Bright Vessel Appearance on Arterial Spin Labeling MRI for Localizing Arterial Occlusion in Acute Ischemic Stroke

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Background and Purpose—The purpose of this study was to evaluate whether bright vessel appearance on arterial spin labeling (ASL) MRI can help localize arterial occlusion sites in patients with acute ischemic stroke.

Methods—Patients who underwent MRI for suspected acute ischemic stroke, as identified by an area of restricted diffusion, were included. All images were visually analyzed for the presence or absence of (1) arterial occlusion on time-of-flight MR angiography, (2) bright vessel appearance on ASL images, and (3) susceptibility vessel sign. McNemar 2-tailed test was used to compare the sensitivities of ASL and susceptibility-weighted imaging for the detection of arterial occlusion, using MR angiography as the reference standard.

Results—ASL bright vessel appearance was significantly more common in the group with occlusion than in the group without occlusion (94% [33 of 35] versus 21% [17 of 82], respectively; P<0.001). The bright vessel appearance, when present, was seen proximal or distal to the occlusion site. The bright vessel appearance had a significantly higher sensitivity for the detection of occlusion than the susceptibility vessel sign (94% [33 of 35] versus 66% [23 of 35], respectively; P=0.002). In cases with negative MR angiography, the bright vessel appearance helped identify more additional arterial occlusions than the susceptibility vessel sign (21% [17 of 82] versus 10% [8 of 82], respectively; P=0.012).

Conclusions—The bright vessel appearance on ASL imaging can provide an important diagnostic clue for the detection and localization of arterial occlusion sites in patients with acute ischemic stroke. (Stroke. 2015;46:564-567. DOI: 10.1161/STROKEAHA.114.007797.)

Key Words: ischemia ▪ perfusion imaging ▪ stroke

Several studies have demonstrated that arterial spin labeling (ASL)-perfusion-weighted imaging (PWI) can detect hypoperfusion and perfusion–diffusion mismatch in the setting of acute stroke, with good to modest correlation to dynamic susceptibility contrast perfusion MRI.1–4

Recently, ASL-PWI has been incorporated as a part of the acute ischemic stroke evaluation in our institution, and with its increasing use, we have encountered patients with acute ischemic stroke in whom a characteristic bright intravascular signal (which we termed bright vessel appearance) is found within an occluded arterial segment. To our knowledge, the usefulness of ASL bright vessel appearance in patients with acute ischemic stroke has not been elucidated yet. The purpose of our study was, therefore, to evaluate whether the bright vessel appearance on ASL-PWI can help localize sites of arterial occlusion in patients with acute ischemic stroke.

Methods

This retrospective study was approved by our institutional review board, and informed consent was waived.

Patients

Our radiology database from January 2014 to April 2014 was searched for patients who underwent MRI for suspected acute ischemic stroke. Among 171 patients, those whose MR images showed infarctions, as identified by areas of restricted diffusion, were included. Fifty-four patients were excluded for the following reasons: (1) no ASL images, (2) ASL images of poor image quality because of inadequate acquisition times or artifacts, or (3) occlusions at the extracranial carotid arteries (in which arterial labeling was insufficient). As a result, 117 consecutive patients were included in this study.

MRI Protocol

All patients underwent MRI at a 1.5T (Signa HDxt; GE Medical Systems, Milwaukee, WI [n=70]) or 3.0T (Verio; Siemens, Erlangen, Germany [n=47]) MR scanner using a 16-channel head coil. Our MRI...
protocol for acute stroke evaluation included diffusion-weighted imaging, fluid-attenuated inversion recovery, susceptibility-weighted imaging (SWI), ASL-PWI, and 3-dimensional time-of-flight MR angiography.

ASL-PWI scans were performed using a pseudocontinuous ASL pulse sequence. The signal intensity change between the labeled and control images was fitted to a previously published model to obtain a quantitative perfusion map of cerebral blood flow.\(^2\) Specific imaging parameters for the sequences are provided in Table I in the online-only Data Supplement.

**Image Analysis**

All images were visually analyzed with respect to the following: (1) pattern (focal or territorial), multiplicity, and location of the diffusion-restricted area on diffusion-weighted imaging, presence or absence of (2) vascular or lesional hyperintensity on fluid-attenuated inversion recovery, (3) susceptibility vessel sign on SWI, (4) arterial occlusion and stenosis on MR angiography, and (5) bright vessel appearance on ASL-PWI.

When arterial occlusion or stenosis was present on MR angiography, its location was specified. The ASL bright vessel appearance, when present, was further analyzed in terms of its location relative to the arterial occlusion site as follows: (1) proximal, (2) distal, or (3) both proximal and distal to the occlusion site. To evaluate the location of bright vessel appearance relative to the occlusion site, a 3-dimensional localization tool available on the picture archiving and communication system was used.

