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Localisation value of ictal arterial spin-labelled sequences in partial seizures

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ABSTRACT – Perfusion-based magnetic resonance imaging (MRI) using pulsed arterial spin-labelled (ASL) sequences is becoming a more commonly used tool for the diagnosis of patients with focal epilepsy. We report a patient with post-traumatic epilepsy and cortical haemorrhage who had a complex partial seizure characterised mainly by ictal speech (verbalisation) during MRI acquisition. Ictal ASL showed focal hyperperfusion over the right temporal region which had resolved on follow-up MRI, two weeks later. Seizure semiology and interictal EEG suggested seizure origin in the non-dominant temporal lobe, which matched the increased ictal blood flow observed by ASL. The patient had language dominance in the left hemisphere, as observed by functional MRI. Our findings suggest that focal hyperperfusion, as observed by ASL, may have localising value in temporal epilepsies when performed in the ictal period.

Key words: epilepsy, ictal MRI, perfusion-based MRI, temporal lobe epilepsy, ictal verbalization

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Magnetic resonance imaging (MRI) is the imaging modality of choice for detecting structural lesions in patients with epilepsy. In addition, dynamic and functional MRI sequences are becoming a field of interest in epilepsy research as a tool for epileptogenic zone localisation. Studies describing ictal perfusion changes during single seizures are scarce, probably due to the lack of availability of MRI studies obtained in the ictal phase (Pizzini *et al.*, 2008). This case report describes the ictal perfusion changes demonstrated by means of pulsed arterial spin-labelled (ASL) sequences during a complex partial seizure with ictal speech.

Case study

A 37-year-old right-handed man suffered cranio-encephalic trauma with loss of consciousness for approximately one hour. An emergency cerebral computed tomography (CT) scan performed three hours after the traumatic brain injury showed diffuse microbleeding spots in the right fronto-temporal

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region. After recovering, a neurological examination was unremarkable except for a short-term amnesic deficit that persisted for more than 48 hours. The patient was discharged from the hospital seven days after the trauma with post-traumatic short-term memory deficit and mild depressive disorder.

Three months after the trauma, the patient developed two types of seizure: one with loss of awareness and inappropriate language production; and another characterised by a non-specific psychic aura followed by headache, ocular rolling movement, and subsequent loss of consciousness with ictal speech and left-hand dystonic posturing. These spells were followed by a prolonged postictal period with confusion and intense fatigue. Ictal verbalisation was defined as identifiable speech which was inappropriate for the time and situation. Seizure duration varied from one to three minutes. Furthermore, the patient started experiencing frequent seizures.

The patient was started on oxcarbazepine, 300 mg twice a day after the first seizure. Despite antiepileptic therapy, he continued having seizures once every two weeks. The patient underwent continuous video-EEG monitoring for 72 hours which showed interictal right temporal slow waves and occasional spike-and-wave activity (with an average of one discharge/10 minutes) over the right posterior temporal region (maximum T6), present at awake and sleep stages I-II. No seizure was captured in the video-EEG recording.

Three months after the trauma, a 3.0 T MRI (Siemens Magnetom Trio., Iselyn, NJ) examination was performed including T1 and T2 fluid-attenuated inversion recovery (FLAIR) and diffusion-weighted images (b value of 1,000). Susceptibility-weighted images (SWI) and pulsed ASL were also obtained.

Structurally, chronic diffuse punctiform hemosiderin deposits over the right fronto-parietal region were seen exclusively on SWI while the ASL showed an increase in the relative cerebral blood flow (rCBF) over the right posterior temporal region *(figure 1)*. Approximately one minute after the onset of ASL acquisition, the patient started having one of his typical seizures characterised by a confused state, ictal speech and hand automatisms. When ASL acquisition was complete, the MRI study was stopped as the patient started to move in the scanner.

