reached in cases of disagreement. Both observers were independent from each other and blinded to clinical information and blinded to results from MR angiography. Kappa values were used to determine interrater agreement. Information on vessel occlusion from time-of-flight MR angiography was available from 2 centers (Hamburg, Berlin) and one imaging database (VIRAGE).6-9 Group comparison depending on the presence or absence of HV was performed using the Mann-Whitney U test and Fisher exact test as appropriate. In the subgroup of patients with data on vessel occlusion, a multivariable logistic regression analysis was performed with presence of HV as the dependent variable (enter model) including the variables “time from symptom onset,” “DWI lesion volume,” “National Institutes of Health Stroke Scale score,” and “vessel occlusion (yes or no).” All statistical analysis was performed using commercial statistical software (SPSS 19.0; SPSS, Chicago, IL).

Results

FLAIR images of 516 patients were included in the analysis (Table 1). Presence of HV was observed in 240 patients (46.5%). Interrater agreement for the detection of HV was 94% with a κ of 0.91 (95% CI, 0.89–0.97). In group comparison, patients with HV had larger DWI lesion volumes (geometric mean, 11.9 versus 4.9 mL; P<0.001) and were more severely impaired (mean National Institutes of Health Stroke Scale score 12.3 versus 4.9; P<0.001) as compared with patients without HV (Table 1). Data for stroke etiology

Figure. Diffusion-weighted imaging (DWI, left) and fluid-attenuated inversion recovery (FLAIR, right) sequences of 2 patients with acute stroke. FLAIR hyperintensities in arteries (1) and no FLAIR hyperintensities in arteries (2).
classified by Trial of ORG 10172 in Acute Stroke Treatment were available from 428 (82.9%) of all patients, and significant differences were detected with small-vessel occlusion being less frequently the cause of stroke in patients with HV (1% versus 8.9%; \( P=0.001 \)). HVs were more frequently associated with territorial strokes in the middle cerebral artery territory as compared with lacunar lesions or infarctions in the territory of the posterior or anterior cerebral artery.
Patients with HV and those without were comparable with regard to time from symptom onset and the presence of visible parenchymal hyperintensities on FLAIR.

MRI angiography was available for 198 of 516 patients (38.4%). Vessel occlusion was found more frequently in patients with HV (80.2%) as compared with patients without HV (17.1%). In the multivariable logistic regression model, only vessel occlusion was significantly associated with HV (P<0.001; OR, 21.7; 95% CI, 9.6–49.0), whereas National Institutes of Health Stroke Scale score, time from symptom onset, and acute DWI lesion volume were not (Table 2). In this subgroup of patients, presence of HV predicted vessel occlusion as demonstrated by MR angiography with high specificity (0.86; 95% CI, 0.80–0.90) and sensitivity (0.76; 95% CI, 0.69–0.83). The positive predictive value was 0.80 (95% CI, 0.72–0.87) and negative predictive value 0.83 (0.77–0.87). Overall diagnostic accuracy was 0.82 (95% CI, 0.75–0.87).

Discussion

Hyperintense vessels are a frequent observation in acute stroke. However, the mechanisms underlying this phenomenon and clinical implications of HV have been a matter of debate. Previously, correlative angiographic studies demonstrated that HVs most likely reflect slow arterial blood flow in leptomeningeal collateral circulation resulting in a loss of “flow void” and increased signal in FLAIR sequences. This hypothesis has been corroborated by several observations reporting the presence of HV with large-vessel stenosis or occlusion, showing a transient nature of HVs and their absence in the hemisphere contralateral to cerebral ischemia. We aimed to clarify whether clinical and imaging findings from a large, typical acute stroke population would be in line with this hypothesis.

Presence of HV was observed in almost half of our patients. As a main finding, HV occurred as a function of proximal vessel occlusion. HVs were associated with larger ischemic lesion volumes and higher National Institutes of Health Stroke Scale scores. Large lesion volume and clinically severe strokes are both related to the presence and location of large vessel occlusion. Unlike parenchymal hyperintensities in FLAIR, HVs were not related to time from symptom onset. HVs have been observed in areas supplied by collateral blood flow over weeks, but a clear time dependency of their presence has not been demonstrated yet.

To further elucidate the clinical implications of HV, we characterized stroke etiology indirectly by visually assessing images from DWI in terms of ischemic lesion pattern and distribution. HVs were mainly present in territorial lesions occurring in the arterial territory of the middle cerebral artery (Table 1). HVs were observed significantly less frequent in patients with lacunar infarctions, a finding that is most likely explained by the small size of the occluded vessel representing end arteries without appreciable collateral circulation.

Information on vessel status assessed by MR angiography was available in a subgroup of patients. Congruent to visual lesion pattern characterization, presence of HV corresponded to proximal vessel occlusion, particularly affecting the M1 segment of the middle cerebral artery as reported previously. However, because we had no data on conventional angiography, we cannot prove a causal link between collaterals and HV.