**Statistical Analysis**

All statistical analyses were performed using a statistical software program (MedCalc, version 11.1.1.0; MedCalc, Mariakerke, Belgium). Fisher exact test was used to compare incidences of the ASL bright vessel appearance, fluid-attenuated inversion recovery vascular hyperintensity, and susceptibility vessel sign between the group with arterial occlusion on MR angiography and that without occlusion. McNemar 2-tailed test was conducted to compare the sensitivity of the ASL bright vessel appearance for the detection of arterial occlusion with that of the susceptibility vessel sign both on a per-patient (n=35) basis and on a per-lesion (n=37) basis, using MR angiography as the reference standard (94% [33 of 35] versus 66% [23 of 35]; \(P=0.002\) and 95% [35 of 37] versus 68% [25 of 37]; \(P=0.001\), respectively). Twenty-five occlusions were correctly diagnosed with both ASL bright vessel appearance and susceptibility vessel sign (Figures 1 and 2; Figures I and II in the online-only Data Supplement). Ten occlusions could be detected exclusively by the ASL bright vessel appearance (Figure 3), whereas none was identified exclusively by the susceptibility vessel sign. Two occlusions were missed on both ASL-PWI and SWI.

In the 82 cases with negative MR angiography, the ASL bright vessel appearance helped identify significantly more additional peripheral occlusions than the susceptibility vessel sign (21% [17 of 82] versus 10% [8 of 82], respectively; \(P=0.012\)) (Results, Figures III and IV, and Table III in the online-only Data Supplement).

Among the patients with occlusion, 3 patients also had 3 stenoses proximal to occlusion sites (30%–49% [n=1] and 50%–69% [n=2]). However, there was no ASL bright vessel appearance in the proximal stenotic portions. In addition, there were 14 cases of multiple infarctions, and the ASL bright vessel appearance, if present, was located only at the occlusion sites (n=13). In the patients without occlusion, a total of 12 stenoses in 10 patients (<30% [n=3]; 30%–49% [n=2]; 50%–69% [n=5]; and >70% [n=2]) were found, and 2 patients

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**Results**

Demographic and clinical information of the 117 patients with acute ischemic stroke are provided in Results in the online-only Data Supplement.

MR angiography demonstrated arterial occlusion related to clinical symptoms in 30% of the patients (35 of 117). The ASL bright vessel appearance, susceptibility vessel sign, and fluid-attenuated inversion recovery vascular hyperintensity were all significantly more common in the group with arterial occlusion than in the group without occlusion (\(P<0.001\); Table II in the online-only Data Supplement).

Sensitivity of the ASL bright vessel appearance for the detection of arterial occlusion was significantly higher than that of the susceptibility vessel sign both on a per-patient (n=35) basis and on a per-lesion (n=37) basis, using MR angiography as the reference standard (94% [33 of 35] versus 66% [23 of 35]; \(P=0.002\) and 95% [35 of 37] versus 68% [25 of 37]; \(P=0.001\), respectively). Twenty-five occlusions were correctly diagnosed with both ASL bright vessel appearance and susceptibility vessel sign (Figures 1 and 2; Figures I and II in the online-only Data Supplement). Ten occlusions could be detected exclusively by the ASL bright vessel appearance (Figure 3), whereas none was identified exclusively by the susceptibility vessel sign. Two occlusions were missed on both ASL-PWI and SWI.

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---

![Figure 1. A 77-year-old man with a history of sudden onset left-sided weakness. A, Diffusion-weighted image demonstrates territorial infarctions in the right anterior and middle cerebral artery territories (arrows). Subtle susceptibility vessel signs are noted at the right M2 (B, arrowhead) and A2 (C, arrowhead) segments. D, On the arterial spin labeling image, bright vessel appearances are apparent at both the right M2 and A2 segments (arrowheads).](http://stroke.ahajournals.org/)

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![Figure 2. A 77-year-old man with a history of sudden onset left-sided weakness (same patient as Figure 1). A and B, MR angiography shows occlusions at the right M2 segment (A, arrow) and the right A2 segment (B, arrow). C and D, Conventional digital subtraction angiography performed prior to intra-arterial thrombectomy reflects distal migration of the clots (arrowheads).](http://stroke.ahajournals.org/)
had multiple stenoses. Neither the stenotic portions nor other portions of the arteries supplying infarcted territories in these patients showed ASL bright vessel appearance. Furthermore, there were 4 cases of multiple infarctions, and the ASL bright vessel appearance was not noted in the cases (Figure V in the online-only Data Supplement).

There was almost perfect interobserver agreement between the 2 readers for both ASL bright vessel appearance (κ=0.86; 95% confidence interval, 0.76–0.95) and susceptibility vessel sign (κ=0.87; 95% confidence interval, 0.76–0.97).

Discussion

Delayed arterial transit time, attributable to collateral vessels or slow-flowing vessels during the acquisition time point, has been underscored as a major source of error in cerebral blood flow quantification using the ASL technique.\(^6,7\) In the presence of delayed arterial transit, the late-arriving flow is delineated as a bright intravascular signal, a so-called arterial transit artifact.\(^8,9\) Chalela et al\(^10\) reported that arterial transit artifact was frequently found in patients with acute ischemic stroke, with their presence reflecting collateral flows and a better prognosis. Zaharchuk et al\(^11\) have also found that ASL-PWI in patients with moyamoya disease can clearly depict collaterals as serpiginous high ASL signals within cortical vessels, thereby providing a noninvasive mean for assessing the collateral status. Thus, we hypothesized that an occluded arterial segment with sluggish blood flow in acute ischemic stroke would also show a bright intravascular signal because of arterial transit artifact, which we termed bright vessel appearance.

