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Case Report

Neuroimaging Findings in Patients with Status Epilepticus: The Role of Diffusion and Perfusion Imaging

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Abstract

Status epilepticus may have long-term consequences, including neuronal injury. Some patients with status epilepticus have neuroimaging findings, including cytotoxic and vasogenic edema, abnormal signal intensity on T1-weighted, T2-weighted, and the T2 fluid-attenuated inversion recovery images, and perfusion abnormalities. The prognosis of these findings is unclear; they might be associated with de novo epilepsy and poor prognosis. In this report, we describe the clinical, electroencephalographic and the magnetic resonance, and the computerized tomographic perfusion findings in 4 patients with status epilepticus and emphasize the variable characteristic of the imaging findings, the correlation of the clinical and electroencephalography findings with magnetic resonance image lesions, and the key features to differentiate these lesions from vascular lesions.

Keywords: Status epilepticus, magnetic resonance imaging, diffusion-weighted imaging, perfusion imaging

INTRODUCTION

Status epilepticus (SE) is a neurological emergency that may result in dis ability and death due to exitotoxic injury.[1,2] Cases with reversible and irreversible magnetic resonance image (MRI) findings associated with SE have been reported to date.[3,4] The aim of this article is to describe the MRI abnormalities and their correlation with the clinical and the electroencephalography (EEG) findings in 4 patients with SE. Detailed laboratory investigations for infectious, inflammatory, autoimmune, vascular, and mitochondrial disorders as well as prion diseases were performed in all patients, resulting in no abnormal findings. Brain MRI scans including T1-weighted, T2-weighted, and T2 fluid-attenuated inversion recovery (FLAIR) images, diffusion-weighted images (DWIs), and apparent diffusion coefficient (ADC) images were obtained in all patients.

CASE PRESENTATIONS

Case 1

A 45-year-old male patient with a history of epilepsy was admitted to the emergency department (ED) with frequent generalized onset motor tonic–clonic seizures (GTCs). The patient had been on oral levetiracetam. On admission, he was unresponsive, and an EEG showed continuous, rhythmic electrographic seizure activity that has higher amplitude on the right occipital electrodes (Figure 1A). A brain MRI showed restricted diffusion in the bilateral parietooccipital lobes with hyperintense signal changes on the FLAIR images (Figure 1B-D). He was treated with intravenous (IV) levetiracetam and oral topiramate with clinicoelectrographic improvement after 15 minutes of clinical seizure activity. As the patient had been admitted with frequent clinical seizures without regaining consciousness between them, we do not know the exact duration of the SE. A repeated brain MRI obtained 3 weeks later showed the complete resolution of the MRI findings (Figure 1E and F).

Case 2

An 18-year-old female patient with a history of cerebral palsy was taken to the ED of our hospital for frequent GTCs. She did not have a history of epilepsy. The patient was transferred to the neurointensive care unit (NICU). The EEG showed generalized spike and sharp waves (Figure 2A). Her brain MRI showed restricted diffusion in the bilateral frontal and parietal lobes and the insular cortices (Figure 2B-E). She was treated with IV diazepam and levetiracetam, and no further clinical seizures were observed. The duration of SE in our hospital was half an hour; however, the patient had been reported to have GTCs for at least a few hours before admission. A repeated brain MRI could not be obtained.

Case 3

A 37-year-old female patient with a history of recurrent major depressive episodes became unresponsive with diaphoresis and tachycardia (focal impaired awareness autonomic seizures) while being managed in the psychiatry inpatient ward. The patient did not have a history of epilepsy. On examination, the patient was unresponsive. An EEG showed frequent generalized semi-rhythmic sharp waves (Figure 3A). Her brain MRI showed hyperintense signal changes in the bilateral insular cortices and the pulvinar thalami on the DWIs and the FLAIR images without apparent signal

