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Arterial spin labeling perfusion-weighted MRI for long-term follow-up of a cerebral arteriovenous malformation after stereotactic radiosurgery

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Abstract

We present a longitudinal series of arterial spin-labeling magnetic resonance imaging (ASL-MRI) in a patient with cerebral arteriovenous malformations (AVMs) treated by stereotactic radiosurgery (SRS). Pretreatment ASL-MRI showed high signal intensity in both the nidus and draining veins, and the latter signal abnormality gradually moved proximally by 14 months after SRS. At 24 months, the signal abnormalities finally disappeared, indicating complete obliteration of the nidus. The hemodynamic changes in the AVM were clearly visualized in the longitudinal ASL-MRI series, thus this non-invasive MR method may be useful not only for detecting AVMs but also for assessment of their response after SRS.

Keywords

Magnetic resonance imaging (MRI), brain, arteriovenous malformation (AVM), radiosurgery, arterial spin labeling (ASL)

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Introduction

Cerebral arteriovenous malformations (AVMs) are congenital vascular abnormalities in which arteriovenous shunting occurs through an abnormal vascular network (nidus) in the parenchyma. These lesions typically present with cerebral bleeding, seizures, headache, or neurological deficits; however, they are sometimes found incidentally (1). As this abnormality has a high risk of rupture (2–4% per year), intensive therapeutic interventions are generally indicated, including surgical resection, transcatheter embolization, and stereotactic radiosurgery (SRS). For AVMs that are unresectable due to size or location, SRS can avoid the potential risks associated with traditional surgery; however, complete elimination of the nidus occurs more slowly with this technique than with conventional surgery/embolization, taking 2–4 years (2). Although the potential for hemorrhage remains during this latency period, proliferation of the vascular endothelium is induced by irradiation, slowly but progressively obliterating the nidus and subsequently decreasing the volume of blood shunted (3). Evaluation of hemodynamic changes in and around the AVM after SRS is therefore crucial for appropriate patient management, and is generally achieved by conventional digital subtraction angiography (DSA) or contrast-enhanced computed tomography (CT)/ magnetic resonance imaging (MRI). However, it is difficult to perform these evaluations with optimal frequency due to factors such as side-effects of contrast material, cumbersome procedures, radiation exposure, and expense.

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Arterial spin-labeling MRI (ASL-MRI) is a brain perfusion imaging method that can generate images without injection of contrast material (4). Its clinical utility has been established in several cerebral conditions such as brain tumors (5), infarction, and vascular lesions (6). In this case report, we present a long-term sequential series of ASL-MRI as well as conventional MRI of an AVM treated with SRS. ASL-MRI clearly demonstrated hemodynamic changes after SRS, in a non-invasive manner and without administration of contrast material. It may, therefore, be useful in evaluating the therapeutic response of AVMs treated by SRS.

Case report

A 42-year-old man presented to our hospital with a 3-year history of recurrent seizures. Contrast-enhanced MRI was performed with a 3.0-T clinical MRI scanner (Signa Excite HD, GE Healthcare, Milwaukee, WI, USA) and revealed a Spetzler-Martin grade III AVM in the right temporal lobe (Fig. 1a). The AVM was fed by branches of the right middle and posterior cerebral arteries, and it drained to the dilated sphenoparietal sinus and other superficial veins. Along with conventional contrast-enhanced MRI, ASL-MRI was performed with a pseudo-continuous ASL sequence (label duration, 1.5 s; post-label delay, 1.5 s; spiral acquisition with 8 arms × 512 points; image matrix, 128 × 128; field of view, 240 mm; locations, 38; number of excitations, 3). These imaging techniques showed high signal intensity in the both nidus and distal portion of the draining veins (Fig. 1b). These MRI findings were also confirmed by DSA (Fig. 1c). Stereotactic radiosurgery was performed, in which the nidus and marginal areas were irradiated with 22 Gy and 20 Gy, respectively (Fig. 1d). The post-radiosurgical course was uneventful.

