

REVIEW ARTICLE

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Fluid-Attenuated Inversion Recovery Vascular Hyperintensities: An Important Imaging Marker for Cerebrovascular Disease

SUMMARY: Vascular hyperintensities have been noted on FLAIR sequences obtained in the setting of acute stroke and intracranial steno-occlusive disease. The presence of FVHs likely represents disordered blood flow, often from collaterals distal to arterial occlusion or stenosis. As opposed to other vessel signs seen in arterial insufficiency, FVH is unique in that it does not represent thrombus, but rather sluggish or disordered blood flow through vessels. This review will discuss the diagnostic and prognostic value of FVH and its impact on clinical decision-making.

ABBREVIATIONS: DWI = diffusion-weighted imaging; FLAIR = fluid-attenuated inversion recovery; FVH = FLAIR vascular hyperintensity; GRE-BA = gradient-echo susceptibility vessel blooming artifacts; HMCAS = hyperdense MCA sign seen on CT; HVS = hyperintense vessel sign; MCA = middle cerebral artery; MRA = MR angiography; MRI = MR imaging; NIHSS = National Institutes of Health Stroke Scale; PWI = perfusion-weighted imaging; rtPA = recombinant tissue plasminogen activator; TOF = time of flight; TIA = transient ischemic attacks

Advances in MR imaging have allowed better characterization of tissue and vessel status in cerebrovascular diseases, including acute stroke. Although the particular MR imaging sequences used for evaluation of stroke vary among institutions, FLAIR sequences are usually obtained. FLAIR sequences have a high sensitivity and specificity for the evaluation of brain parenchyma pathology and the subarachnoid spaces.^{1,2} One frequently encountered imaging finding in acute ischemic stroke is high signal intensity within blood vessels on FLAIR sequences (Fig 1). We aimed to review the current understanding of the etiology, physiology, and clinical significance of FVH. This underappreciated neuroimaging sign may have important clinical implications.

In the past decade, FVHs have been associated with large-vessel occlusion³⁻⁷ or stenosis.⁸ This finding has been termed “FVH,” “hyperintense vessel sign,” “hyperintense vessels on FLAIR,” and the “ivy sign” (Table). For this review, it will be referred to exclusively as FVH. FVHs are described as focal, tubular, or serpentine hyperintensities seen, often transiently, in the subarachnoid space against the relative hypointensity of CSF. As opposed to other vessel signs seen in arterial insufficiency, FVH is unique in that it does not represent thrombus but rather is a representation of the sluggish or disordered blood flow through vessels, most often leptomeningeal collaterals.^{9,10} Its presence indicates regions of abnormal blood flow and potentially salvageable brain tissue in acute stroke. This

review will discuss the diagnostic and prognostic value of FVH and its impact on clinical decision-making.

Identification of FVH

The key to identification of FVH is to be aware of its appearance and of the clinical conditions in which it appears with greater frequency. Although the most frequent location is within the Sylvian fissure, FVH has been noted within distal branches of the anterior, middle, and posterior cerebral arteries, as well as more proximally within the intracranial carotid artery and the proximal MCA (Fig 1). When present, the intravascular hyperintensity can be subtle. It is unclear whether FVH is seen in the posterior fossa, though cerebellar collateral circulation has been described. In most cases, FVH is unilateral, and in bilateral arterial disease, it is often asymmetric. This comparison of one half with the other can aid in identification of hyperintense vessels. Unfortunately the presence of FVH can be missed when images are degraded by motion.

There are conditions that should warrant the clinician's particular attention to the presence of FVH, including acute ischemic stroke and intracranial steno-occlusive disease. There will be cases in which the findings of FVH will be unexpected, such as in a reported case in the setting of trauma.¹¹ In this case, the presence of FVH was not noted, and the patient later had a stroke in the same vascular territory. In the authors' experience, FVHs can sometimes be seen in individuals undergoing MR imaging sequences for vague neurologic symptoms and are often not described. Further imaging with MRA may reveal underlying cerebrovascular disease, or the patient may present with a neurologic event (Fig 2).