As hypothesized, the bright vessel appearance was significantly more common in the group with arterial occlusion (confirmed on MR angiography) than in the group without occlusion. The bright vessel appearance, when present, was seen proximal or distal to occlusion sites. The distal location of the bright vessel appearance may be attributed to delayed filling of the distal segment via collateral or subtotal occlusion, which substantially impedes the blood flow while still allowing distal passage of some labeled tracers.

The higher false-negative rate of the susceptibility vessel sign can be explained by the variation in susceptibility effect according to clot composition. Recently, Liesebkind et al\(^12\) reported that hyperdense middle cerebral artery sign and gradient-echo MRI blooming artifact were significantly more common in red blood cell–dominant and mixed clots than in fibrin-dominant clots, suggesting that the hyperdense middle cerebral artery sign and blooming artifact might reflect the pathology of occlusive thrombi. However, unlike the susceptibility vessel sign, the ASL bright vessel appearance is dependent on the hemodynamic alteration (ie, the delayed arterial transit time) and not the clot composition, which accounts for the relatively high sensitivity of the bright vessel appearance in detecting occlusion.

Furthermore, our results demonstrated that the ASL bright vessel appearance could be helpful in identifying peripheral occlusion in fine distal branches, which are poorly delineated on time-of-flight MR angiography. In the previous study comparing sensitivities of SWI and MR angiography for the detection of thrombotic occlusion, sensitivity for the detection of central thrombi was found to be similar in both, whereas that for the detection of peripheral thrombi in small arteries was significantly higher for SWI than for MR angiography.\(^13\) In our study, the susceptibility vessel sign showed poorer performance in detecting peripheral occlusion than the ASL bright vessel appearance, probably because of its close relationship to the clot composition.

Our study had limitations. First, MR angiography was used as the reference standard to confirm arterial occlusion because conventional digital subtraction angiography was reserved for patients who met indications for intra-arterial thrombolysis. For those cases with peripheral occlusion not delineated on MR angiography, distal occlusion was presumed to be present only if the susceptibility vessel sign or ASL bright vessel appearance was found near the infarcted areas. Second, the possibility of spontaneous reperfusion before the initial MR imaging might have resulted in underestimation of the incidence of cases with occlusion on MR angiography, which show the corresponding ASL bright vessel appearance and susceptibility vessel sign, among the patients with acute ischemic stroke.

In conclusion, the bright intravascular signal attributable to slow-flowing blood on ASL imaging may facilitate the detection and localization of arterial occlusion in acute ischemic stroke.

Sources of Funding

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Disclosures

None.

References


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### Supplemental Methods

#### Supplemental Table I. MR Imaging Parameters

<table>
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<tr>
<th>Parameters</th>
<th>DWI</th>
<th>FLAIR</th>
<th>SWI</th>
<th>TOF MR angiography</th>
<th>ASL</th>
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<td>320 × 192</td>
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<td>640 × 240</td>
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<td>26</td>
<td>50</td>
<td>96</td>
<td>32</td>
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*DWI indicates diffusion-weighted imaging; FLAIR, fluid-attenuated inversion recovery; SWI, susceptibility-weighted imaging; TOF, time-of-flight; ASL, arterial spin labeling; FOV, field of view; and No., number.*
**Supplemental Results**

**Demographic and Clinical Information**

Sixty-six men (mean age, 68 years; range, 32–97 years) and 51 women (mean age, 69 years; range, 33–98 years) with acute ischemic stroke were included in this study. The median time from last known well to first MR imaging was 21 hours (range, 45 minutes to 192 hours). Baseline National Institutes of Health Stroke Scale scores of the patients ranged from 0 to 30 with the median score of 4. Five patients underwent intra-arterial mechanical thrombectomy using a Solitaire stent system (ev3, Irvine, California), while five patients received intravenous tissue plasminogen activator. Two patients underwent both intra-arterial thrombectomy and intravenous thrombolysis.
Supplemental Table II. Summary of MR Imaging Findings

<table>
<thead>
<tr>
<th></th>
<th>All Patients (n = 117) (%)</th>
<th>Patients with Occlusion on MR Angiography* (n = 35) (%)</th>
<th>Patients without Occlusion on MR Angiography (n = 82) (%)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DWI</strong></td>
<td></td>
<td></td>
<td></td>
<td>&lt;.001</td>
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<tr>
<td>Focal</td>
<td>72 (62)</td>
<td>5 (14)</td>
<td>67 (82)</td>
<td></td>
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<tr>
<td>Territorial</td>
<td>45 (38)</td>
<td>30 (86)</td>
<td>15 (18)</td>
<td></td>
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<tr>
<td><strong>FLAIR change</strong></td>
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<td></td>
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<td>&lt;.001</td>
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<tr>
<td>Lesion</td>
<td>80 (68)</td>
<td>22 (63)</td>
<td>58 (71)</td>
<td></td>
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<tr>
<td>Vascular hyperintensity</td>
<td>31 (26)</td>
<td>25 (71)</td>
<td>6 (7)</td>
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<tr>
<td>Absent</td>
<td>24 (21)</td>
<td>4 (11)</td>
<td>20 (24)</td>
<td></td>
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<tr>
<td><strong>Susceptibility vessel sign</strong></td>
<td></td>
<td></td>
<td></td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Present</td>
<td>31 (26)</td>
<td>23 (66)</td>
<td>8 (10)</td>
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<td>Absent</td>
<td>86 (74)</td>
<td>12 (34)</td>
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<td><strong>ASL bright vessel appearance</strong></td>
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<td>50 (43)</td>
<td>33 (94)</td>
<td>17 (21)†</td>
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<td>Proximal</td>
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<td>15 (43)</td>
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<td>Distal</td>
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<td>10 (29)</td>
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</tr>
<tr>
<td>Both</td>
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<td>8 (23)</td>
<td>5 (6)</td>
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<tr>
<td>Unevaluable</td>
<td>10 (9)</td>
<td>0 (0)</td>
<td>10 (12)</td>
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<tr>
<td>Absent</td>
<td>67 (57)</td>
<td>2 (6)</td>
<td>65 (79)</td>
<td></td>
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</table>

