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Arterial spin-labeling magnetic resonance imaging for diagnosis of late seizure after stroke

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ABSTRACT

Background and purpose: Arterial spin labeling (ASL) is a non-invasive modality of magnetic resonance imaging (MRI) used to evaluate cerebral perfusion without a contrast agent. The usefulness of ASL for diagnosis in the acute phase of late seizure after stroke was evaluated.
Methods: Twelve consecutive patients diagnosed with late seizure after stroke were enrolled in this study. MRI including ASL was performed for each patient at the time of the emergency department visit. Eight of the patients underwent electroencephalography (EEG).
Results: All patients showed hyperperfusion around the stroke lesion on ASL. Only 6 patients showed high signal intensity along the cerebral cortex around the stroke lesion on diffusion-weighted imaging. The patients who underwent EEG showed slow activity, but paroxysmal discharges such as spikes or sharp waves were not observed.
Conclusions: ASL was able to reveal hyperperfusion and was of great diagnostic value in the peri-ictal phase of late seizure after stroke.

1. Introduction

Stroke is the most common cause of seizures in the elderly [1]. The incidence of post-stroke seizure is estimated at 5–10% in stroke patients. Late seizure is defined as a seizure occurring more than 2 weeks after the stroke, and it has a high risk of recurrence. The frequency of recurrence in post-stroke epilepsy is reported to be 2–3% [2,3].

The diagnosis of late seizure is easy in the case with a typical clinical course that shows a hemi-convulsion on the paralyzed side followed by disturbance of consciousness and a generalized convulsion. However, some seizures are not associated with convulsions (i.e., inhibitory seizures and non-convulsive status epilepticus). Inhibitory seizures are characterized by neurological deficits as the ictal manifestation. Furthermore, status epilepticus showing changes in behavior and/or mental processes without convulsions is called non-convulsive status epilepticus (NCSE), and NCSE has attracted great attention in the last few years [4]. Particularly in post-stroke patients who present with aphasia or paralysis without convulsions, the differential diagnosis among recurrent stroke, Todd's palsy, or inhibitory seizures is difficult [5].

History taking, neurological examination, computed tomography (CT), magnetic resonance imaging (MRI), electroencephalography (EEG), single photon emission computed tomography (SPECT), and positron emission tomography (PET) have been used for the diagnosis of late seizure, as well as common epileptic seizures. Nevertheless, it is difficult to perform all of these examinations in the emergency department, because of the limitations of time and cost.

Arterial spin labeling (ASL) MRI is a non-invasive method to evaluate cerebral perfusion that does not require the administration of a contrast agent [6]. ASL has been widely used in cerebrovascular diseases [7]. Recently, the utility of ASL for the diagnosis of epilepsy has been reported [8–12]. However, the usefulness of this technique in late seizure has not been determined. The aim of the present study was to evaluate the diagnostic utility of ASL for the acute phase of late seizure after stroke.

2. Subjects and methods

Twelve consecutive patients diagnosed with late seizure after stroke between July 2011 and November 2013 were enrolled in this study. Clinical information including classification and location of stroke, and seizure symptoms observed in the clinical course were obtained from

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the medical record. Each patient underwent MRI at the time of the emergency department visit on a 1.5-Tesla unit (SIGNA, GE Medical Systems, Milwaukee, WI) with a standard quadrature head coil. Pulsed continuous ASL perfusion images with background suppression using a 3D stack of spiral fast spin echo readout [13] were obtained with the following parameters: repetition time (TR) = 4500 ms, echo time (TE) = 10 ms, and post-labeling delay = 1500 ms. The images were postprocessed in the MRI machine and cerebral blood flow maps were generated using a single tissue compartment model [14]. The emergency protocol including the following sequences was performed simultaneously: T2-weighted images (TR = 5000 ms, TE = 100 ms), fluid-attenuated inversion recovery (TR = 8000 ms, TE = 120 ms), diffusion-weighted imaging (DWI) (TR = 5850 ms, TE = 95 ms, b-values = 1000 s/mm^2), and MR angiography (time-of-flight, TR = 32 ms, TE = 2.8 ms). EEG was performed in 8 patients. This study was approved by the local ethics committee, and informed consent was obtained in compliance with the committee.

3. Results

The patients' demographic, clinical, and imaging data are summarized in Table 1. A convulsion was observed in 6 patients, and 6 others showed various neurological deficits. All patients were diagnosed with partial seizures or partial seizures with secondary generalization. Four patients showed status epilepticus, one of whom had NCSE. All patients showed hyperperfusion around the stroke lesion on ASL. Only 6 patients showed high signal intensity along the cerebral cortex around the stroke lesion on DWI. Follow-up MRI was performed in 3 patients and those findings seen in ASL and DWI were diminished (Fig. 1, Table 2). The interval between the occurrence of seizures and the first MRI scans ranged from less than 1 to 22 h, and those between the first and the follow-up MRI scans ranged from 7 to 289 days. EEG showed slow activity, but paroxysmal discharges such as spikes or sharp waves were not observed. The delay between the occurrence of seizures and EEG ranged from 21 to 167 h.

4. Discussion

ASL is a non-invasive MR technique and it clearly demonstrated ictal hyperperfusion in late seizure after stroke: this was found in all our cases.