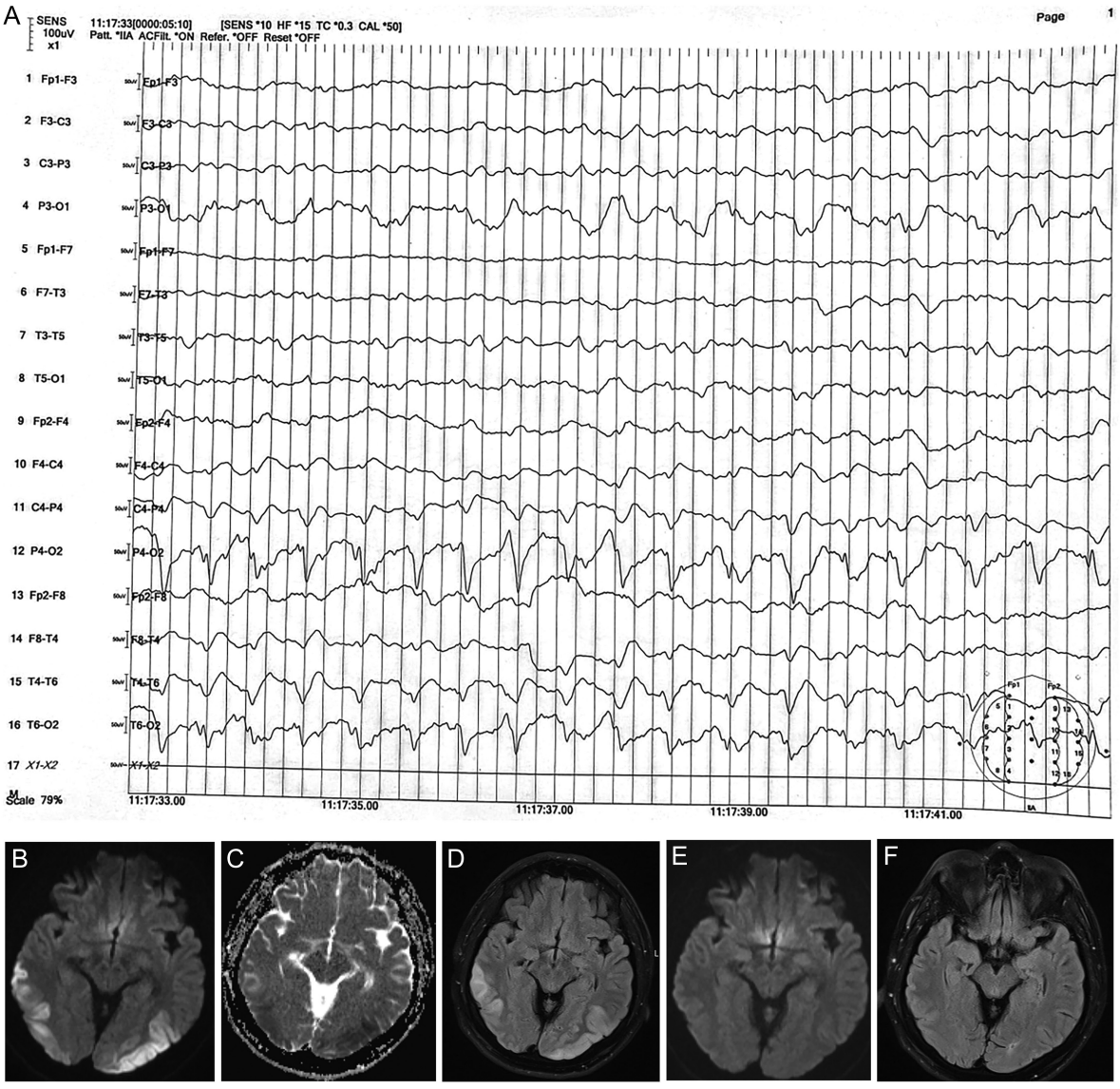

Figure 1. Case 1. (A) The electroencephalogram showing continuous, rhythmic electrographic seizure activity that has higher amplitude on the right occipital electrodes. (B-F). Brain MRI. (B) Axial DWI showing hyperintense signal changes in the bilateral parietoocipital lobes. (C) Axial ADC image showing hypointense signal changes in the bilateral parietoocipital lobes, indicating cytotoxic edema. (D) Axial FLAIR image showing hyperintense signal changes in the bilateral occipital lobes. (E, F) A repeated brain MRI. (E) Axial DWI. (F) Axial FLAIR images are normal, indicating the complete reversibility of the signal changes. ADC, apparent diffusion coefficient; DWI, diffusion-weighted image; FLAIR, fluid-attenuated inversion recovery; MRI, magnetic resonance imaging.