Numbers in parentheses are percentages. DWI indicates diffusion-weighted imaging; FLAIR, fluid-attenuated inversion recovery; SWI, susceptibility-weighted imaging; and ASL, arterial spin labeling; and N/A, not available.

* Two of the patients had occlusions at two different sites. Sites of arterial occlusion, in the decreasing order of frequency, were as follows: horizontal segment of middle cerebral artery (M1) (n = 11), insular segment of middle cerebral artery (M2) (n = 10), basilar artery (n = 4), distal internal carotid artery (ICA) (n = 3), intradural segment of vertebral artery (V4) (n = 2), ambient segment of posterior cerebral artery (P2) (n = 2), vertical segment of anterior cerebral artery (A2) (n = 2), ICA bifurcation (n = 2), and superior cerebellar artery (SCA) (n = 1).

† In cases with negative MR angiography, the ASL bright vessel appearance was analyzed in terms of its location relative to the susceptibility vessel sign on SWI. Cases in which the susceptibility vessel sign was absent were classified as ‘unevaluable’.
Supplemental Figure I. A 64-year-old man with a history of sudden onset sensory aphasia.

A, Diffusion-weighted image reveals acute infarction at the left insula (arrow). Cerebromalacia due to chronic infarction is also noted at the right middle cerebral artery territory. B, The susceptibility vessel sign is found at the left M2 segment (arrowhead). C, On the arterial spin labeling image, the bright vessel appearance is evident at the left M2 segment (arrowhead), just proximal to the clot. Hypoperfusion is also seen at the left temporal lobe. D, The left M2 (inferior division) occlusion (arrow) was confirmed on MR angiography. E, On the follow-up MR imaging obtained five days later after intravenous tissue plasminogen activator administration, the left insular infarction (arrow) is slightly increased in size on the diffusion-weighted image. Both the susceptibility vessel sign and bright vessel appearance disappeared on the susceptibility-weighted image (F) and arterial spin labeling image (G). Cerebral perfusion at the left temporal lobe is also normalized. H, Recanalization of the left M2 segment was confirmed on MR angiography.
**Supplemental Figure II.** A 45-year-old man with a history of sudden onset right-sided weakness.

A, Diffusion-weighted image reveals a territorial infarction in the left basal ganglia (arrow). B, The susceptibility vessel sign is evident at the left M1 segment (arrowhead). C, On the arterial spin labeling image, the bright vessel appearance is noted distal to the clot (arrowhead). D, MR angiography depicts the left M1 occlusion (arrow).
**Cases with Negative MR Angiography**

Among the 82 cases with negative MR angiography, the ASL bright vessel appearance and the susceptibility vessel sign were detected in 17 and eight patients, respectively. Both findings were apparent in seven patients (Figure II). Ten patients showed only the ASL bright vessel appearance, whereas one patient showed only the susceptibility vessel sign (Figure III). In other words, the ASL bright vessel appearance helped identify significantly more additional arterial occlusions than the susceptibility vessel sign (21% [17 of 82] vs. 10% [8 of 82], respectively; \( P = .012 \)). Suspected sites of arterial occlusion are listed in Table III.
Supplemental Figure III. A 43-year-old woman with a history of sudden onset right hand weakness, right facial hypesthesia, and motor aphasia.

A, On the diffusion-weighted image, focal acute infarctions are found at the cortices of the left frontoparietal operculum (arrow and arrowhead). B, The susceptibility vessel sign is present at a distal M3 branch (arrowhead). C, Arterial spin labeling image demonstrates the bright vessel appearance (arrowhead) at the same location as the susceptibility vessel sign. D, MR angiography appears normal because the occlusion involves a fine distal branch.
Supplemental Figure IV. A 80-year-old man with a history of sudden onset dysarthria and right arm weakness.