Follow-up MRI using the same scanning protocol was performed two weeks later when the patient had been

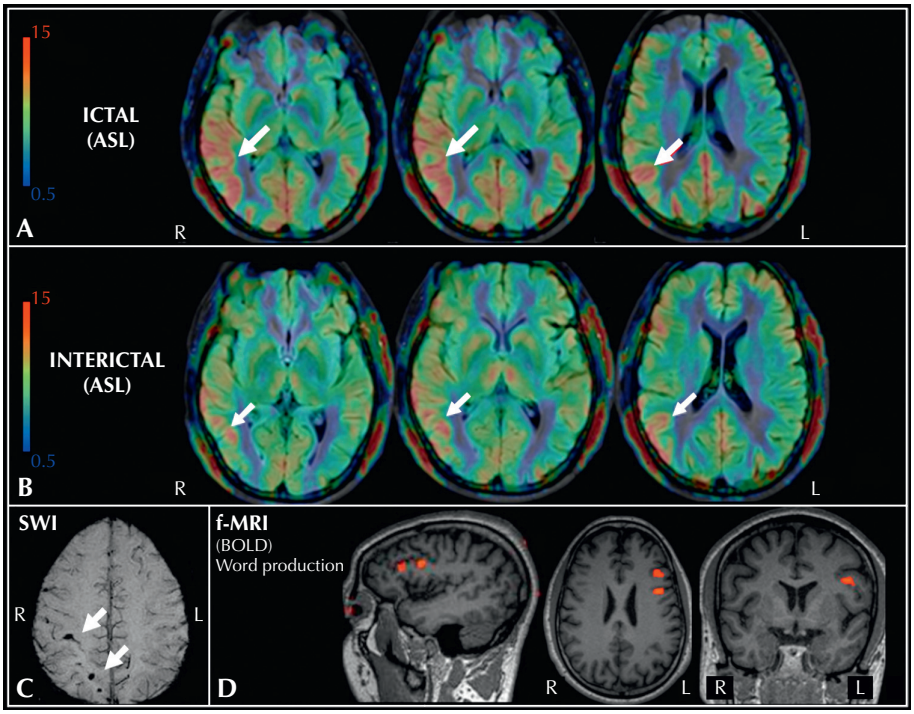

Figure 1. MRI study: The "hot" colours (red) seen in the arterial spin-labelled (ASL) co-registered with fluid attenuated inversion recovery (FLAIR) sequence (**A**) are representative of the higher relative cerebral blood flow observed in the region of interest (arrows) of the right temporal lobe in the ictal ASL map (12.1 L/100 gr/min) as compared with the contralateral side (10.8 L/100 gr/min), and to the same localisation in the interictal MRI (11.1L/100 gr/min) (**B**). Reference colour scales are on the left side. Susceptibility weighted imaging shows small hemosiderin deposits in the right postcentral sulcus (**C**). f-MRI (Blood Oxygen Level Dependent [BOLD] fused with MPRAGE 3D) showed left opercular activation during the word generation paradigm (**D**). R: right; L: left.

asymptomatic for more than 24 hours. Measurements of rCBF were performed during ictal and follow-up MRI. We placed the region of interest (ROI) over the grey matter of both temporal lobes in the same anatomical position in the ictal and interictal MRI studies. We found that the ratio of rCBF between the ROIs in the right temporal and left temporal lobe was higher for the ictal ASL (1.3) than for the follow-up MRI (1.1) *(figure 1)*.

Functional MRI (with blood oxygen level dependent [BOLD] sequences) was also performed in the follow-up to determine which cerebral hemisphere was language dominant, using the simple word generation FAS language paradigm. This paradigm is performed to activate the language production areas and is conducted by asking the patient to think of words starting with the letter "F", then "A" and finally "S". During the word task, an increased signal was seen over the left opercular frontal region suggesting that the patient had language dominance in the left hemisphere *(figure 1)*.

Diffusion-weighted imaging was normal in both the ictal and interictal studies.

