Editorial

The clinical significance of arterial transit artifact on arterial spin labeling in patients with acute ischemic stroke

Naoto Kohno[1], Kazunori Okada[2], Shingo Yamagata[3], Hiroyuki Takayoshi[4], Shuhei Yamaguchi[4]

[1]Department of Internal Medicine, Seto Inland Sea Hospital, Imabari, Japan; [2]Ohda Silver Clinic, Ohda, Japan; [3]Department of Internal Medicine, Ohda Municipal Hospital, Ohda, Japan; [4]Department of Neurology, Faculty of Medicine, Shimane University, Izumo, Japan

Correspondence to: Naoto Kohno, MD, PhD. Department of Internal Medicine, Seto Inland Sea Hospital, Kitahorai-cho 2-4-9, Imabari 794-0028, Japan. Email: kohnonaoto@gmail.com.

Comment on: de Havenon A, Haynor DR, Tirschwell DL, *et al.* Association of Collateral Blood Vessels Detected by Arterial Spin Labeling Magnetic Resonance Imaging With Neurological Outcome After Ischemic Stroke. JAMA Neurol 2017;74:453-8.

Received: 08 August 2017; Accepted: 22 August 2017; Published: 18 September 2017.

doi: 10.21037/amj.2017.08.27

View this article at: http://dx.doi.org/10.21037/amj.2017.08.27

Arterial spin labeling (ASL) is a noninvasive magnetic resonance imaging (MRI) technique used to assess brain perfusion quantitatively in humans. Many studies have reported the safety and utility of ASL in acute ischemic stroke (AIS); however, few reports have investigated the clinical significance of arterial transit artifact (ATA) in AIS. In this report, we focus on the utility of ATA in AIS.

de Havenon *et al.* evaluated 38 patients with AIS who underwent 3 tesla (3T) MRI, including diffusion-weighted imaging (DWI) and ASL, within 3 d of stroke onset (1). They defined ASL collaterals (ASLcs) as the presence of curvilinear areas of hyperintensity, known as ATA, along 10% or more of the border of the ASL hypoperfusion area that corresponded to the DWI lesion. They retrospectively analyzed the association between the occurrence of ASLcs and clinical prognosis. ASLcs were detected in 25 of 38 patients (65.8%) and were significantly associated with a good clinical outcome [i.e., a modified Rankin scale (mRS) score of 0–2 at discharge and 1-point decrease in the mRS score at discharge]. They identified two key features of ATA that were critical for correctly identifying a high signal in collateral vessels: (I) the high signal must be curvilinear (intravascular) along the expected trajectory of the circle of Willis vessels and/or overlying the greater convexities (representative of pial collateral vessels); and (II) the adjacent target tissue must be hypoperfused relative to nonischemic brain regions. These two features were mutually dependent, as affected tissue in AIS was typically ischemic because of delayed arterial transit time, which permitted simultaneous evaluation of cerebral hypoperfusion and collateral vessels. This study suggests a novel MRI technique for assessing collateral blood supply in AIS.

Regarding the clinical utility of the ASL technique in AIS, we recently evaluated 103 patients with AIS (mean age: 79.0 years) within 24 h after stroke onset and reported the utility of ASL depending on the stroke subtype: transient ischemic attack (TIA), lacunar infarction (LI), atherothrombotic infarction (AT), and cardiogenic embolic (CE) infarction (2). ATA was observed in 44.4% of patients with TIA, 11.1% with LI, 45.2% with AT, and 80.6% with CE. ATA was observed in 33% of patients without DWI lesions, 12% of those with a small DWI lesion, 69% of those with a medium DWI lesion, and 77% of those with a large DWI lesion. We additionally analyzed the relationship between ATA and clinical prognosis in the 103 patients; we did not detect a significant association between ATA and the mRS or the National Institutes of Health Stroke Scale score upon discharge. The discordance between de Havenon's study and ours might be due to differences in clinical features, such as the subject age (61 *vs.* 79 years), imaging device used (3T *vs.* 1.5T MRI), post-labeling delay (PLD) (1,800 *vs.* 1,525 ms), time from stroke onset (3 *vs.* 1 d), and symptom severity at onset.