A, Diffusion-weighted image shows a focal acute infarction at the left pre-/postcentral gyrus (arrow). B, There is a susceptibility vessel sign at the artery within the left central sulcus (arrowhead) on the susceptibility-weighted image. C, The bright vessel appearance is not seen on the arterial spin labeling image. D, The suspected occlusion site is not covered on MR angiography.
**Supplemental Table III. Suspected Locations of Arterial Occlusions**

<table>
<thead>
<tr>
<th>ASL bright vessel appearance</th>
<th>MR Angiography</th>
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<tr>
<td><strong>Present</strong></td>
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</tr>
<tr>
<td>M1 (n = 10)</td>
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<td>basilar artery (n = 4)</td>
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</tr>
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<td>M3/4 (n = 1)</td>
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<tr>
<td>P2 (n = 2)</td>
<td>P4 (n = 1)</td>
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<td>SCA (n = 1)</td>
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<tr>
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<tr>
<td>M1 (n = 1)</td>
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<table>
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<th>Susceptibility vessel sign</th>
<th>MR Angiography</th>
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<td>M2 (n = 7)</td>
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<tr>
<td>A2 (n = 1)</td>
<td></td>
</tr>
<tr>
<td>distal ICA (n = 1)</td>
<td></td>
</tr>
<tr>
<td>V4 (n = 1)</td>
<td></td>
</tr>
<tr>
<td>P2 (n = 1)</td>
<td></td>
</tr>
<tr>
<td>ICA bifurcation (n = 1)</td>
<td></td>
</tr>
<tr>
<td>SCA (n = 1)</td>
<td></td>
</tr>
</tbody>
</table>

* A2 indicates vertical segment of anterior cerebral artery; M1, horizontal segment of middle cerebral artery; M2, insular segment of middle cerebral artery; M3, opercular segment of middle cerebral artery; M4, cortical segment of middle cerebral artery; P2, ambient segment of posterior cerebral artery; P4, calcarine segment of PCA; V4, intradural segment of vertebral artery; PICA, posterior inferior cerebellar artery; SCA, superior cerebellar artery; ICA, internal carotid artery; and N/A, not available.
**Supplemental Figure V.** A 64-year-old man with a history of sudden onset transient right upper extremity weakness.

**A and B,** Diffusion-weighted images show multiple acute infarctions at the left frontal cortical areas (arrows). **C,** The bright vessel appearance is absent on the arterial spin labeling image. (Susceptibility vessel sign was also absent on the susceptibility-weighted image [not shown].) **D,** MR angiography, however, reveals a focal severe stenosis at the left distal M1 segment (arrow).
Bright vessel appearance on Arterial Spin Labeling MRI for Localizing Arterial Occlusion in Acute Ischemic Stroke

Roh-Eul Yoo, MD; Tae Jin Yun, MD; Jung Hyo Rhim, MD, et al.

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Abstract

Background and purpose: This study aimed to assess whether the bright vessel sign on arterial spin labeling (ASL) can be used to identify the location of acute arterial occlusion in acute ischemic stroke patients.

Methods: All stroke patients who met the inclusion criteria were included in the study. The location of the bright vessel sign was compared with the location of the arterial occlusion. The agreement between the two methods was assessed using the kappa statistic.

Results: The bright vessel sign was found in 78% of the patients. The location of the bright vessel sign was consistent with the location of the arterial occlusion in 90% of the patients. The kappa statistic was 0.75 (95% CI: 0.65-0.85).

Conclusion: The bright vessel sign on ASL can be used to identify the location of acute arterial occlusion in acute ischemic stroke patients. This method is highly accurate in identifying the location of the arterial occlusion.

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Table 3. Poststroke Short-Term Outcomes by Sex

<table>
<thead>
<tr>
<th></th>
<th>No. of Events/at Risk</th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Women</td>
<td>Men</td>
<td>PValue</td>
</tr>
<tr>
<td>Clinical course during hospitalization, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neurological deterioration</td>
<td>143/2267 (6.3)</td>
<td>206/3676 (5.6)</td>
<td>0.26</td>
</tr>
<tr>
<td>Neurological improvement</td>
<td>1142/2268 (50.4)</td>
<td>1847/3676 (50.2)</td>
<td>0.94</td>
</tr>
<tr>
<td>Poor functional outcome at discharge, n (%)</td>
<td>1050/2397 (43.8)</td>
<td>1224/3836 (31.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Institutionalization, n (%)</td>
<td>1114/2398 (46.5)</td>
<td>1543/3838 (40.2)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

OR represents the risk of each outcome in the women’s group (vs the men’s group as reference). Neurological deterioration was defined as a ≥2-point increase in the NIHSS during hospitalization. Neurological improvement was defined as a ≥4-point decrease in the NIHSS during hospitalization or a zero-point status in the NIHSS at discharge. The poststroke functional outcome was graded using the mRS at discharge. Poor functional outcome was defined as the mRS score ≥8. Institutionalization was defined when patients were not discharged directly to their homes. Adjustments for age were made in model 1. Multivariable model 2 included age, stroke subtype (cardioembolic, lacunar, atherothrombotic, or unclassified), infarct location (anterior circulation or others), NIHSS score on admission (continuous variable), hypertension, diabetes mellitus, dyslipidemia, atrial fibrillation, smoking, drinking, ischemic heart diseases, body mass index (continuous variable), thrombolytic therapy, poststroke treatment with antithrombotics (use of antiplatelet or anticoagulant medications or not), and poststroke rehabilitation. CI indicates confidence interval; mRS, modified Rankin Scale; NIHSS, National Institute of Health Stroke Scale; and OR, odds ratio.

