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Case Report

Periodic Slow Waves Presenting as Ictal Electroencephalography Findings in Complex Partial Status Epilepticus

Daisuke Yasugi[a] Takeshi Sasaki[a] Go Taniguchi[b]

[a]Department of Psychiatry, Tokyo Metropolitan Health and Medical Treatment Corporation Toshima Hospital, Tokyo, Japan; [b]Department of Neuropsychiatry, The University of Tokyo Hospital, Tokyo, Japan

Keywords
Periodic discharge · Nonconvulsive status epilepticus · Electroencephalography · Slow wave

Abstract
The diagnosis of nonconvulsive status epilepticus (NCSE) largely relies on electroencephalography (EEG) findings, but the existing diagnostic criteria for EEG results are sometimes inconsistent. Much debate has centered on periodic epileptic discharges (PEDs) and their relationship with seizures. The recently published Salzburg Consensus Criteria for diagnosis of NCSE, which consider PEDs to be ictal findings under several conditions, have been proven to have high diagnostic accuracy. However, the criteria do not include periodic slow waves (PSWs) and do not consider these as overall ictal electrographic changes. Here, we report 2 cases of complex partial status epilepticus in which routine EEG showed PSWs without epileptiform activity during the clinical ictal phase. Both patients were elderly males who had histories of seizures and presented with impaired consciousness and signs such as aphasia or tongue automatism that indicated a temporal lobe origin. After we administered antiepileptic drugs (AED), the clinical signs and periodic EEG slow waves disappeared. These cases show that PSWs may appear as ictal electrographic changes in NCSE. When PSWs accompany clinical signs suggestive of NCSE, they should be considered ictal findings, and physicians should administer AED.

KARGER

Daisuke Yasugi
Department of Psychiatry
Tokyo Metropolitan Health and Medical Treatment Corporation Toshima Hospital
33-1, Sakae-cho, Itabashi-ku, Tokyo 173-0015 (Japan)
E-Mail yasugi-psy@umin.ac.jp

Introduction

Nonconvulsive status epilepticus (NCSE) is commonly defined as a prolonged epileptic state associated with impaired consciousness and behavioral or mental changes but no prominent convulsions [1, 2]. Electroencephalography (EEG) findings are therefore critical for diagnosing NCSE because of the paucity of specific manifestations [3].

Periodic epileptic discharges (PEDs) have been a major issue in EEG interpretation for NCSE, because PEDs can be caused by heterogeneous factors and are thought to saddle the borderlands of epilepsy and encephalopathy, as well as between ictal and interictal states. Over the last 2 decades, several EEG criterions to diagnose NCSE were developed, but these were nonstandardized and were often used inconsistently [1, 2, 4–7]. A set of standardized consensus criteria, the Salzburg Consensus Criteria for the diagnosis of NCSE (SCNC), was developed by a panel of experts at the 4th London-Innsbruck Colloquium on status epilepticus in 2013 [3]. Leitinger et al. [8] subsequently proved, in a multi-center study, that SCNC has high diagnostic accuracy and an excellent inter-rater agreement.

Although SCNC include PEDs (spikes, poly spikes, sharp waves, sharp- and-slow-wave complexes) at ≤2.5 Hz under several conditions, SCNC has never referred to periodic slow waves (PSWs) as ictal findings for NCSE. Here, we describe 2 patients with complex partial status epilepticus (also called focal NCSE with impaired consciousness using the of International League Against Epilepsy terminology [9]) whose routine EEG recordings showed PSWs without epileptiform discharges during the ictal phase.

Case Presentation

Case 1

A 62-year-old male who had been hospitalized at an alcoholism rehabilitation center for 2 months was confused and experienced difficulties in communicating after vomiting one morning. He remained confused and continued vomiting through to the evening, when he was transferred to our hospital's neurology unit. His wife reported that he had histories of subarachnoid hemorrhage and hemorrhagic infarction of the left middle cerebral artery within the last 2 years. These events had caused mild right-side hemiparesis and mild aphasia. She also reported that he had experienced a tonic-clonic seizure 1 year ago and had been prescribed levetiracetam (500 mg/day) for several months.

