A rtioveral spin labeling (ASL) is one of the most recent magnetic resonance imaging (MRI) sequences used to assess brain perfusion noninvasively. It can be used in the acute phase of ischemic stroke (IS) to identify ischemic penumbra. In patients in acute phase of IS, thrombus assessment is of major clinical relevance because the presence and location of the thrombus may determine therapeutic strategy. An arterial bright signal (ABS), at the level of vascular occlusions, can be observed on raw data of ASL sequence performed for stroke.

The aim of this study is to evaluate the relevance of this MRI sign in patients admitted for IS.

Patients and Methods

With the approval of the local ethics committee, we retrospectively analyzed MRI sequences of patients with an IS suspicion admitted in the Department of Neuroradiology (University Hospital of Martinique) from December 2011 to August 2014. MRI (GE Optima MR450W, 1.5 T) was performed within 6 hours from stroke onset and included diffusion weighted imaging sequence, echo planar imaging T2* (EPI T2*), fluid attenuated inversion recovery (FLAIR) and MR angiography (Willis time of flight (TOF)). ASL sequence was performed only in case of doubtful diffusion weighted imaging or to highlight a mismatch before a thrombolytic treatment.

ASL scans were performed using a pseudocontinuous mode with a repetition time of 4554 ms, an echo time of 10 ms, a postlabeling delay of 1525 ms, and a total acquisition time of 4 minutes. Main judgment criteria were the assessment and the concordance of ABS compared with other sequences (TOF, EPI T2*, and FLAIR).

Moreover, a vessel occlusion was diagnosed if an artery was missing on Willis TOF. An intra-arterial clot could be diagnosed on T2* (as a focal hypersignal) and on FLAIR sequences (as a focal hypersignal). ABS was diagnosed according to 2 different patterns upstream of a hypoperfused territory: spot-like (rounded or oval, with sharp edges, on a vascular path) or vessel-like (linear hypersignal on an artery path).

One neuroradiologist (AA), with 11 years of experience, first analyzed ASL data while being blinded to clinical data and other sequences. A radiology resident, with a 6-month experience in neurroradiology, independently repeated the whole data analysis process in the same conditions.

A stroke was considered ongoing in case of the detection of an area of restricted diffusion, identified while being blinded to ASL results.

The absence of stroke diagnosis was made if no restricted diffusion area was observed, while still blinded to ASL results. This was further corroborated by clinical data and computed tomography or MRI follow-up for 1 week after patient admission for IS suspicion.

Statistical Analysis

Interobserver variability for ABS was assessed using Cohen κ statistic. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for ABS were also determined. All statistical analyses were conducted using SPSS software 22.1 for Windows (SPSS, Inc, Chicago, IL).

Results

One hundred adult patients, seen consecutively in the Department of Neuroradiology, were retrospectively considered. Ten patients were excluded because of artifact. Overall, 90 patients (56 men; mean age, 67±18 years) were finally considered for data analysis. Of these 90 patients with stroke suspicion, 57 had an ongoing IS.

ABS could be seen according to 2 isolated or combined patterns, corresponding either to a spot or a vascular path (Figures 1 and 2). A substantial interobserver agreement was established for ABS detection (κ=0.80; 95% confidence interval, 0.56–1.00; P<0.0001).

Of the 33 patients without ongoing IS, 1 case had an ABS corresponding to a false-positive (Figure 3).

Among the 57 patients with ongoing IS, 51 presented an ABS with sensitivity, specificity, PPV, and NPV values of 89% (51/57), 97% (32/33), 98% (51/52), and 84% (32/38), respectively, on an IS occurrence. This ABS signal was localized in (1) the anterior cerebral artery for 2 cases, (2) the posterior cerebral artery for 1 case, (3) the internal carotid artery for 5 cases, and (4) the middle cerebral artery for 43 cases.

Furthermore, in the ongoing IS patient group, 40 of them had an occlusion diagnosed on TOF resulting in a sensitivity,
specificity, PPV, and NPV of 70% (40/57), 96.97% (32/33), 97.56% (40/41), and 65% (32/49), respectively, on an IS occurrence. Using MR angiography as a reference standard, the ABS had a sensitivity, specificity, PPV, and NPV of 100% (40/40), 35% (6/17), 78% (40/51), and 100% (6/6), respectively, among patients with IS.

Of the 17 remaining patients with stroke with no TOF occlusion, 11 cases presented an ABS. The signal was localized as follows: (1) in the A3 branch (superior limit of TOF field of view) for 2 patients, (2) in the M3/M4 branch for 5 patients and (3) in the M2 branch for the 4 remaining patients. Among the latter, 2 patients had a M2 stenosis on TOF, whereas the others had an area of hyperperfusion suggesting a possible vessel recanalization.