Pathophysiology Resulting in FVH

The typical FLAIR sequence used in MR imaging of the brain is a heavily T2-weighted pulse sequence with a long TE spin-echo acquisition with reduction or elimination of the very high signals from CSF. Blood vessels on FLAIR sequences are normally dark due to a loss of signal intensity from blood protons moving out of the imaging section before the section-selective 180°

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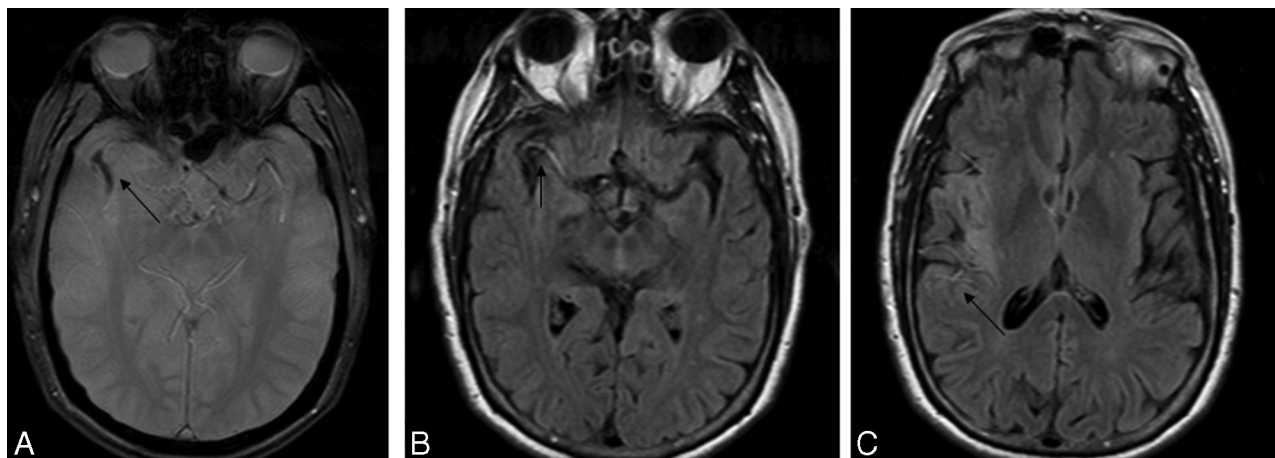


Fig 1. FVH can be seen in acute stroke. *A*, In this case, blooming artifacts are seen in the right MCA M2 segment on gradient-echo imaging from an acute occlusive thrombus. *B* and *C*, FVH is noted proximal (*B*) and distal (*C*) to the arterial occlusion, which was confirmed on angiography.

pulse is applied, so that a spin-echo is not formed.⁹ This is also referred to as the “flow void” phenomenon. FVH represents the relative absence of this flow void.

Initially, there were postulations that FVH represented clot¹² or hemodynamic stress^{4,13} within intracerebral arteries. Others have related the phenomenon to alterations in blood flow.^{4,7,9} When FLAIR images were compared with catheter angiograms obtained in <6 hours of the MR imaging acquisition, FVHs were noted in areas of retrograde leptomeningeal collateral flow and just proximal to large-vessel occlusion.⁹ Further evidence for FVH representing impaired hemodynamics and retrograde collateral blood flow includes its presence in acute stroke, due to large-vessel stenosis⁸ or occlusion,¹² its transient nature,^{9,12} and the fact that it was not seen in the hemisphere contralateral to cerebral ischemia.⁹

Retrograde leptomeningeal collateral flow is a predictor of clinical outcome in the setting of acute stroke,¹⁴ and when well-developed, it can sustain ischemic regions where the primary source of arterial inflow is blocked.¹⁵ The extent and variability of collaterals among patients presenting with acute stroke should be better characterized.¹⁶ In conditions in which arterial blockage occurs gradually, such as atherosclerosis, there is the opportunity to gradually develop more extensive collaterals, which prove beneficial during acute cerebral ischemia. There are likely to be a host of yet unidentified factors, which promote collateral formation and further account for collateral variability.¹⁷ FVHs are seen in some but not all cases of collateral flow, but it is not clear which additional factors are associated with their presence and extent.