At admission, he initially looked alert but could speak only a few words. He also showed mild right-side hemiparesis. Head magnetic resonance imaging revealed T1-isointensity/T2-hyperintensity of the perisylvian cortex and white matter that suggested chronic hemorrhage. The physician suspected a recurrent infarction in the left middle cerebral artery area and prescribed anticoagulants and levetiracetam (1,000 mg/day) to prevent post-stroke seizures. On day 2, his speech recovered, but he exhibited frequent verbal paraphasia. He also exhibited confused behavior, so he was referred to a consultation-liaison psychiatrist. The EEG recordings on day 4 were dominated by low-voltage, diffuse, and irregular 1- to 3-Hz delta-band activity. However, the recordings also revealed periods of several seconds that contained left-parietal dominant, low-voltage, periodic (~1 Hz), 5-Hz theta waves. No sharp waves or spikes were observed (Fig. 1). No benzodiazepine was administered intravenously during the EEG recording because NCSE was only suspected after detailed interpretation of the EEG recordings. After the EEG interpretation on the same day, the psychiatrist increased the levetiracetam dose to 2,000 mg/day immediately.

On day 6, the patient showed dramatic improvements in his aphasia, such that only mild difficulties in word recall remained. On day 10, EEG recordings showed a right-dominant, low-voltage, 9-Hz alpha rhythm and occasional low-voltage, 4- to 5-Hz theta waves in the left hemisphere. No sharp waves or spikes were apparent. His wife reported that he had returned to normal, and he was returned to his original facility on day 13.

Case 2

A 62-year-old male in a psychiatric facility had been unresponsive for 2 days following a tonic-clonic seizure. He was transferred to our hospital after producing bloody vomit. He had a 30-year history of schizophrenia with frequent hospitalizations and had been admitted to a psychiatric hospital 4 years earlier. He also had a 2-year history of poorly described generalized seizures and had been prescribed levetiracetam (2,000 mg/day) after an attempt to prevent seizures by reducing his doses of antipsychotics and valproate (blood concentration: 80–100 μg/mL) had failed.

According to the referral letter, after the tonic-clonic seizure, he had been nearly stuporous, vocalized nonsensical words, and repeatedly protruded his tongue. During admission to our hospital, he repeated a few meaningless words and answered "museum" when asked where he was. Furthermore, he exhibited stereotyped behaviors such as tongue protrusion and throwing his arms into the air. Head magnetic resonance imaging revealed no significant abnormalities, and EEG recordings revealed diffuse 3- to 4-Hz delta activity and rare sharp waves that were most prominent in the right central and parietal regions (Fig. 2).

Despite the diagnosis being undecided, phenytoin (250 mg/day) was administered intravenously on day 1. On day 2, no significant changes were observed in the morning, but in the afternoon, he briefly showed improved responsiveness after a 10-mg bolus injection of diazepam for a gastroscopy. The postgastroscopy EEG recordings were dominated by diffuse and irregular 3- to 4-Hz slow waves but also revealed several series of diffuse periodic (~1 Hz) theta waves that lasted for 10–20 s (Fig. 3). No epileptiform discharges were seen. During this recording, additional diazepam was administered intravenously, and the patient exhibited stereotyped behaviors such as lip pouting and tongue protrusion after an initial 10-mg bolus. However, these movements and the EEG slow waves disappeared after a subsequent 10-mg bolus (Fig. 4). Seven hours after the gastroscopy, diazepam (30 mg) and fosphenytoin (6 mg/kg/day) were started following a 22-mg/kg fosphenytoin bolus dose.

On day 4, he became aware of his environment, but he presented verbal perseveration and registration deficits over the next several days. With gradual improvements, he became completely alert and attentive without speech problems by day 16. EEG recordings on day 20 revealed an occipital-dominant alpha rhythm accompanied by occasional low-voltage diffuse slow waves and rare positive sharp waves in the right hemisphere, but the periodic discharges had disappeared. On day 27, he was returned to his original institution.