Early restoration of blood flow in AIS, particularly to regions of ischemic penumbra, improves the recovery and the prognosis of patients (3). Information on collateral flow is important to predict the prognosis of patients with

AIS. ATAs are often seen proximal or distal to the arterial occlusion site and provide an important diagnostic clue for detection and localization of arterial occlusion sites in patients with AIS (4). Furthermore, ATA represents slow stagnant and collateral flow, for example, through the ophthalmic artery in patients with acute internal carotid artery (ICA) occlusion (5). In animal models of AIS, the perfusion of penumbra was correlated with the perfusion of adjacent tissue regions more strongly than was the perfusion of regions undergoing infarction (6). This was interpreted as an effect of preserved collateral blood flow. Treatment with collateral therapeutics to the penumbra was associated with lower infarct volumes and a greater probability of a good functional outcome (7). This indicates the importance of collateral vessels in the penumbra in improving the prognosis of patients with AIS.

van den Wijngaard assessed collateral filling with dynamic computed tomography angiography (CTA) and its relationship with infarct volume at follow-up (8). Dynamic CTA provides a more detailed assessment of collaterals than does single-phase CTA, and collaterals have a stronger relationship with infarct volume at follow-up. The extent of collateral flow is more important in determining tissue fate than is the velocity of collateral filling. The timing of dynamic CTA acquisition in relation to intravenous contrast administration is critical for optimal assessment of the extent of collaterals.

Akiyama *et al.* estimated collateral vessels in five patients with unilateral occlusion or stenosis of the ICA (9). The ASL revealed low cerebral blood flow (CBF) with a 1.5-s PLD in the target area and improved CBF with a 2.5-s PLD. By visual inspection, they compared ASL findings with digital subtraction angiography (DSA) findings at 1.5 and 2.5 s after injection of the contrast. DSA revealed that the hypovascular areas observed at 1.5 s were improved via primary and secondary collaterals and delayed anterograde flow at 2.5 s. ATAs, which appeared in nearly the same configuration for both PLDs, were attributed to stagnant collaterals and flow in the M2 portion of the middle cerebral artery (MCA) and ICA during the late venous phase. The use of both PLDs was validated by the DSA findings.

ATA using both PLDs is also useful to differentiate well-developed and stagnant collateral vessels from focal hyperperfusion. Lou *et al.* assessed the associations of leptomeningeal collateral perfusion scores based on ASL with four PLDs (1.5, 2, 2.5, and 3 s) and investigated the outcome of endovascular treatment in patients with AIS in the MCA territory (10). Higher leptomeningeal collateral perfusion scores on cerebral blood volume (CBV) images by ASL may be a specific marker of good clinical outcomes after endovascular treatment in patients with acute MCA ischemic stroke.

ATA is almost compatible with the susceptibility vessel sign (SVS) in patients with cardioembolic cerebral infarction (11). The SVS on T2-weighted MR angiography was detected more frequently in CE than in AT. Moreover, the proximal intra-arterial signal (IAS) on ASL and the distal IAS on fluid-attenuated inversion recovery MRI was detected less frequently in chronic occlusion than in acute occlusion due to cardioembolic or *in situ* stenosis. Multivariate regression analysis indicated that the SVS was significantly associated with CE.

Clinical features of acute stroke with major intracranial vessel occlusion vary depending on the etiology. The SVS and ATA are useful for distinguishing CE from AT (12). Multiple hypointense vessels (MHVs) on susceptibility-weighted imaging (SWI) are associated with an increased oxygen demand in acute cerebral ischemia. Occasionally, some patients exhibit extensive MHVs on SWI despite negative DWI, a phenomenon called total DWI-SWI mismatch. Total DWI-SWI mismatch is associated with good collateral flow and may be a predictor of a good response to treatment in patients with AIS (13).