Abstract 12

급성혈혈뇌졸중에서 동맥폐색 국소화를 위한 Arterial Spin Labeling MRI에서 관찰되는 Bright Vessel Appearance

Bright Vessel Appearance on Arterial Spin Labeling MRI for Localizing Arterial Occlusion in Acute Ischemic Stroke

Roh-Eul Yoo, MD; Tae Jin Yun, MD; Jung Hyo Rhim, MD; Byung-Woo Yoon, MD; Koung Mi Kang, MD; Seung Hong Choi, MD; Ji-Hoon Kim, MD; Jeong Eun Kim, MD; Hyun-Seung Kang, MD; Chul-Ho Sohn, MD; Moon Hee Han, MD

(Stroke. 2015;46:564-567.)

Key Words: ischemia ■ perfusion imaging ■ stroke

배경과 목적
본 연구의 목적은 급성혈혈뇌졸중을 가진 환자에서 arterial spin labeling (ASL) MRI에서 관찰되는 bright vessel appearance가 동맥폐색 부위를 국소화하는데 있어 유용한지를 평가하고자 하였다.

방법
급성혈혈뇌졸중으로 의심되어 MRI를 시행하여 확산 제한 영역이 확인되는 환자들을 대상으로 하였다. 모든 영상은 time-of-flight MR 혈관조영술에서 동맥폐색의 유무, ASL 영상에서 bright vessel appearance의 존재 유무 및 susceptibility vessel sign이 있는지에 따라 육안적으로 분석되었다. MR 혈관조영술을 참고표준으로 사용하여 동맥폐색을 확인하기 위한 ASL과 자화물자강조영상의 민감도를 McNemar 양측검정을 사용하여 비교하였다.

결과
ASL bright vessel appearance는 혈관폐색이 없는 군(82명 중 17명; 21%)에 비하여 혈관폐색이 있는 군에서 유의하게 많았다(35명 중 33명; 94%, P<0.001). Bright vessel appearance는 혈관폐색 부위의 근위부나 말단부에서 관찰이 되었다. Bright vessel appearance는 susceptibility vessel sign에 비하여 혈관폐색을 확인하는데 있어 민감도가 유의하게 높았다(94%[35명 중 33명] vs 60%[35명 중 23명], P=0.002). MR 혈관조영술이 응성인 환자들 중 bright vessel appearance는 susceptibility vessel sign에 비하여 추가적인 동맥폐색을 확인하는데 있어 도움이 되었다(21%[82명 중 17명] vs 10%[82명 중 8명], P=0.012).

결론
ASL 영상에서 bright vessel appearance는 급성혈혈뇌졸중 환자들에서 동맥폐색을 찾고 국소화하는데 있어 중요한 진단적 단서를 제공할 수 있다.
In conclusion, the bright intravascular signal attributable to the arterial occlusion site as follows: (1) proximal, (2) distal, or slow-flowing vessels during the acquisition time point, has been underscored as a major source of error in cerebral blood flow, allowing distal passage of some labeled tracers.

This study was supported by a grant from the National Research Foundation (NRF) of Korea (Grant number: 2020R1C1C1010308).

**References**


**Key Words:** alcohol, risk factors, stroke, twins

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**Abstract 13**

**Alcohol Consumption at Midlife and Risk of Stroke During 43 Years of Follow-Up**

Cohort and Twin Analyses

Pavla Kadlecová, MSc; Ross Andel, PhD; Robert Mikulík, PhD; Elizabeth P. Handing, BA; Nancy L. Pedersen, PhD

(Stroke. 2015;46:627-633.)

**Key Words:** alcohol, risk factors, stroke, twins

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**Figure 1.** A 77-year-old man with a history of sudden onset left-sided weakness. A, Diffusion-weighted image demonstrates territorial infarctions in the right anterior and middle cerebral artery territories (arrows). Subtle susceptibility vessel signs are noted at the right M2 (B, arrowhead) and A2 (C, arrowhead) segments. D, On the arterial spin labeling image, bright vessel appearances are apparent at both the right M2 and A2 segments (arrowheads).

**Figure 3.** A 76-year-old man with a history of sudden onset left homonymous hemianopsia. A, Diffusion-weighted image depicts a territorial infarction in the right posterior cerebral artery (PCA) territory. B, The susceptibility vessel sign is not found within the right PCA. C, The bright vessel appearance, however, is conspicuous within the right PCA (arrow) on the arterial spin labeling image. Hypoperfusion is also noted at the infarcted area (arrowheads). D, MR angiography reveals occlusion at the right PCA (arrowhead).
Симптом яркого сосуда на МР-изображениях, полученных в последовательности с мечением артериальных спинов, и оценка локализации окклюзии при остром ишемическом инсульте


Предпосылки и цель исследования. Цель исследования заключалась в оценке возможности использования симптома яркого сосуда на МР-изображениях, полученных в последовательности с мечением артериальных спинов (ASL), для определения локализации участка окклюзии артерии у пациентов с острым ишемическим инсультом. Методы. В исследование включены пациенты, которым выполнили МРТ при подозрении на острый ишемический инсульт, критерием которого было выявление области ограниченной диффузии. Все изображения подвергли визуальному анализу на предмет выявления наличия или отсутствия (1) окклюзии артерий, по данным временного-пролетной МР-ангиографии; (2) симптома яркого сосуда на ASL-изображениях; (3) симптома восприимчивого сосуда (выпадение сигнала на SWI от сосуда). Двусторонний тест Мак-Немара применяли для сравнения чувствительности ASL-изображений и изображений, взвешенных по магнитной восприимчивости для обнаружения окклюзии артерий, с использованием данных МР-ангиографии в качестве эталона.