Discussion

Periodicity and slow-wave activity have been controversial issues in the EEG-based diagnosis of NCSE. Although it has been difficult to use slow-wave activity to distinguish NCSE from other conditions, such as toxic-metabolic encephalopathy, rhythmic delta activity has been recognized as an ictal and interictal finding of temporal lobe epilepsy since the 1950s and was recently reported to manifest as an ictal finding of NCSE [2, 10]. On the other hand, PEDs have

been well studied as a boundary area between ictal and peri-ictal states [1, 11] and are regarded as ictal findings in some NCSE criteria. PEDs (spikes, poly spikes, sharp waves, sharp-and-slow-wave complexes) at ≤2.5 Hz or rhythmic delta/theta activity (>0.5 Hz) are included in SCNC when patients also present one of the following: EEG and clinical improvement after intravenous administration of antiepileptic drugs (AED), subtle clinical ictal phenomena during the EEG patterns mentioned above, or typical spatiotemporal evolution [3]. Although SCNC are flexible recommendations and allow for exceptions [3], PSWs are not explicitly recognized as criteria and have scarcely been studied. Although an early study did report PSW complexes in children with subacute sclerosing panencephalitis, it did not investigate the relationship between PSW and seizures [12]. Recently, however, a large cohort study of critically ill neurological patients investigated the relationship between periodic EEG patterns of 'ictal-interictal uncertainty' and electrographic seizures and suggested that periodic patterns were highly predictive of electrographic seizures [13]. There are no previous reports of patients with NCSE who presented PSWs as the only ictal EEG changes.

The 2 patients in this report showed PSWs in scalp EEG recordings without apparent epileptiform discharges during the clinical ictal phase. They also exhibited some signs indicative of NCSE, such as prolonged confused states, aphasia, and stereotyped behaviors. Both the signs and EEG findings were ameliorated with AED, which strongly suggests that the signs were of epileptic origin and that the PSWs reflected ongoing epileptic brain activity.

These PSWs are subtle and might not have been specific etiological findings. Rather, they might have just been electrically attenuated or deformed patterns of deep-lesion epileptic discharges that the intracranial EEG could have detected [14]. Furthermore, obvious epileptiform discharges might have been detected if the EEG had been recorded continuously [15]. Nevertheless, the clinical significance of PSWs in standard scalp EEG should be investigated, because many patients with NCSE do not present to neurological settings where intracranial or continuous EEG recordings can be performed.

Conclusion

SCNC should be used to diagnose NCSE as these are standardized and proven criteria and have been proven useful for clinical application. Nevertheless, some periodic patterns remain uncertain findings.

In the presence of signs of NCSE such as a previous history of seizures or subtle motor signs, PSWs in routine EEG recordings could be electrographic signs of ongoing seizures for which rapid AED administration is worth attempting.

Statement of Ethics

The patients provided written informed consent for the publication of this report.

Disclosure Statement

The authors declare that they have no conflicts of interest.

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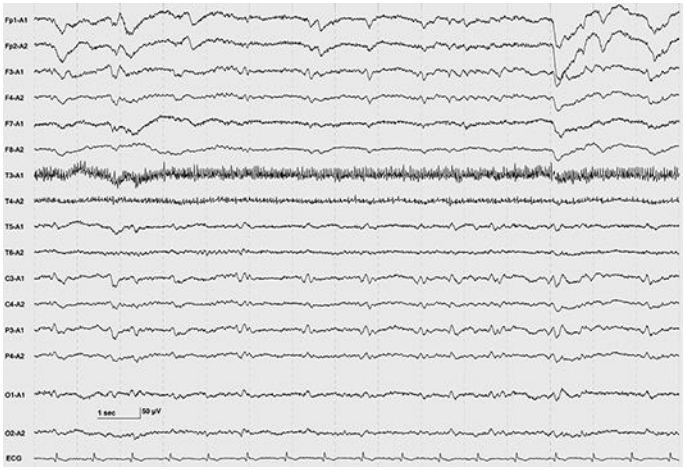

Fig. 1. EEG recordings of Patient 1, during the clinical ictal phase. Anteriorly dominant, low-voltage, periodic (~1 Hz) theta waves were observed. No epileptic discharges were recorded. Electrode coordinates are based on the international 10–20 system.

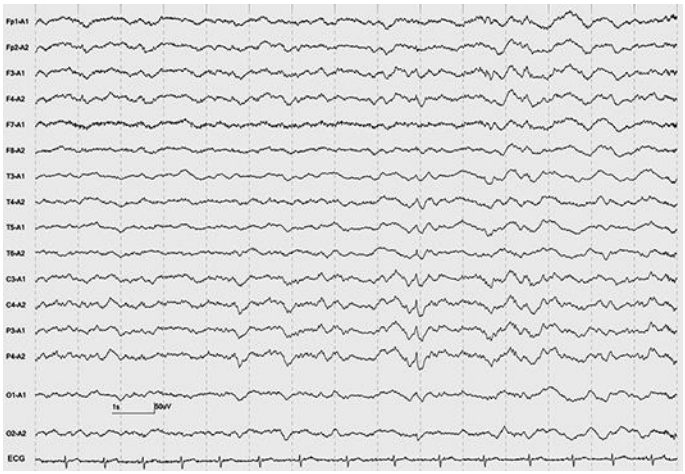

Fig. 2. EEG recordings of Patient 2 on day 2. These revealed diffuse 3- to 4-Hz delta activity and rare sharp waves that were most prominent in the right central and parietal regions.