ATA reflects the hemodynamic pathology of acute obstruction of a major arterial trunk. Conversely, the lack of ATA development may be attributed to gradual progression of arterial occlusion in AIS (2). ATA used in conjunction with other MRI modalities may help reveal the pathophysiology underlying the stroke-related hemodynamic state and guide treatment decision-making for patients with AIS. Further studies in a larger population are needed to confirm the clinical significance of ATA, particularly as a diagnostic tool for assessing collateral hemodynamics.

Acknowledgements

Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned and reviewed by the Section Editor Rui Liu (Department of Neurology, Jinling Hospital, Nanjing, China).

Conflicts of Interest: The authors have completed the

ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/amj.2017.08.27). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. de Havenon A, Haynor DR, Tirschwell DL, et al. Association of Collateral Blood Vessels Detected by Arterial Spin Labeling Magnetic Resonance Imaging With Neurological Outcome After Ischemic Stroke. JAMA Neurol 2017;74:453-8.
2. Kohno N, Okada K, Yamagata S, et al. Distinctive Patterns of Three-Dimensional Arterial Spin-Labeled Perfusion Magnetic Resonance Imaging in Subtypes of Acute Ischemic Stroke. J Stroke Cerebrovasc Dis 2016;25:1807-12.
3. Olsen TS, Larsen B, Herning M, et al. Blood flow and vascular reactivity in collaterally perfused brain tissue. Evidence of an ischemic penumbra in patients with acute stroke. Stroke 1983;14:332-41.
4. Yoo RE, Yun TJ, Rhim JH, et al. Bright vessel appearance on arterial spin labeling MRI for localizing arterial occlusion in acute ischemic stroke. Stroke 2015;46:564-7.
5. Sogabe S, Satomi J, Tada Y, et al. Intra-arterial high signals on arterial spin labeling perfusion images predict the occluded internal carotid artery segment. Neuroradiology 2017;59:587-95.
6. Little P, Kvist O, Grankvist R, et al. Preserved Collateral Blood Flow in the Endovascular M2CAO Model Allows for Clinically Relevant Profiling of Injury Progression in Acute Ischemic Stroke. PLoS One 2017;12:e0169541.
7. Beretta S, Versace A, Carone D, et al. Cerebral collateral therapeutics in acute ischemic stroke: A randomized preclinical trial of four modulation strategies. J Cereb Blood Flow Metab 2017. [Epub ahead of print].
8. van den Wijngaard IR, Holswilder G, Wermer MJ, et al. Assessment of Collateral Status by Dynamic CT Angiography in Acute MCA Stroke: Timing of Acquisition and Relationship with Final Infarct Volume. AJNR Am J Neuroradiol 2016;37:1231-6.
9. Akiyama T, Morioka T, Shimogawa T, et al. Arterial Spin-Labeling Magnetic Resonance Perfusion Imaging with Dual Postlabeling Delay in Internal Carotid Artery Steno-occlusion: Validation with Digital Subtraction Angiography. J Stroke Cerebrovasc Dis 2016;25:2099-108.
10. Lou X, Yu S, Scalzo F, et al. Multi-delay ASL can identify leptomeningeal collateral perfusion in endovascular therapy of ischemic stroke. Oncotarget 2017;8:2437-43.
11. Kato A, Shinohara Y, Kuya K, et al. Proximal Bright Vessel Sign on Arterial Spin Labeling Magnetic Resonance Imaging in Acute Cardioembolic Cerebral Infarction. J Stroke Cerebrovasc Dis 2017;26:1457-61.
12. Horie N, Tateishi Y, Morikawa M, et al. Acute stroke with major intracranial vessel occlusion: Characteristics of cardioembolism and atherosclerosis-related in situ stenosis/occlusion. J Clin Neurosci 2016;32:24-9.
13. Park MG, Yeom JA, Baik SK, et al. Total mismatch of diffusion-weighted imaging and susceptibility-weighted imaging in patients with acute cerebral ischemia. J Neuroradiol 2017. [Epub ahead of print].

doi: 10.21037/amj.2017.08.27
Cite this article as: Kohno N, Okada K, Yamagata S, Takayoshi H, Yamaguchi S. The clinical significance of arterial transit artifact on arterial spin labeling in patients with acute ischemic stroke. AME Med J 2017;2:140.