The association of HV with DWI lesion volume and severity of symptoms is in line with previous studies of patients with acute stroke in which correlations between the extent of HV and initial lesion size as well as clinical condition have been observed. Nonetheless, Lee et al found smaller ischemic lesion volumes and milder clinical severity in association with HV occurring distally in relation to the site of middle cerebral artery occlusion. In turn, a more recent study showed an association between HV and worse functional outcome 3 months after stroke. Clinical or functional outcome was not available for all contributing studies. Future studies should address the question whether the presence of HV is related to both tissue outcome and clinical outcome.

To our knowledge, our study represents the largest group of patients with acute stroke studied with regard to the presence of HV so far. Although imaging parameters and quality of scans differed significantly between examinations, agreement for the detection of HV was almost perfect between the 2 raters. Our observations are of additional value to previous studies, in which smaller groups of patients examined at various time points have been studied, thus limiting direct comparability.

In conclusion, imaging and clinical findings in a large population of patients with acute ischemic strokes are consistent with the hypothesis that HVs represent arterial collateral flow in patients with proximal large-vessel occlusion. Further studies are needed to investigate the full clinical impact of HV in stroke.

Acknowledgments

STroke Image Repository (STIR) and Virtual International Stroke Trials Archive (VISTA) Imaging steering committee: Steven Warach (chair), Gregory Albers, Stephen Davis, Geoff Donnan, Marc Fisher, Tony Furlan, James Grotta, Werner Hacke, Dong-Wa Kang, Chelsea Kidwell, Kenneth R. Lees, Michele Lev, David Liebeskind, Vincent Thijs, Götz Thomalla, Joanna Wardlaw, and Max Wintermark.

Sources of Funding

This work was supported by the National Institute of Neurological Disorders and Stroke (NINDS). The PREdictive value of FLAIR and
DWI for the identification of acute ischemic stroke patients ≤3 and ≤4.5 h of symptom onset—a multicenter study (PRE-FLAIR) has received funding from the Else-Krönner-Fresenius-Stiftung (2009_A36). In Berlin, data were collected within the 1000+ study, which has received funding from the Federal Ministry of Education and Research via the grant Center for Stroke Research Berlin (01 EO 0801). This work was further supported by the European Union’s Seventh Framework Programme grant agreement No. 202213 and No 223153 (European Stroke Network), the Volkswagen Foundation, and the Deutsche Forschungsgemeinschaft. Echoplanar Imaging Thrombolysis Evaluation Trial (EPITHET) was a Phase II prospective, randomized, double-blinded, placebo-controlled, multinational trial funded by the National Health and Medical Research Council (Australia), the National Stroke Foundation (Australia), and the Heart Foundation of Australia. Valeur predictive des parametres IRM à la phase aigue de l’accident vasculaire cerebral: application à la gestion des essaisthérapeutiques (VIRAGE) is a national multicentre study supported by French national grant “Le programme hospitalier de recherche Clinique” (PHRC).

Disclosures
J.B.F. has received fees as a board member, consultant, or lecturer from Boehringer Ingelheim, Lundbeck, Siemens, Syngis, and Synarc. C.G. has received fees as a consultant or lecture fees from Bayer Vital, Boehringer Ingelheim, EBS Technologies, Glaxo Smith Kline, Lundbeck, Pfizer, Sanofi Aventis, Silk Road Medical, and UCB. D.L. has received fees as a consultant for CoAxia and Concentric Medical, Inc. G.T. has received a research grant from the Else Krönner-Fresenius-Stiftung. T.T. has received a national grant from the French national grant “Le programme hospitalier de recherche Clinique” (PHRC). O.W. was supported in part by grants from Fresenius-Stiftung. T.T. has received fees as a consultant for CoAxia and Concentric Medical, Inc. G.T. has received a research grant from the Else Krönner-Fresenius-Stiftung. T.T. has received a national grant from the Federal Ministry of Education and Research via the grant Center for Stroke Research Berlin (01 EO 0801). This work was further supported by the European Union’s Seventh Framework Programme grant agreement No. 202213 and No 223153 (European Stroke Network), the Volkswagen Foundation, and the Deutsche Forschungsgemeinschaft. Echoplanar Imaging Thrombolysis Evaluation Trial (EPITHET) was a Phase II prospective, randomized, double-blinded, placebo-controlled, multinational trial funded by the National Health and Medical Research Council (Australia), the National Stroke Foundation (Australia), and the Heart Foundation of Australia. Valeur predictive des parametres IRM à la phase aigue de l’accident vasculaire cerebral: application à la gestion des essaisthérapeutiques (VIRAGE) is a national multicentre study supported by French national grant “Le programme hospitalier de recherche Clinique” (PHRC).

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Stroke. 2012;43:2957-2961; originally published online August 28, 2012;
doi: 10.1161/STROKEAHA.112.658906

The online version of this article, along with updated information and services, is located on the World Wide Web at:
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