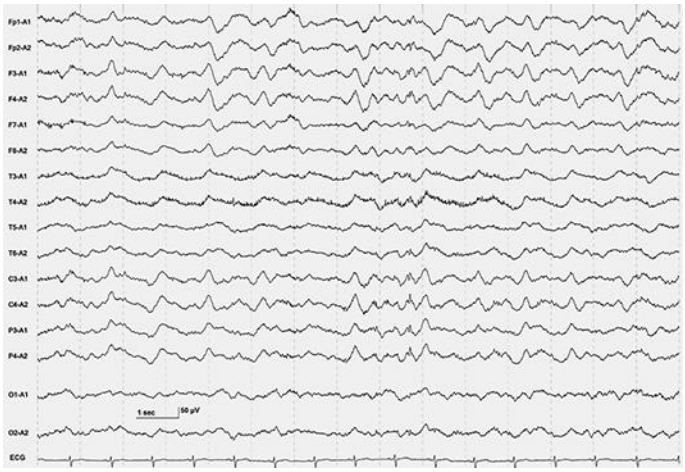

Fig. 3. EEG of Patient 2 on day 2 before diazepam administration. Anteriorly dominant, diffuse, moderate-voltage, periodic theta waves (~1 Hz) but no epileptic discharges were observed.

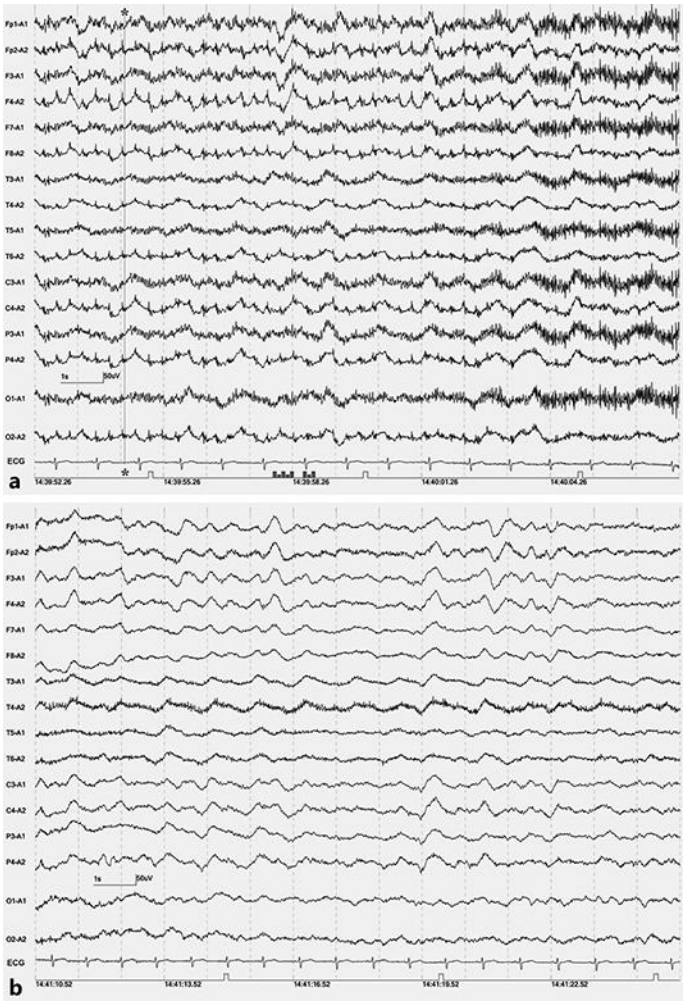

Fig. 4. EEG of Patient 2 on day 2 after the second bolus administration of diazepam 10 mg. **a** Soon after diazepam administration (*), repetitive movements such as lip pouting and tongue protrusion attenuated. **b** Around 1 min after the administration, movements as well as PSWs disappeared.