MAIN POINTS

- Variable magnetic resonance imaging alterations may be seen in patients with status epilepticus, including cytotoxic and vasogenic edema, signal changes on T1-weighted, T2-weighted and T2 fluid-attenuated inversion recovery images, gyral swelling, and cerebral hyperperfusion.
- In patients without a history of epilepsy or convulsive seizures, these findings may pose a diagnostic challenge for clinicians. Therefore, it is important to differentiate these findings from those of infectious, inflammatory, mitochondrial, and vascular disorders.
- The combined use of diffusion and perfusion imaging and electroenc ephalography findings may serve as variable diagnostic tools in these circumstances.

changes on the ADC images (Figure 3B-E). The patient was treated with IV diazepam and phenytoin. The treatment was unsuccessful and the patient was transferred to the NICU for continuous thiopental and midasolam infusion. A complete clinicoelectrographic improvement was obtained after the treatment which lasted for 48 hours. A repeated brain MRI obtained 2 weeks later revealed the resolution of the abnormalities (Figure 3F and G).

Case 4

An 18-year-old female patient with a history of febrile convulsions was taken to the ED for drowsiness during the last few days. The patient did not have a history of previous seizures except febrile convulsions. She had had infrequent episodes of headache and speaking difficulty followed by drowsiness for years. On admission, the patient was drowsy, and no convulsive seizure was observed. The diagnosis of