Studies evaluating FVH and concurrent perfusion MR imaging indicate an association with smaller ischemic DWI lesion volume and larger DWI-to-PWI mismatch.¹⁰ This may indicate that the collateral blood flow represented by FVH may help decrease the volume of cellular damage as indicated by the reduced size of diffusion restriction on DWI. The DWI-PWI mismatch is thought to represent ischemic penumbra or ischemia without permanent cellular damage. Thus, FVH may indicate salvageable brain parenchyma in the setting of acute stroke. This may be useful when advanced MR imaging techniques such as perfusion MR are unavailable.

Epidemiology of FVH

FVH has been observed in both large-vessel steno-occlusive disease due to atherosclerosis^{4,8} and other vasculopathies such as Moyamoya disease.¹⁸ FVH is best characterized in the setting of acute ischemic stroke, and Kamran et al⁴ noted it to be present in $\leq 10\%$ of MR imaging studies in this population. When the authors evaluated only the MR images obtained within 24 hours of neurologic symptom onset, FVH was noted in 45% of cases. Furthermore, in the subgroup of patients who demonstrated MCA occlusion in the first 24 hours, the incidence of FVH was $>90\%$. Two studies looking at the presence of FVHs within the first 3 hours after symptom onset found FVHs present in 66% and 77% of patients.^{10,12} Studies have found FVHs present ipsilateral and distal to an acute occlusion.⁹

FVH can also be seen the setting of chronic intracerebral arterial steno-occlusive disease. Iancu-Gontard et al⁸ compared a group of patients with known stenoses with patients with proved lack of stenoses. In the stenosis group, FVH was present on 68% of the MR imaging studies compared with only in 5% of the MR imaging studies in patients without stenosis.

FVH has been described in Moyamoya disease and is often referred to as the ivy sign. Because of the chronic progressive nature of Moyamoya disease, there is time for collateralization to form from the leptomeninges as well as from the arteries at the base of the brain. The FVH seen represents diffuse leptomeningeal collaterals, and its presence varies immensely from patient to patient and even intrahemispherically in the same patient. Particular to Moyamoya disease is the finding of Kawashima et al¹⁸ that unilateral FVH indicated decreased vascular reserve and a potentially higher risk of ischemia.

Clinical Utility

Diagnostic Value

The presence of FVH in acute ischemic stroke may indicate cerebral hypoperfusion. In 1 study, 85% of patients who were positive for FVH went on to have infarction in the corresponding brain region on follow-up imaging.³ Not only was the presence of FVH fairly consistent with areas of hypoperfusion,

