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Brief Communication

Ictal EEG/fMRI study of vertiginous seizures

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ABSTRACT

Vertigo and dizziness are extremely common complaints, related to either peripheral or central nervous system disorders. Among the latter, epilepsy has to be taken into consideration: indeed, vertigo may be part of the initial aura of a focal epileptic seizure in association with other signs/symptoms, or represent the only ictal manifestation, a rare phenomenon known as "vertiginous" or "vestibular" seizure. These ictal symptoms are usually related to a discharge arising from/involving temporal or parietal areas, which are supposed to be a crucial component of the so-called "vestibular cortex". In this paper, we describe three patients suffering from drug-resistant focal epilepsy, symptomatic of malformations of cortical development or perinatal hypoxic/ischemic lesions located in the posterior regions, who presented clusters of vertiginous seizures. The high recurrence rate of such events, recorded during video-EEG monitoring sessions, offered the opportunity to perform an ictal EEG/fMRI study to identify seizure-related hemodynamic changes. The ictal EEG/fMRI revealed the main activation clusters in the temporo-parieto-occipital regions, which are widely recognized to be involved in the processing of vestibular information. Interestingly, ictal deactivation was also detected in the ipsilateral cerebellar hemisphere, suggesting the ictal involvement of cortical–subcortical structures known to be part of the vestibular integration network.

1. Introduction

Dizziness, consisting of an impression of bodily rotation/displacement, is an extremely common symptom, accounting for 3.5% of annual arrivals to emergency departments [1]. Among "central" causes (e.g. brainstem/cerebellar strokes, posterior fossa tumors, multiple sclerosis, migraine), focal epilepsy is often overlooked: in fact, vertigo may be part of the initial aura of focal seizures, or exceptionally occur as an isolated manifestation, configuring the so-called "vertiginous" or "vestibular" seizures [2,3]. The common association with visual and, less frequently, somatosensory and auditory experiences has suggested the ictal involvement of posterior regions in the genesis of epileptic vertigo [4]. Such hypothesis has been supported by several experimental and functional studies, confirming the paramount role of temporal and parietal areas in the formation of the much-debated "vestibular cortex", a complex widespread neuronal network subserving highly organized functions, such as postural control, motion perception, and eye movements [5].

We report a small series of three patients suffering from symptomatic focal epilepsy and presenting with isolated vertiginous seizures, who underwent an ictal EEG/fMRI study intended to identify the possible hemodynamic correlates of epileptic vestibular sensations.

2. Patients and methods

We selected three subjects, already attending our outpatient clinic, who reported dizziness/vertigo as the predominant or unique ictal manifestation during a prolonged EEG-documented seizure cluster. These patients were identified during daily activity of our video-EEG (VEEG) laboratory, where about 2800 recordings per year are performed. At the time of VEEG monitoring, they were carefully tested

Abbreviations: AED, antiepileptic drug; BA, Brodmann area; BOLD, blood oxygenation level dependent; MCD, malformation of cortical development; sGTCS, secondarily generalized tonic–clonic seizure; TPSVC, temporo-peri-Sylvian vestibular cortex; VEEG, video-EEG; VSs, vestibular sensations.

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by a trained neurophysiology technician. The consistent time-locked correlation between the onset of the subjective manifestations and the appearance of paroxysmal EEG abnormalities confirmed the epileptic nature of these phenomena. Clinical reports and EEG tracings were then reviewed by two neurologists expert in the field of epilepsy (CDB and ATG), in order to clarify the patients' epileptic syndrome, seizure frequency and semiology, comorbidities, and therapeutic regimens.

The present study was approved by the local Ethics Committee.

2.1. Case 1

A 58-year-old right-handed woman was diagnosed with focal epilepsy at the age of 7, when she developed seizures characterized by early vertiginous manifestations, followed by confusion, dysphasia and consciousness impairment. Secondarily generalized tonic–clonic seizures (sGTCSs) seldom occurred. Despite several antiepileptic drug (AED) combinations, monthly seizures persisted. Following a therapeutic change, the patient's typical seizures resolved, but she began experiencing different subjective phenomena described as "a dizziness…a sense of instability…", which were firstly interpreted as AED side effects and then proved to be of epileptic origin.

2.2. Case 2

The patient, a 33-year-old right-handed woman, developed focal seizures with staring and oro-alimentary automatisms at the age of 6, along with sGTCSs. In her prior medical history, perinatal distress and hypoglycemia were reported; febrile seizures also occurred when she was 2. Since late childhood, her seizures mainly consisted of dizziness, inconstantly followed by acoustic manifestations, speech impairment, and confusion. Despite several drug regimens, at the time of observation the patient was still experiencing frequent vertiginous seizures.