Subsequently, follow-up contrast-enhanced and ASL-MRI were performed at 3, 14, 24, and 30 months after SRS (Fig. 2). At 3 months, the nidus had shrunk slightly on conventional MRI, but the high signal intensity on ASL-MRI and dilatation of the draining veins were unchanged. At 14 months, the nidus had shrunk further and the draining veins were less dilated. Although the high signal intensity of the draining veins was still present on ASL-MRI, it was more proximal than in pretreatment images obtained with exactly same ASL parameters. Finally, at 24 months, when the high flows in the nidus and dilatation of the draining veins became unclear on T2-weighted (T2W) images and time-of-flight MR angiography, the high signal intensity on ASL-MRI had also completely disappeared. However, contrast-enhanced T1-weighted (T1W) images showed ring-like enhancements,

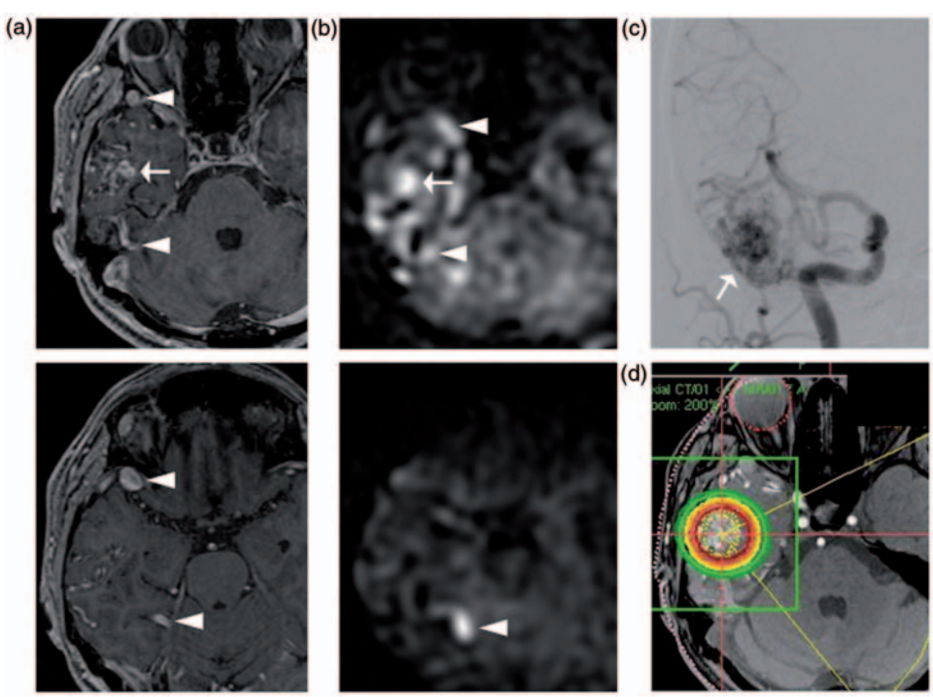

Fig. 1. MRI and DSA image before SRS. (a) Contrast-enhanced T1W MR images reveal an AVM in the right temporal lobe. A nidus (arrow) and dilated draining veins (arrowheads) are visible. (b) ASL-MRI show high signal intensity in both the nidus (arrow) and distal portion of the draining veins (arrowheads). (c) A DSA image also reveals the AVM corresponding to MRI findings (arrow). (d) An SRS radiation-dose distribution image is shown.

probably due to radiation necrosis. These MRI findings remained unchanged at 30 months after SRS (not shown).

Discussion

Consistent ASL-MRI findings of high signal intensity in both the nidus and draining veins of cerebral AVMs have been reported by several authors (7,8). Hence, the present ASL-MRI findings of a cerebral AVM were in keeping with previous reports. Regarding response of these lesions to treatment, a few studies have focused on hemodynamic changes evaluated by ASL-MRI after radiosurgery/embolization (7,9). In a study of 21 patients with AVM, Pollock et al. demonstrated quantitatively lower regional blood flow and a progressive decrease in nidal perfusion after SRS when compared with untreated AVM (7). However, a detailed visual assessment of hemodynamic changes using ASL-MRI in a single patient has not been well described. In the present case, unchanged dilatation of the draining veins and high signal intensity of this vessel on ASL-MRI indicated unchanged shunting at 3 months. At 14 months, when further shrinkage of the nidus was achieved, the high signal intensity of the draining veins moved more proximally on ASL-MRI obtained with exactly same ASL parameters. This change may represent a decrease of shunting due to partial obliteration of the nidus, since the draining veins also became less dilated. Finally, when no