Of the 6 patients with IS but neither ABS nor TOF occlusion, 5 cases had an anterior choroidal artery stroke and 1 case had a stroke in the territory of the perforating arteries of the basilar trunk.

In addition, 24 patients with stroke had an intr-arterial clot on EPI T2* (sensitivity 42% [24/57], specificity 100% [33/33], PPV 100% [24/24], and NPV 50% [33/66]), whereas 29 patients with stroke had an intra-arterial clot on FLAIR sequence (sensitivity 51% [29/57], specificity 100% [33/33], PPV 100% [29/29], and NPV 54% [33/61]) on an IS occurrence.

**Discussion**

Our study demonstrates the presence of an ABS upstream of a hypoperfused territory on ASL sequences of patients with acute stroke. This signal is on an arterial path highly correlated with IS, especially in the presence of vessel occlusion. In 6 stroke cases concerning small arteries (branches from basilar artery and anterior choroidal artery), ABS was not visible which may indicate that this signal only appears for a definite vessel caliber.

Few studies have focused on vessel visualization using raw ASL data. Zaharchuk et al have shown that ASL could predict the presence and intensity of cortical collateral vessels in patients with moy-a-moya disease, as compared with cerebral angiography (considered as gold standard). Other studies have further described an arterial transit artifact within or around a hypoperfused territory, which may correspond to collateral circulation in patients with IS. In all these studies, vessels were highlighted in the cortical region and were because of bloodstream derivation or retrograde flow so as to maintain cerebral blood flow. Tada et al recently described this arterial transit artifact in patients with stroke, but restricted its localization to the middle cerebral artery only. In contrary to previous observations which have located the ASL artifact on the outskirts of the hypoperfusion area, our study describes its occurrence upstream of an occlusion (visible or not) during the acute phase of IS in different arteries.

We further hypothesize that ABS is because of a blocked flow related to an occlusion. This is based on the fact that ASL consists in the subtraction of 2 acquisitions of the same image slice (with and without spin labeling provoked

![Figure 1. Spot-like arterial bright signal (ABS; A) upstream of a proximal middle cerebral artery occlusion confirmed on Willis time of flight (TOF) (B). Vessel-like ABS of the internal carotid artery on raw arterial spin labeling data (C) seen upstream of a middle cerebral artery occlusion or stenosis on Willis TOF (D).](image1)

![Figure 2. Patient with a right posterior cerebral artery occlusion (A). A spot-like arterial bright signal is seen on raw arterial spin labeling data (B). Stroke territory is visible on apparent diffusion coefficient sequence (C) and a clot in posterior cerebral artery is visible on fluid attenuated inversion recovery sequence (D).](image2)
overestimated ABS presence in these patients, confounding with distal and collateral slow flow (arterial transit artifact) without effective occlusion. However, some authentic distal occlusions could have been missed because of a low MR angiography sensitivity.

We found a false-positive but it was a patient who presented sequelae of IS with residual occlusion of the terminal branches of the middle cerebral artery. ABS could then be explained by a slowdown of cerebral blood flow (Figure 3).

Hence, overall, the ASL sign might help identify a vascular occlusion or a narrow stenosis, especially when other MRI sequences are doubtful. Assessing a vascular occlusion in IS is of major clinical relevance in therapeutic decision. Moreover, the significant substantial inter-reader agreement (κ = 0.80) indicates that the ABS can be detected by any radiologist after a short training.

However, our study has some limitations. First, its small retrospective feature may generate some selection biases that might influence the accuracy of observed ABS sign. Second, our evaluation of arterial occlusion is based on TOF sequence. Digital subtraction angiography, which is a more precise and conventional evaluation, was only reserved for patients who met indications for intra-arterial thrombolysis.

In conclusion, we have described an imaging signal, with a high specificity rate, on raw ASL data related to IS. This signal also has a high sensitivity when an occlusion or a clot is visible and could therefore be of major interest in clinical practice. Thus, if a single sequence can provide information on occlusion occurrence and brain perfusion status simultaneously, it will also increase ASL sequence value in MRI protocols during acute stroke phase. Prospective studies with bigger patient samples and angiography (as the ideal gold-standard procedure) could help confirm these results.

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Disclosures

None.

References


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Raw Arterial Spin Labeling Data Can Help Identify Arterial Occlusion in Acute Ischemic Stroke

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