Summary of studies describing FLAIR vascular hyperintensities

Author (Publication Year)	Population Studied	No.	Age Range/ Mean (yr)	Criteria for FVH Diagnosis	Study	Conclusions
Cosnard et al (1999) ³	Acute cerebral ischemia imaged <6 hours from symptom onset	53	26–90/69	High signal from vessels on FLAIR sequences	Comparison of 3D-TOF MRA and FLAIR images for stroke diagnosis	FVH corresponded to MRA evidence of stenosis/occlusion; FVH correlated to the territory of brain infarction on follow-up imaging in 85% of cases
Kamran et al (2000) ⁴	Retrospective blinded analysis of 304 MRIs of patients admitted for acute MCA stroke	30	52–81	Tubular hyperintense signal relative to gray matter on FLAIR	Determined the clinical correlates of FVH	FVH observed in 10% of cases; FVH associated with MCA occlusion or severe stenosis; Angiographic studies correlated FVH with slow flow in leptomeningeal collaterals; NIHSS scores higher in patients demonstrating greater burden of FVH in MCA territory
Maeda et al (2001) ⁵	Review of patients imaged within 6 hours of stroke-symptom onset	11	63–88/74	Arterial hyperintensity on FLAIR images	Comparison of FVH with DWI for diagnosis of acute stroke	FVH present in 8 of 11 patient MRIs; FVH can precede DWI abnormalities and may provide a clue to early detection of impending infarction
Toyoda et al (2001) ⁶	Imaging within 6 hours of onset of acute cerebral ischemia caused by intracranial arterial occlusion	60	27–93/70.3	HVS	Described FVH, MRA, flow voids on T2, and DWI findings in select group	FVH present in 98%; FVH seen in areas outside increased DWI signal; Final infarct volume intermediate to DWI signal area and FVH area
Iancu-Gontard et al (2003) ⁸	Cases with multiple intracerebral arterial stenoses imaged nonacutely with FLAIR and control group	19 vs 19	Study group (22–67/43), control group (42.2)	HVS on FLAIR = focal or tubular hyperintensities in the subarachnoid space (within dark CSF signal)	Determined whether HVS is more common in patients with known intracerebral arterial stenosis	High inter-reader concordance in identifying FVH; FVH seen in 68% of cases and 5% of controls; Concordance of territorial distribution of stenoses on FVH highest in MCA distribution; FVH seen mostly in high-grade stenosis or occlusion
Schellinger et al (2005) ¹²	Review of 127 patients who received rtPA within 3 hours of stroke onset	56	63–89/76	HVS	Comparison of HMCAS, GRE-BA, and FVH for diagnosis of stroke and predicting response to rtPA	FVH associated with vessel occlusion but has little prognostic value; FVH more sensitive than HMCAS and GRE-BA in diagnosis if large-vessel occlusion (66% vs 40% vs 34%); HVS represents slow flow whereas the other 2 signs represent the thrombus; FVH not an independent predictor of intracranial hemorrhage, recanalization, and clinical outcome, including response to rtPA
Sanossian et al (2009) ⁹	Acute cerebral ischemia imaged within 6 hours of angiography	74	43–83/63	Focal, tubular, or serpentine hyperintensity relative to gray matter in the subarachnoid space or extending into the parenchyma	Description of the correlates of FVH on concurrent angiography	FVH was present in 53/74 (72%) of all acute strokes with subsequent angiography; FVH was seen in areas of blood flow proximal and distal to stenosis or occlusion; FVH distal to high-grade arterial occlusion is associated with a high-grade leptomeningeal collateral blood flow
Lee et al. (2009) ¹⁰	Consecutive patients with MCA territory infarct imaged prior to treatment with rtPA	52	54–84/69	Linear- or serpentine-appearing hyperintensity on FLAIR imaging, corresponding to a typical arterial course in the hemisphere of arterial occlusion	Study of the hemodynamic correlates of FVH	FVH observed distal to arterial occlusion in 73% and proximal to 77% of patients; FVH due to collateral flow beyond the site of occlusion; FVH associated with smaller ischemic lesion volumes, as well as lower initial NIHSS scores; The presence of distal FVH before rtPA is associated with large diffusion-perfusion mismatch; FVH not an independent predictor of 5-day NIHSS