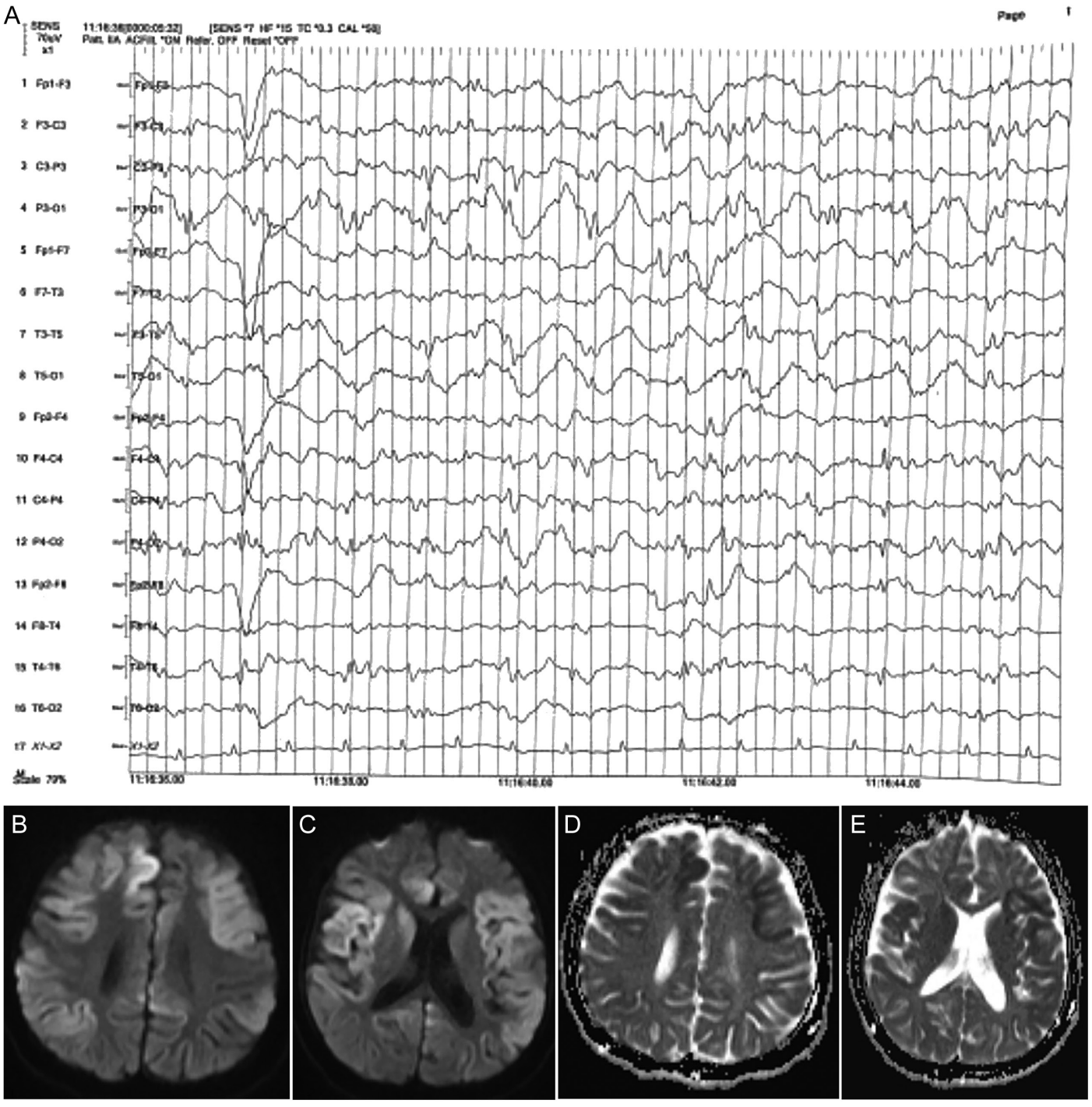

Figure 2. Case 2. (A) The electroencephalogram showing generalized spike and sharp waves. (B-E) Brain MRI. (B). Axial DWI showing hyperintense signal changes in the bilateral frontal and the parietal lobes. (C) Axial DWI showing hyperintense signal changes in the bilateral temporal and the insular cortices. (D) Axial ADC showing hypointense signal changes in the bilateral frontal and the parietal lobes, indicating cytotoxic edema. (E) Axial ADC showing hypointense signal changes in the bilateral temporal and the insular cortices, indicating cytotoxic edema. ADC, apparent diffusion coefficient; DWI, diffusion-weighted image; MRI, magnetic resonance imaging.

focal impaired awareness behavior arrest seizures was made. An EEG showed frequent sharp waves in the left hemisphere, with higher amplitude on the frontotemporal electrodes (Figure 4A). The patient was treated with oral valproic acid. During her follow-up, she became unresponsive. A repeated brain MRI revealed widespread signal changes in the bilateral frontal, temporal, and the parietal lobes as well as on the bilateral insular cortices (Figure 4B-G). A computerized tomographic perfusion imaging of the brain showed hyperperfusion (Figure 4H-J). The patient was transferred to the NICU to be treated with IV diazepam and levetiracetam. After the treatment, the responsiveness of the patient gradually improved. The duration of the SE was estimated to be 4 hours. A repeated brain MRI could not be obtained.