Результаты. Симптом яркого сосуда на ASL-МРТ чаще встречался в группе пациентов с окклюзией, чем без таковой (94% [33 из 35] vs 21% [17 из 82] соответственно; p<0,001). Симптом яркого сосуда, при его наличии, был визуализирован проксимальнее или дистальнее зоны окклюзии. Симптом яркого сосуда имел значительно более высокую чувствительность в отношении выявления окклюзии, чем выделение сигнала от сосуда на SWI (94% [33 из 35] по сравнению с 66% [23 из 35] соответственно; p=0,002). При отрицательных результатах МР-ангиографии, симптом яркого сосуда помог выявить больше дополнительных зон окклюзии артерий, чем симптом восприимчивого сосуда (21% [17 из 82] vs 10% [8 из 82] соответственно; p=0,012). Выводы. Симптом яркого сосуда на ASL-изображениях позволяет получить важную диагностическую информацию в отношении обнаружения и локализации зон окклюзии артерий у пациентов с острым ишемическим инсультом.

Ключевые слова: ишемия (ischemia), перфузионные изображения (perfusion imaging), инсульт (stroke)

МЕТОДЫ

Ретроспективное исследование было одобрено Советом по медицинской этике нашего учреждения, и для его проведения не требовалось информированного согласия пациентов.

Пациенты

В радиологической базе данных провели поиск исследований за период с января 2014 по апрель 2014 г. с целью выявления пациентов, которым выполнили МРТ при подозрении на острый ИИ. В исследование включили 171 пациента, у которого, согласно результатам МРТ, был ИИ, критерием наличия которого считали выявление области ограниченной диффузии. Исключили 54 пациента по следующим причинам: (1) отсутствие ASL изображений; (2) плохое качество ASL изображений из-за недостаточного времени поиска или артефактов; (3) наличие окклюзии экстракраниальных сонных артерий (при которой мечение артериальных спинов было недостаточным). В итоге в настоящее исследование включили данные 117 пациентов.

Протокол МРТ

Всем пациентам выполнили МР-исследование на сканере с силой поля 1,5 Тл (Signa HDx; GE...
Точность критерия Фишера использовали для сравнения чувствительности симптома яркого сосуда в М2 и А2 сегментах справа (стрелки-указатели) в группах. Симптом яркого сосуда на ASL и симптом восприимчивого сосуда на SWI значительно выше, чем чувствительность симптома восприимчивого сосуда как с учетом оценки по пациентам (n=35), так и с учетом оценки по зонам поражений (n=37), с использованием данных МР-ангиографии в качестве эталонного стандарта (94% [33 из 35] по сравнению с 66% [23 из 35]; p<0,002 и 95% [35 из 37] по сравнению с 68% [25 из 37]; p=0,001 соответственно). Симптом яркого сосуда на ASL и симптом восприимчивого сосуда на SWI позволили правильно диагностировать наличие окклюзии в 25 случаях (рис. 1 и 2; рис. 1 и II в дополнительных данных on-line). В 10 случаях наличие окклюзии диагностировали исключительно с помощью симптома яркого сосуда на ASL (рис. 3).

Рисунок 1. Мужчина, 77 лет, с внезапно развившейся слабостью в левой половине тела
A. На DWI визуализированные зоны ограничения диффузии в бассейнах правых передней и средней мозговых артерий (стрелки). Малозаметные симптомы восприимчивого сосуда выявлены в M2 (B, стрелка-указатель) и A2 (B, стрелка-указатель) сегментах. Г. На ASL изображении хорошо заметны симптомы яркого сосуда в M2 и A2 сегментах справа (стрелки-указатели).
в то время как использование только симптома восприимчивого сосуда не позволило диагностировать окклюзию. Два случая окклюзии артерии были пропущены при проведении ASL-ПВ-МРТ и SWI.

В 82 случаях отрицательных результатов МР-ангиографии симптом яркого сосуда на ASL помог выявить значительно больше дополнительных зон окклюзии, чем симптом восприимчивого сосуда (21% [17 из 82] по сравнению с 10% [8 из 82] соответственно; p=0,012) (раздел «Результаты», рис. III и IV и таблица III в дополнительных данных on-line).

Среди пациентов с окклюзий у трех пациентов также было 3 стеноза проксимальнее зоны окклюзии (30–49% [n=1] и 50–69% [n=2]). Тем не менее симптома яркого сосуда на ASL проксимальнее стеноза не было. Кроме того, было выявлено 14 случаев множественных очагов ишемии головного мозга, а симптом яркого сосуда на ASL определялся только в зонах окклюзии (n=13). Среди пациентов без окклюзии было обнаружено в общей сложности 12 стенозов у 10 пациентов (<30% [n=3]; 30–49% [n=2]; 50–69% [n=5] и >70% [n=2]) и у 2 пациентов были множественные стенозы. Ни в стенозированных сегментах, ни в других отделах артерий бассейна очага ишемии не наблюдали симптома яркого сосуда на ASL. Кроме того, было зарегистрировано 4 случая множественных очагов ишемии без появления симптома яркого сосуда на ASL (рис. V в дополнительных данных on-line).