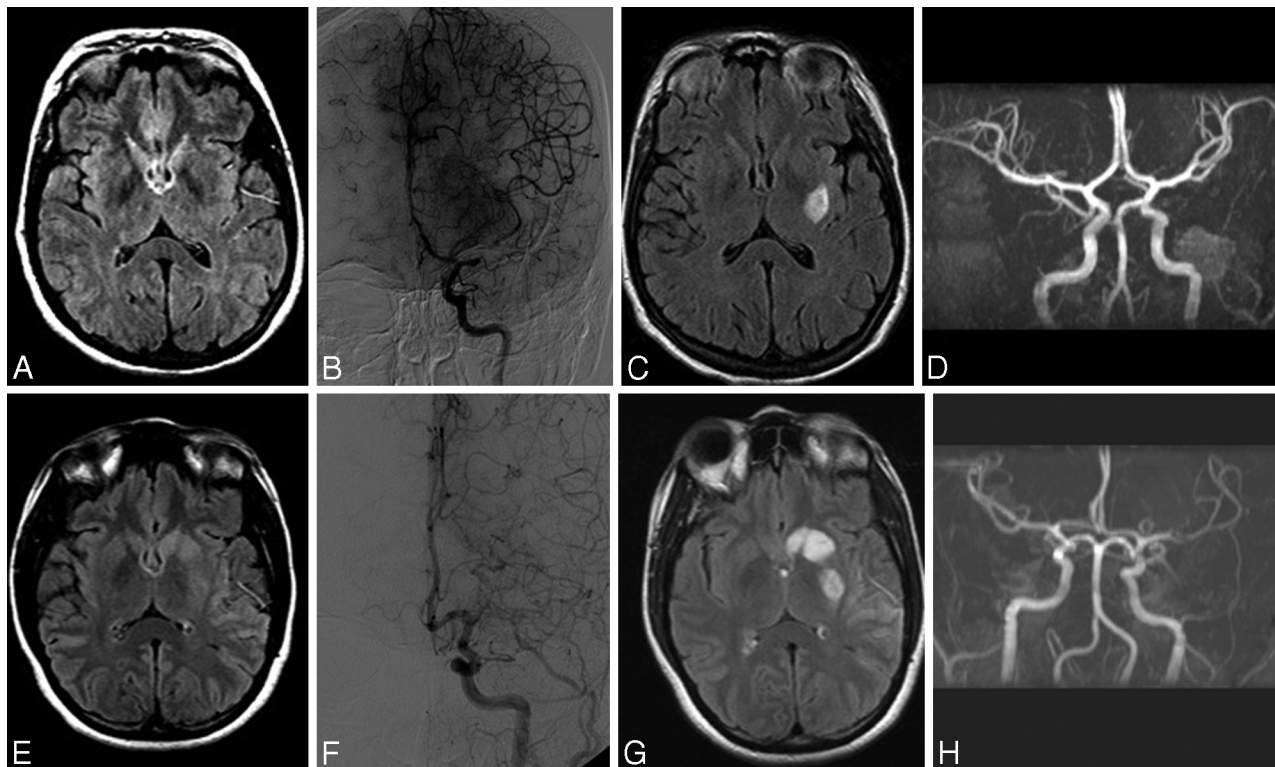


Fig 2. FVH is often transient and is a marker of collateral flow. *A*, In case 1 (top row), preangiogram FLAIR image demonstrates FVH in the left temporal lobe. *B*, The angiogram obtained soon after demonstrates MCA occlusion and very good leptomeningeal collateral flow. The MR image obtained at 24 hours after presentation (*C*) demonstrates absence of FVH, the presence of T2 signal-intensity abnormality in the basal ganglia and subcortical white matter consistent with acute infarction, and a normal flow-related enhancement in the left MCA on a concurrent MR angiogram (*D*). The absence of FVH on follow-up imaging is consistent with restoration of normal flow. In case 2 (bottom row), preangiogram FLAIR image (*E*) demonstrates FVH in the left temporal lobe, and an angiogram (*F*) obtained soon after shows MCA occlusion and very good collateral flow. *G*, MR image obtained the day after demonstrates continued presence of FVH and T2 signal-intensity abnormality in the basal ganglia, consistent with acute infarction. There is reduced flow-related enhancement in the left MCA territory on a concurrent MR angiogram (*H*), indicating continued abnormal arterial flow.

but it had sensitivity and specificity similar to findings in TOF MRA for large-vessel occlusion. The authors of this study concluded that the absence of FVH could be used to rule out the need for performing a time-consuming MRA. Toyoda et al⁶ came to a similar conclusion, stating that the presence of FVH could be used in place of PWI. An additional 2 studies also determined that the presence of FVH was a reasonable alternative to MRA and PWI if these studies were not available or were degraded.^{9,12}

FVH may have utility in the evaluation of patients experiencing TIAs, especially in cases in which angiography is not performed or is degraded.¹¹ A case series describes patients presenting with resolved cerebral ischemia and no abnormality on initial DWI, yet with FVH going on to infarct while the patient is hospitalized. The authors concluded that FVH represented persistent large-vessel stenosis or occlusion, a condition that is known to increase the short-term risk for stroke. Although the risk of stroke after TIA in the first 48 hours is roughly 5%,¹⁹ it is 3 times as high in the setting of large-vessel occlusion.²⁰ Because FVH can be interpreted as a marker of large-vessel occlusion, its presence can help the clinician identify patients at higher risk for stroke after TIA.