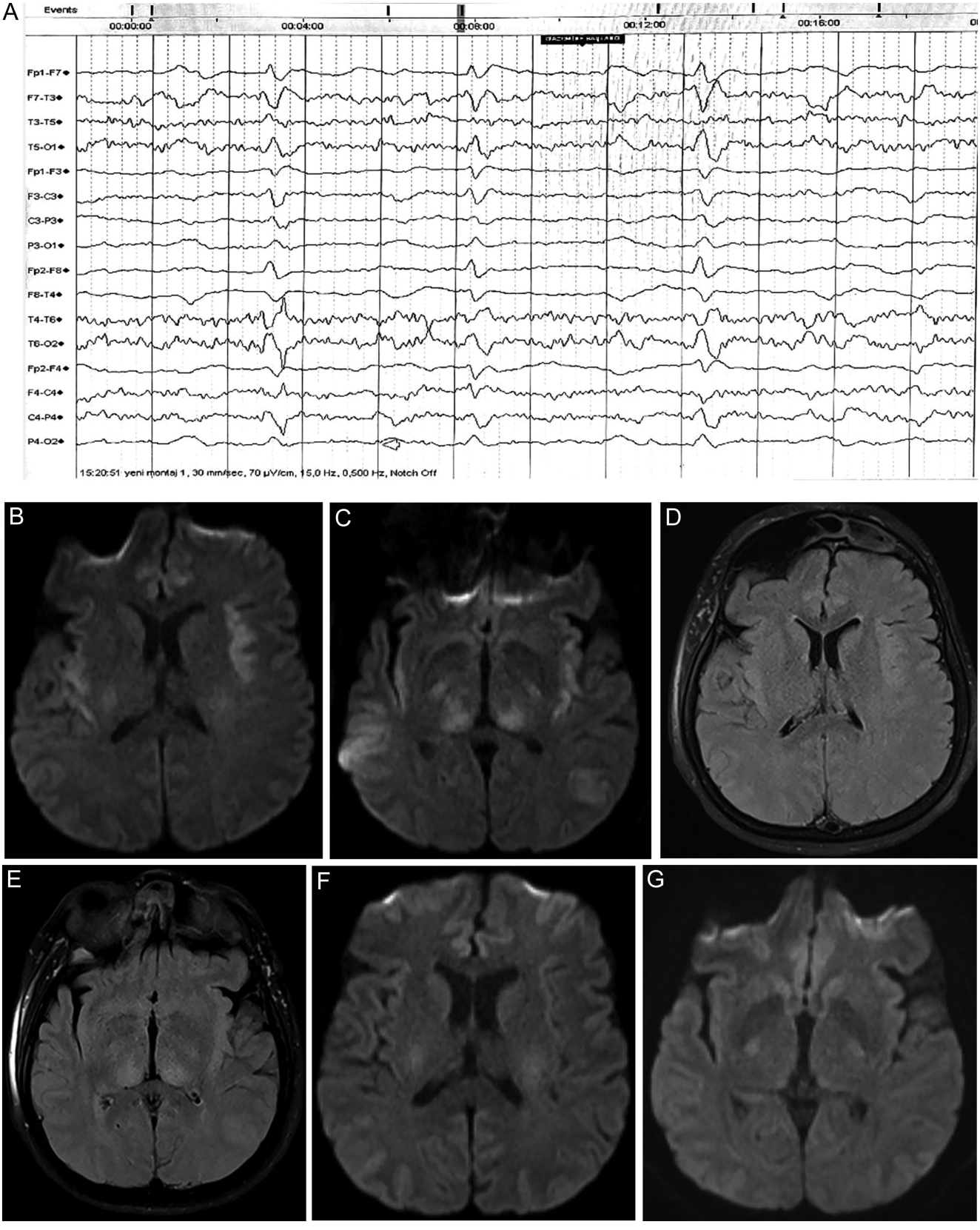

Figure 3. Case 3. (A) The electroencephalogram showing frequent generalized semi-rhythmic sharp waves. (B-G) Brain MRI. (B, C) Axial DWI showing hyperintense signal changes in the bilateral insular cortices and the pulvinar thalami. (D, E) Axial FLAIR image showing hyperintense signal changes in the bilateral insular cortices and the pulvinar thalami. (F, G) A repeated axial DWI showing the resolution of the abnormalities. DWI, diffusion-weighted image; FLAIR, fluid-attenuated inversion recovery; MRI, magnetic resonance imaging.