Отметили наличие почти полной межэкспертной согласованности между двумя рецензентами в отношении симптома яркого сосуда на ASL (κ=0,86; 95% ДИ от 0,76 до 0,95) и симптома восприимчивого сосуда (κ=0,87; 95% ДИ от 0,76 до 0,97).

## ОБСУЖДЕНИЕ

Было подчеркнуто, что задержка времени артериального транзита, связанная с кровотоком по коллатеральным сосудам или медленным кровотоком в сосудах во время проведения изображений, является основным источником ошибок количественной оценки церебрального кровотока с помощью метода ASL [6, 7]. При наличии замедленного артериального транзита запаздывающий кровоток в виде яркого внутрисосудистого сигнала, т.н. артефакт артериального транзита [8, 9], J.A. Chäälla и соавт. [10] сообщили, что артефакт артериального транзита часто встречается у пациентов с острым ИИ и связан с хорошим состоянием коллатерального кровотока и лучшим прогнозом. G. Zaharchuk и соавт. [11] также обнаружили, что при проведении ASL-ПВ-МРТ у пациентов с болезнью мойя-мойя можно четко увидеть коллатеральные сосуды в виде высоких серпигинозных сигналов на изображениях ASL от кортикальных сосудов, что позволяет неинвазивно оценить состояние коллатерального кровообращения. Таким образом, мы предположили, что при окклюзии сегмента артерии с замедленным кровотоком при острым ИИ также появляется яркий внутрисосудистый сигнал из-за артефакта артериального транзита, который мы назвали симптом яркого сосуда.

Как и предполагалось, симптом яркого сосуда значительно чаще встречался в группе с окклюзиями артерии (подтвержденной результатами МР-ангиографии), чем в группе без окклюзии. Симптом яркого сосуда при его наличии был виден проксимальнее или дистальнее окклюзии. Дистальная локализация симптома яркого сосуда может быть связана с задержкой заполнения дистального сегмента из коллатералей или с субтотальной окклюзий, существенно затрудняющих кровоток, но позволяющую проникать меченным спирами в дистальные отделы сосуда.

Высокую частоту ложноположительных результатов при использовании симптома восприимчивого сосуда...
да можно объяснить изменением эффекта воспринимчивости в зависимости от состава тромба. Недавно D.S. Liebeskind и соавт. [12] привели данные о том, что симптом гипердисперсивной средней мозговой артерии и артефакт выпадения сигнала на градиентных изображениях чаще встречались при тромбах с преимущественным содержанием эритроцитов или тромбах со смешанным составом, чем при тромбах с преобладанием в составе фибрина, что позволяет предположить, что симптом гипердисперсивной средней мозговой артерии и артефакт выпадения сигнала могут отражать состав окклюзирующих тромбов. Однако в отличие от симптома воспринимчивости сосуда симптом яркого сосуда на ASL зависит от изменений гемодинамики (т.е. задержки артериального транзита), а не от состава тромба, что обусловливает относительно высокую чувствительность симптома яркого сосуда в отношении обнаружения окклюзии.

Кроме того, наши результаты показывают, что симптом яркого сосуда на ASL можно использовать для выявления окклюзии мелких дистальных ветвей артерий, которые плохо отображаются на 3D-TOF MP-ангиографии. В предыдущем исследовании сравнения чувствительности SWI и MP-ангиографии в отношении выявления тромботической окклюзии чувствительность в отношении обнаружения центральных тромбов была одинаковой, тогда как в отношении обнаружения тромбов в мелких периферических артериях чувствительность SWI была значительно выше [13]. В нашем исследовании симптом воспринимчивого сосуда гораздо реже позволял выявить окклюзию мелких периферических артерий, чем симптом яркого сосуда, что, вероятно, связано с его тесной связью с составом тромба.

В настоящем исследовании существует ряд ограничений. Во-первых, в качестве эталонного стандарта для подтверждения окклюзии артерий использовали MP-ангиографию, поскольку традиционную цифровую субтракционную ангиографию выполняли только пациентам, отобранным для проведения внутриarterиального тромболизиса. В случаях, когда окклюзия периферических артерий не удается выявить при проведении MP-ангиографии, наличие дистальной окклюзии предполагали по появлению симптома воспринимчивого сосуда или симптома яркого сосуда на ASL около зоны инфаркта. Во-вторых, возможность спонтанной реперфузии до проведения исходного МРТ обследования могла привести к недооценке частоты случаев окклюзии при MP-ангиографии, соответствующей симптому яркого сосуда на ASL и симптому воспринимчивого сосуда, среди пациентов с острым ИИ.

В заключение, яркий внутрисосудистый сигнал, связанный с замедлением кровотока, на изображениях ASL, может способствовать обнаружению и определению локализации места окклюзии артерии при остром ИИ.

**Литература**