Prognostic Value

In determining the prognostic information provided by FVHs, the data are seemingly split. On the one hand, some authors have noted that the presence of FVH is correlated with

larger infarct volume and a higher NIHSS score.⁴ Flacke et al²¹ similarly noted worse clinical outcome if FVH was present >2 hours after initial imaging, which they attributed to persistent occlusion. In patients with FVH, they also observed a significantly higher risk for intracranial hemorrhage. However, another study found that the presence of FVH is insufficient in providing prognostic information because it was shown not to be an independent predictor of intracranial hemorrhage, recanalization, or clinical outcome after administration of intravenous rtPA.¹²

In seeming contradiction to these previous studies, Lee et al¹⁰ observed that the presence of FVH distal to arterial occlusion was, in fact, associated with better prognosis and smaller infarct size. A possible reason for this difference is that Lee et al used angiographic information to categorize FVHs into those that occurred proximal to the occlusion or stenosis and those that occurred distally due to leptomeningeal collaterals. Whereas proximal FVHs did not offer prognostic information, the presence of distal FVH was associated with better outcome. In the presence of good collateral flow distal to an occlusion, patients were found to have smaller infarct sizes and lower initial NIHSS scores. In patients with distal FVHs, there were large DWI-PWI mismatches, indicating that these patients had large areas of salvageable brain parenchyma. Accordingly, they fared better after the administration of intravenous rtPA because there was a greater potential for benefit. Limitations of FVH were that it was only an independent pre-

dictor for initial stroke severity measured by the NIHSS but not of 5-day outcome measured by the NIHSS.

Conclusions and Future Directions

FVH is a phenomenon on MR imaging that occurs in patients with acute ischemic stroke, intracranial stenoses, Moyamoya disease, and TIA. It represents disordered blood flow from collaterals distal to arterial occlusion or stenosis. Unlike other imaging signs of vessel occlusion such as gradient-echo susceptibility or CT hyperattenuation within a vessel lumen, it indicates the status of leptomeningeal collateral perfusion to vulnerable brain tissue rather than directly visualizing thrombus. Thus, it is not an indicator of infarction but rather of tissue that is at risk for infarction. This makes it more clinically valuable than the other 2 vessel signs because it can help clinicians decide when recanalization should be attempted and whether tissue salvage can be expected. Furthermore, FVH has high specificity and sensitivity for detecting arterial occlusion and stenosis.¹² In fact, FVH is so powerful in detecting areas of collateral circulation that it can reasonably serve as a substitute for PWI sequences when these are not available or are degraded.^{3,6,9,12}

The prognostic value of FVH still needs to be better elucidated. The categorization of distal-versus-proximal FVH has been shown to be significant.¹⁰ Other authors have indicated that FVHs in different regions of the intracranial vasculature yield different diagnostic and prognostic values.^{4,10} Thus FVH within the MCA may give the most clear and consistent prognostic information as opposed to posterior and vertebral-basilar circulation FVH. Future studies will determine in which settings the presence of FVH can be used as a valuable datum to the clinician. FVH indicates the danger of persistent vascular stenosis or occlusion, with the associated risk of future stroke and also identifies patients with favorable collateral blood flow who would benefit from aggressive revascularization therapies.