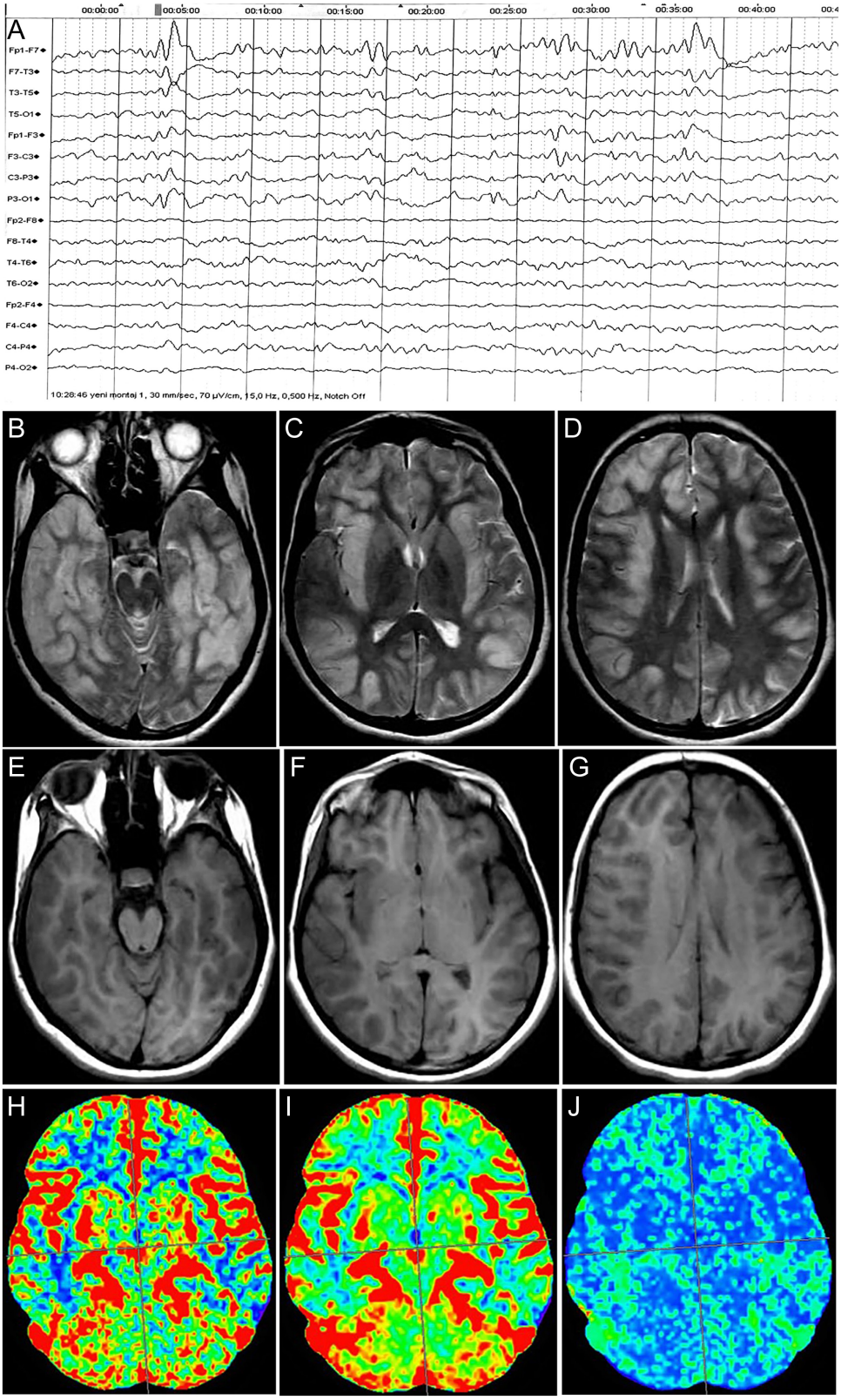

Figure 4. Case 4. (A) The electroencephalogram showing frequent sharp waves in the left hemisphere, with higher amplitude on the frontotemporal electrodes. (B-G) Brain MRI. (B-D) Axial T2-weighted image showing hyperintense signal changes in the bilateral frontal, temporal, and the parietal lobes and the insular cortices. (E-G) Axial T1-weighted image showing hypointense signal changes in the bilateral frontal, temporal, and the parietal lobes and the insular cortices. (H-J) A CTPI of the brain showing increased cerebral blood flow (CBF) and cerebral blood volume (CBV) and decreased mean transit time (MTT), indicating cerebral hyperperfusion. The cross-sectional images of the CTPI were chosen to correspond to the most prominent signal changes on the brain MRI. CTPI, computerized tomographic perfusion imaging; MRI, magnetic resonance imaging.