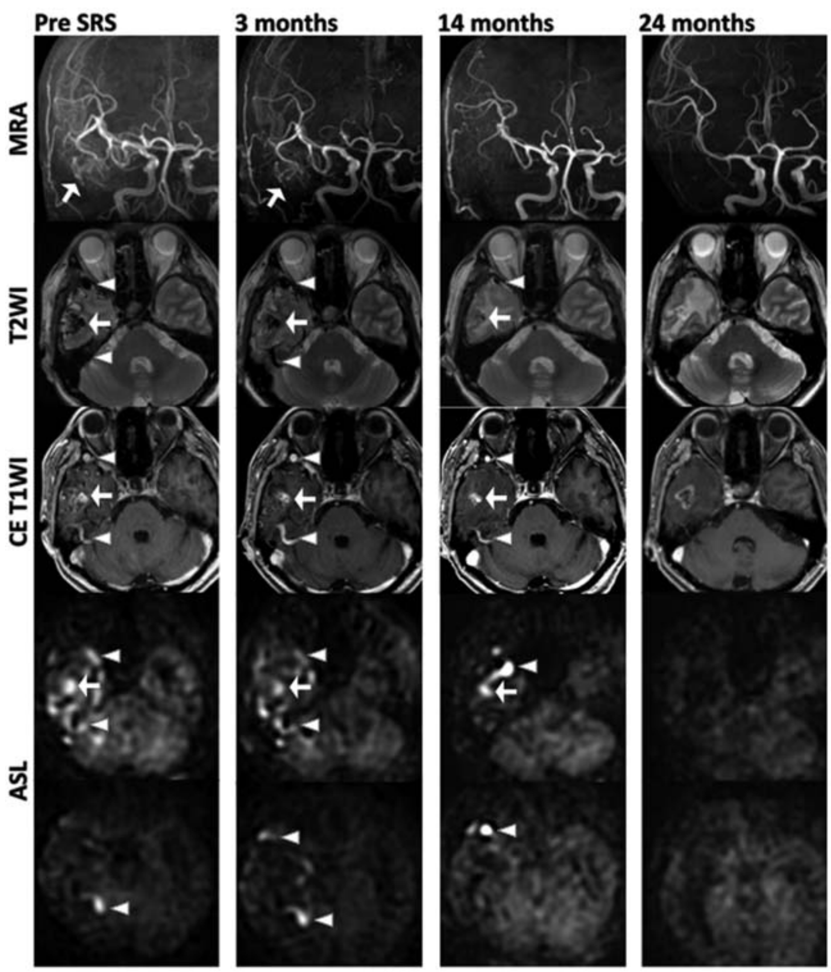

Fig. 2. Longitudinal series of MR images after SRS. At 3 months after SRS, the nidus (arrow) had shrunk slightly on conventional MRI (MR angiography [MRA], T2W images, and contrast-enhanced T1W images), while high signal intensity on the ASL-MRI was unchanged. At 14 months, the high signal intensity of draining veins (arrowheads) on ASL-MRI was observed more proximally than on pre-SRS images, and shrinkage of the nidus and dilated draining veins was seen on other MR images. Finally, when the high flows in the nidus and dilatation of the draining veins had become unclear on T2W images and MRA at 24 months, the high signal intensity on ASL-MRI had also completely disappeared. Note that contrast-enhanced T1W images shows ring-like enhancements, probably due to radiation necrosis.

abnormal signals were indentified on ASL-MRI, high flow in the nidus also disappeared on conventional MRI, indicating complete obliteration of the nidus. The remaining ring-like enhancement was probably caused by radiation necrosis.

ASL-MRI has several advantages over conventional MRI in assessing treatment response of AVM after SRS. First, ASL-MRI can be performed without contrast material. Thus, it can avoid the potentially lethal side-effects of contrast materials, and it is also less expensive. Second, ASL signals are reported not to be profoundly affected by vessel membrane permeability (10). Hence, ASL-MRI is not influenced even when radiation necrosis causes breakdown of the blood–brain barrier, whereas contrast-enhanced MRI shows ring-like enhancements like those observed in the present case 24 months after SRS. This feature might be useful in detecting recurrent high flows in a nidus after SRS during MRI follow-up.

In conclusion, the gradual hemodynamic changes in the present AVM after SRS were clearly visualized in a longitudinal ASL-MRI series. Although more cases need to be evaluated, this non-invasive perfusion-weighted MRI method may be useful not only for detecting AVMs, but also for precise assessment of the response of these lesions to SRS.

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