References

- Schellinger PD, Fiebich JB, Hacke W. **Imaging-based decision making in thrombolytic therapy for ischemic stroke: present status.** *Stroke* 2003;34:575–83
- Warach S. **Measurement of the ischemic penumbra with MRI: it's about time.** *Stroke* 2003;34:2533–34
- Cosnard G, Duprez T, Grandin C, et al. **Fast FLAIR sequence for detecting major vascular abnormalities during the hyperacute phase of stroke: a comparison with MR angiography.** *Neuroradiology* 1999;41:342–46
- Kamran S, Bates V, Bakshi R, et al. **Significance of hyperintense vessels on FLAIR MRI in acute stroke.** *Neurology* 2000;55:265–69
- Maeda M, Yamamoto T, Daimon S, et al. **Arterial hyperintensity on fast fluid-attenuated inversion recovery images: a subtle finding for hyperacute stroke undetected by diffusion-weighted MR imaging.** *AJNR Am J Neuroradiol* 2001;22:632–36
- Toyoda K, Ida M, Fukuda K. **Fluid-attenuated inversion recovery intraarterial signal: an early sign of hyperacute cerebral ischemia.** *AJNR Am J Neuroradiol* 2001;22:1021–29
- Tsushima Y, Endo K. **Significance of hyperintense vessels on FLAIR MRI in acute stroke.** *Neurology* 2001;56:1248–49
- Iancu-Gontard D, Oppenheim C, Touze E, et al. **Evaluation of hyperintense vessels on FLAIR MRI for the diagnosis of multiple intracerebral arterial stenoses.** *Stroke* 2003;34:1886–91
- Sanossian N, Saver JL, Alger JR, et al. **Angiography reveals that fluid-attenuated inversion recovery vascular hyperintensities are due to slow flow, not thrombus.** *AJNR Am J Neuroradiol* 2009;30:564–68
- Lee KY, Latour LL, Luby M, et al. **Distal hyperintense vessels on FLAIR: an MRI marker for collateral circulation in acute stroke?** *Neurology* 2009;72:1134–39
- Sanossian N, Ances BM, Shah SH, et al. **FLAIR vascular hyperintensity may predict stroke after TIA.** *Clin Neurol Neurosurg* 2007;109:617–19
- Schellinger PD, Chalela JA, Kang D-W, et al. **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;26:618–24
- Goldstein LB, Adams R, Becker K, et al. **Primary prevention of ischemic stroke: a statement for healthcare professionals from the Stroke Council of the American Heart Association.** *Stroke* 2001;32:280–99
- Jo KD, Saver JL, Starkman S, et al. **Predictors of recanalization with mechanical thrombectomy for acute ischemic stroke (abstract).** *Stroke* 2008;39:599
- Liebeskind DS. **Collateral therapeutics for cerebral ischemia.** *Expert Rev Neurother* 2004;4:255–65
- Liebeskind DS. **Collaterals in acute ischemic stroke: beyond the clot.** *Neuroimaging Clin N Am* 2005;15:553–73, x
- Liebeskind DS, Hao Q, Sanossian N, et al. **Leptomeningeal collateral perfusion in acute MCA occlusion reveals inherent vulnerability to failure: quantifying the hemodynamics of FLAIR vascular hyperintensity.** *Stroke* 2010;41:e21–22
- Kawashima M, Noguchi T, Takase Y, et al. **Unilateral hemispheric proliferation of ivy sign on fluid-attenuated inversion recovery images in Moyamoya disease correlates highly with ipsilateral hemispheric decrease of cerebrovascular reserve.** *AJNR Am J Neuroradiol* 2009;30:1709–16. Epub 2009 Aug 27
- Johnston SC, Gress DR, Browner WS, et al. **Short-term prognosis after emergency department diagnosis of TIA.** *JAMA* 2000;284:2901–06
- Sanossian N, Ovbiagele B. **The risk of stroke within a week of minor stroke or transient ischemic attack.** *Expert Opin Pharmacother* 2008;9:2069–76
- Flacke S, Urbach H, Keller E, et al. **Middle cerebral artery (MCA) susceptibility sign at susceptibility-based perfusion MR imaging: clinical importance and comparison with hyperdense MCA sign at CT.** *Radiology* 2000;215:476–82