Discussion

We report the ictal haemodynamic MRI findings observed during a complex partial seizure of probable right temporal origin. Time serial MRIs indicated that increased focal rCBF, as observed by ASL, in the periictal period may have localising value in temporal lobe epilepsy.

Seizures with ictal verbalisation arise from the non-dominant temporal lobe in 83% to 90% of cases according to previous findings which utilised video-EEG analyses (Horvath *et al*., 2009). This fact is especially reliable in cases of left hemisphere language dominance (Arora *et al*., 2009). Although we did not observe any seizures during the video-EEG monitoring in our studies, the ictal semiology characterised by language production and the interictal epileptiform activity seen over the right posterior temporal lobe suggests that our case is consistent with right temporal lobe epilepsy (Lüders *et al*., 1998; Horvath *et al*., 2009).

Pulsed ASL is a non-invasive and non-gadolinium-dependent method of measuring the rCBF. ASL has been applied in different clinical settings (stroke, tumours or dementia) as a perfusion-MRI based measure (Arfanakis *et al*., 2002). ASL imaging acquisition is based on relative signal differences between magnetised arterial CBF and control with non-magnetized blood. Sequences are measured using echo-planar imaging (EPI) BOLD T2 images. Sequence acquisition time for the entire brain is around four minutes (using 8 mm slice thickness and a 3 mm gap between slices). Finally, ASL results (cerebral blood volume or flux map) are co-registered with FLAIR sequences.

Ictal hyperperfusion is commonly used to localise hypermetabolic areas associated with epileptogenic zones by using the combined single photon emission computed tomography (SPECT)-MRI (Wolf and Detre, 2007). However, reports on haemodynamic or functional MRI changes during seizures are scarce as this technique presents multiple limitations for acquiring images in the periictal period (Pizzini *et al*., 2008).

Focal interictal perfusion abnormalities shown with ASL sequences resemble a good marker for epileptogenic focus localisation according to some authors (Arfanakis *et al*., 2002). One of the present issues is that ictal MRI studies in epilepsy are almost all limited to non-convulsive status epilepticus. Additionally, these studies in non-convulsive status epilepticus have shown that focal increased rCBF has no localisation value, probably due to propagation phenomena of the prolonged epileptiform activity (Szabo *et al*., 2005; Toledo *et al*., 2008). However, in our case we observed an increased blood flow over the non-dominant temporal lobe which correlated well with the presumed area of seizure origin. This result suggests that focal ictal hyperperfusion may have localising value for single seizures in the ictal period.

Currently, 3.0 T MRI provides clinically relevant data for the diagnosis of patients with epilepsy. Cortical anatomical abnormalities, such as cortical dysplasias or tumours, are more likely to be diagnosed using high magnetic fields with dedicated protocols. Post-traumatic brain injury was detected in our study only using SWI (Knake *et al*., 2005). Therefore, our patient could be diagnosed with post-traumatic symptomatic epilepsy.

Interictal hyper- or hypo-perfusion has previously been described relating to the epileptic focus when ASL imaging is used in patients with epilepsy (Wolf and Detre, 2007; Pizzini, *et al*., 2008). This variability depends on the frequency of the interictal epileptiform activity; the higher the interictal epileptiform activity, the higher the focal perfusion (Wolf and Detre, 2007). In our ictal study, we found relevant differences between the blood flow of the ROI and the contralateral side. Differences were also observed when the rCBF of the ROI in the ictal MRI was compared to the same region in the interictal study.

There have been very few reported studies using ictal ASL; most previous ictal perfusion MRI studies in single seizures were immediately postictal (Pizzini *et al*., 2008). One of the advantages of our study is that our patient started a seizure while the ASL acquisition was on-going, therefore making our study an ictal MRI study.

This report suggests that ictal high-field MRI using ASL can be a useful technique to assess the location of the seizure source in focal epilepsies. However, further trials and experience in ictal and interictal imaging with ASL are necessary to determine its reliability as a localising method (Arfanakis *et al*., 2002). □

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