DISCUSSION

We reported the MRI changes attributable to SE in 4 patients with complex partial and generalized tonic–clonic SE. To date, several case series and retrospective studies have reported variable MRI changes, both reversible and irreversible, associated with SE. Diffusion-weighted images are the most sensitive MRI techniques; both vasogenic and cytotoxic edema have been reported.[3-6] All of our patients had abnormal signal intensity on the DWIs; 2 of them had also decreased signal intensity on the ADC, indicating cytotoxic cerebral edema.

The question of why there is cytotoxic edema in some patients and vasogenic edema in other patients has not been fully answered yet; some authors suggest that these 2 types of cerebral edema represent a continuum of a pathological cascade, depending on the timing of MRI acquisition.[7] In pilocarpine-induced SE rat model, ADC was found to increase in the acute phase of SE and gradually decrease after 30-120 minutes.[8]

The pathogenesis of cerebral edema associated with SE differs from acute ischemic stroke. The reversibility of cytotoxic edema is a common finding in SE contrary to acute stroke.[5] The proposed mechanism of diffusion restriction in SE is the mismatch between increased glucose utilization due to prolonged seizure activity and cerebral blood flow, causing a blood flow supply–metabolism uncoupling, whereas in acute stroke the cessation of the blood flow is the cause.[9] Perfusion imaging (PI) findings support this idea, showing a seizure-induced compensatory hyperperfusion in patients with SE; on the contrary, acute stroke is characterized by regional hypoperfusion.[5,10,11] Perfusion imaging has been shown to have a high diagnostic accuracy (a positive predictive value of 93.75% and a negative predictive value of 69.23%) for diagnosis of SE.[10] We performed computerized tomography perfusion in 1 of our patients (Case 4), and the findings indicated seizure-induced hyperperfusion. Combined use of DWIs and PI imaging may serve as a valuable diagnostic tool in patients with SE.

The signal changes due to SE usually have a cortico-subcortical distribution; gyral swelling is a common finding.[3,4] The mesolimbic structures, the pulvinar nuclei, the splenium of the corpus callosum, the insular cortex, the claustrum, and the contralateral cerebellum are the cerebral regions which have been reported to be preferentially affected.[4,7,9,12] These changes localize with the epileptic focus or the remote regions functionally connected to the epileptic focus.[3,4] Focal EEG findings, including periodic lateralized epileptiform discharges (PLEDs), correspond to the local cortical MRI changes as in our Case 1.[4] Although Rennebaum et al[13] reported that patients with peri-ictal DWI abnormalities always had unilateral EEG patterns, mainly PLEDs, 2 of our cases did not have regional epileptiform changes; yet they had widespread DWI signal changes. In addition, Case 4 had localized EEG findings but widespread MRI changes.

The prognosis of patients with neuroimaging abnormalities associated with SE is unclear.[9] Some authors suggest that cytotoxic edema is associated with poor prognosis; others disagree, stating that if cessation of seizures is accomplished, it is not associated with unfavorable outcomes.[5,14,15] Canas et al[3] reported that almost one-third of patients with SE and MRI abnormalities had neurological deficits and almost half of them developed de novo epilepsy. However, in their cohort, there were some confounding factors such as the inclusion of patients with previous epilepsy and structural brain lesions, which may affect long-term prognosis.[3]

In conclusion, variable neuroimaging abnormalities, including cytotoxic and vasogenic edema, FLAIR abnormal signals, and perfusion abnormalities can be seen in patients with SE. Diffusion restriction not respecting vascular territories, hyperperfusion, frequent involvement of the mesial temporal structures as well as the pulvinar thalami and the reversibility of the abnormalities are clues for proper diagnosis. The prognosis is variable.

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