In the present study, convulsions were not witnessed in 6 of the 12 patients. The diagnosis of these cases may be inhibitory seizure or NCSE, and the possibility of post-ictal symptoms such as Todd's palsy with overlooked convulsions should also be considered. In this study, clinical information was collected from bystanders, ambulance crews, and emergency department staff, suggesting that convulsions might have sometimes been overlooked. There may be many cases of convulsions that cannot be confirmed in the real clinical situation in this way. If convulsions are observed, it should be easy to make a diagnosis of epilepsy, but the diagnosis may be difficult in cases without confirmation of convulsions. The final diagnoses of seizure type in the present cases were all either partial seizure or secondary generalization. Accordingly, objective and highly sensitive diagnostic methods should be used for the diagnosis of epilepsy. Recently, several reports have been published on the detection of corresponding findings using ASL [8–12], although comprehensive results on late seizure are lacking. Therefore, in the present study, ASL was performed at the time of the emergency visit of patients with late seizure after stroke. Surprisingly, it was possible to confirm focal hyperperfusion leading to an accurate diagnosis of epilepsy in all cases including non-convulsive types, and appropriate therapy could be started immediately. One hundred percent of the diagnostic value of ASL for late seizure after stroke shown in this study is noteworthy in light of treatment strategy. For one thing, since recovery of Todd's palsy sometimes requires a few days [15], it is easily misdiagnosed as stroke without evidence of convulsion. In such a case, antiplatelet or anticoagulant agents possibly developing hemorrhagic side effects may be administered and untreated epilepsy may result in fatal seizures.

On MRI scans, DWI was obtained simultaneously, but high signal intensity was not confirmed in 6 of the 12 cases. DWI may demonstrate cortical high signal intensity with a corresponding low apparent diffusion coefficient throughout the affected hemisphere in partial seizures [16]. This change is reversible and is assumed to reflect intracellular water accumulation (cytotoxic edema) [17]. The utility of DWI is also reported in post-stroke seizure, but the sensitivity is not high [18], as shown in the present cases. Careful differentiation of late seizure from stroke recurrence is needed, especially in cases in which convulsions are not observed. The diagnosis of hemorrhagic stroke can be easily made by CT or MRI. On the other hand, the recurrence of ischemic stroke shows high intensity lesions on DWI, as do seizures. Therefore, the differentiation may not be easy for the general emergency physician, although the ischemic lesion involves a vascular territory, and a seizure demonstrates cortical high signal intensity.

In the present study, follow-up MRI was obtained only in 3 cases. In each case, the findings of ASL and DWI improved. The improvement of these findings may help the differentiation between late seizure and ischemic stroke.

Table 1
Demographic, clinical, and imaging data of patients.

No.	Age (y)	Sex	Classification of stroke	Location of stroke	Observed primary seizure symptoms	Seizure type	Status epilepticus	Seizure to MRI (hours)	ASL Hyper	DWI High	Seizure to EEG (hours)	EEG findings
1	73	M	AT	Right frontal	Left hemiparesis (i)	Simple partial seizure	No	3	Yes	Yes	65	Right-sided slow
2	84	M	ICH	Left frontal	Right-sided hemiconvulsion	Simple partial seizure	No	<1	Yes	No	N-E	N-E
3	86	M	CE	Left posterior	Right-sided hemiconvulsion	Secondary generalization	No	3	Yes	Yes	N-E	N-E
4	71	M	ICH	Left parietal	Sensory aphasia (i)	Simple partial seizure	No	1	Yes	Yes	21	Left-sided slow
5	64	F	CE	Left parietal	Aphasia and right hemiparesis (i)	Simple partial seizure	No	2	Yes	Yes	N-E	N-E
6	66	M	SAH	Right frontal	Unconsciousness and left hemiparesis (i)	Complex partial seizure	No	7	Yes	No	48	Right-sided slow
7	84	F	AT	Right frontal	Left-sided hemiconvulsion	Secondary generalization	No	22	Yes	No	94	Right-sided slow
8	82	M	AT	Right parietal	Left unilateral spatial neglect (i)	Complex partial seizure	Yes (n)	<1	Yes	No	46	Generalized slow
9	85	M	ICH	Left thalamus	Right-sided hemiconvulsion	Secondary generalization	Yes	14	Yes	No	N-E	N-E
10	73	F	AT	Left insula	Left-sided hemiconvulsion	Simple partial seizure	Yes	4	Yes	Yes	48	Generalized slow
11	75	M	CE	Right posterior	Unconsciousness and restlessness (i)	Secondary generalization	No	1	Yes	No	71	Right-sided slow
12	89	F	ICH	Right posterior	Left-sided hemiconvulsion	Secondary generalization	Yes	<1	Yes	Yes	167	Left-sided slow

MRI, magnetic resonance imaging; ASL, arterial spin labeling; Hyper, hyperintensity; DWI, diffusion weighted image; High, high signal intensity; EEG, electroencephalogram; CE, cardioembolism; ICH, intracerebral hemorrhage; AT, atherothrombosis; SAH, subarachnoid hemorrhage; N-E, not examined; i, inhibitory seizure; n, non-convulsive status epilepticus.