2.3. Case 3

A 34-year-old, right-handed woman, with mild cognitive impairment and behavioral disturbances, was referred to our Unit because of a drug-resistant focal epilepsy developed at the age of 7. Her medical history included celiac disease. Her seizures, recurring several times a week/day, were characterized by a sensation of dizziness with nausea, rapidly followed by consciousness impairment and oro-alimentary automatisms; late dysphasia, exploratory hand movements, and visual hallucinations were sometimes observed. Tonic seizures, often complicated by sudden falls, also appeared. A VEEG recording showed frequent epileptiform discharges arising from right posterior areas with subsequent spreading; on such occasions, the patient often complained of isolated dizziness.

2.4. Video-EEG and EEG/fMRI data

As mentioned above, the patients underwent VEEG monitoring (Telefactor System, 21 channels, International 10–20 System) that documented the epileptic nature of the reported vertiginous episodes. Considering the recurrence of such manifestations, an EEG/fMRI study was performed, which allowed us to record several seizures with exclusively vertiginous semiology for each patient (for methodological aspects of EEG/fMRI, see the Supplementary Material section).

3. Results

3.1. Structural MRI findings

Our MRI study confirmed the lesions, already documented in previous exams, consisting of: a malformation of cortical development (MCD) involving the left parietal lobe in case 1; a T2 hyperintensity located in the white matter of both parietal lobes extending towards the occipital areas, compatible with a perinatal hypoxic–ischemic lesion, in case 2; and a complex MCD involving the parieto-occipital region bilaterally in case 3 (Supplementary Figure).

3.2. Electro-clinical features during EEG/fMRI sessions

During the EEG/fMRI, each patient reported (by means of an acoustic signal) the occurrence of isolated vertiginous sensations (two in patients 1 and 3, thirteen in patient 2); the careful review of EEG tracings, performed after the off-line removal of gradient-induced artifacts, allowed identification of epileptiform discharges clearly correlated with the onset of the patients' symptoms (overall mean duration 20 s, range 6–45 s; specifically, for patient 1: mean duration 33 s, range 30–36 s; for patient 2: mean duration 20.5 s, range 6–36 s; for patient 3: mean duration 31.5 s, range 18–45 s). In case 1, the ictal EEG tracing showed a low voltage fast activity (15- to 20-Hz) arising from the left parietal region with prompt spreading towards ipsilateral centro-temporal areas. In case 2, the ictal EEG documented a rhythmic 3- to 4-Hz spike activity, intermingled with irregular slow waves, arising from the left parietal regions (maximum P3), with early propagation over the ipsilateral posterior temporal area. In case 3, the ictal EEG showed a widespread paroxysmal slow wave activity intermingled with spikes/polyspikes, predominant over the temporal and centro-parietal regions and better defined on the right.

3.3. Ictal hemodynamic changes

The EEG/fMRI study revealed ictal blood oxygenation level dependent (BOLD) signal increase in: left parietal lobe in patient 1 [mainly, Brodmann Area (BA) 40, 7], left temporo-parieto-occipital junction in patient 2 [BA 19], and right parietal lobe/parieto-occipital junction in patient 3 [BA 7, 18, 31, 19]. In all patients, a BOLD signal decrease in the cerebellar hemisphere ipsilateral to activation clusters was also detected (Figs. 1–3).

4. Discussion

Focal epilepsy is often overlooked as a possible cause of dizziness, although the first reports of the so-called vertiginous/vestibular seizures date back to the nineteenth century [6–8]. Vertigo and giddiness may be either part of the symptomatological cluster of a focal seizure, or even represent the seizure itself, in the absence of other signs/symptoms. The latter is thought to be a very rare and frequently misdiagnosed phenomenon, whose identification is made more complicated by the lack of distinctive features of epileptic vertigo, apart from its short duration [9]. Moreover, balance disturbances and dizziness are a frequent complaint in patients taking AEDs, especially sodium channel blockers, which makes the diagnosis of epileptic vertigo even more challenging.

In our paper, we describe three patients suffering from symptomatic focal epilepsy who presented clusters of brief episodes of isolated dizziness, whose epileptic nature was undoubtedly demonstrated by VEEG recordings. In accordance with the few published cases, our patients reported a very brief sensation of postural instability and bodily displacement, mainly involving the head, without nystagmus [10], autonomic symptoms, and actual rotational movements.

In our patients, the frequent recurrence of ictal vertigo offered the opportunity to document their hemodynamic correlates by performing an EEG/fMRI study. The most significant hemodynamic changes, in terms of BOLD signal increase, were detected in the left parietal lobe (case 1), the left temporo-parieto-occipital junction (case 2), and the right parietal lobe/parieto-occipital junction (case 3). These activation clusters overlapped with the MCDs found in two patients, highlighting the intrinsic epileptogenic properties of the dysplastic cortex [11,12].

Vertiginous seizures provide a unique chance to study the cortical representation of the vestibular system, a complex neural network