Epilepsy & Behavior 55 (2016) 128–132

Contents lists available at ScienceDirect

Epilepsy & Behavior

journal homepage: www.elsevier.com/locate/yebeh

Subjective and objective characteristics of altered consciousness during epileptic seizures

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A R T I C L E   I N F O

Article history:
Received 1 October 2015
Revised 28 November 2015
Accepted 2 December 2015
Available online xxxx

Keywords:
Consciousness
Subjective aspect of consciousness
Consciousness in epilepsy

A B S T R A C T

Background: Conscious states are inner states and processes of awareness. These states are by definition subjective.
Methods: We analyzed subjective and objective characteristics of alteration of consciousness (AOC) during epileptic seizures, including its involvement in both the level of awareness and subjective content of consciousness. We evaluated AOC using the Consciousness Seizure Scale, the Ictal Consciousness Inventory, and a new structured survey developed by our group: the Seizure Perception Survey, which incorporates patients' subjective experiences before and after they watch a video-electroencephalographic recording of their own seizure.
Results: We included 35 patients (105 seizures) with drug-resistant epilepsy. Most seizures caused profound AOC. The content of consciousness was lower during temporal seizures with profound AOC. We uncovered a correlation between the subjective perception and objective duration of a seizure using the Seizure Perception Survey regarding memory; the patients had a better recall of ictal onset during wakefulness regardless of the epileptogenic zone, laterality, or magnitude of AOC. Nonetheless, the recovery of memory at the end of a seizure took more time in patients who showed greater AOC, less vivid content of consciousness, or a longer seizure. For 85% of the patients, this was the first time they were able to view their own seizures. The majority of the patients requested to view them again because this procedure allowed them to compare the recordings with their own memories and emotions during a seizure and to verify the real duration of the seizure.
Discussion: Alteration of consciousness is one of the most dramatic clinical manifestations of epilepsy. Usually, practitioners or relatives assume that the patients with AOC may not have any knowledge on their seizures. In this study, however, we found that most patients with AOC had a fairly accurate perception of the duration of a seizure and retained their memory of ictal onset. In contrast, for the majority of the patients, watching their own seizure was an extremely positive experience, and most patients stated that they were surprised as well as glad to view what really happened, without expressing negative opinions. Inclusion of subjective characteristics of AOC into the analysis yielded complete assessment of various dimensions of consciousness and therefore allowed us to gain a more detailed understanding of consciousness.

1. Introduction

Conscious states are inner states and processes of awareness with undeniable neurobiological underpinnings [1,2]. Conscious states are by definition subjective, which scientists studying consciousness must take into consideration [2,3]. In addition, most theories of consciousness assert that all conscious experiences have specific qualitative attributes that differentiate them from each other (qualitativeness), as well as a unified nature (unity) that cannot be reduced to independent components [4]. It has been suggested that the science of consciousness should systematically integrate third-person data, i.e., data on the neurophysiological correlates of conscious states, with first-person data, i.e., data on distinctive qualities of the subjective experience [3]. Neurophysiological parameters alone are not sufficient to describe a conscious state without taking into account the first-person viewpoint and vice versa.

In this regard, epilepsy is an ideal experimental model for studies on human consciousness, because, in most subjects, there is an opportunity to analyze both the patient's subjective experience of the alteration of consciousness (AOC) before and after a seizure as well as neurophysiological data [5–7]. Furthermore, AOC is one of the most dramatic clinical manifestations of epilepsy, and a better understanding of this phenomenon will benefit the patients [8]. Epilepsy negatively affects quality of

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http://dx.doi.org/10.1016/j.yebeh.2015.12.003
1525-5050/

life and is a frequent brain disorder: it affects ~1% of the general population [9]. Since the 1990s, video-electroencephalographic (EEG) studies have produced remarkable data on the correlations of signs and symptoms of clinical seizures with neurophysiological parameters [10,11]. Nonetheless, few studies have included an analysis of subjective characteristics of AOC during seizures [7,8,12,13].

A bidimensional model of consciousness was proposed that is based on neurophysiological and neuroimaging studies, which indicate a subdivision of the neural correlates of consciousness into a) structures necessary for the maintenance of the quantitative parameters (level) of consciousness and b) those responsible for generating the qualitative features (content) of a conscious experience. The level of consciousness means a range of conditions that vary from alertness to coma, and the content of consciousness includes an array of multimodal perceptions (sensations, emotions, intentions, and memories). Thus, generalized seizures are characterized by complete unresponsiveness and the absence of any content of consciousness, whereas during complex partial seizures, both the level and content of consciousness are affected to variable degrees. The interaction between the level and content of consciousness is poorly understood. Alteration of either causes AOC.

The aim of this study was to analyze the behavioral characteristics of subjective and objective AOC during epileptic seizures via examination of preictal, ictal, and postictal behavioral changes and via incorporation of patients' subjective experiences before and after they viewed video-EEG recordings of their own seizures.

2. Materials and methods

Since 2012, we prospectively selected 35 patients with drug-resistant epilepsy in whom the epileptogenic zone (EZ) was clearly localized. In most of these patients, the EZ was lateralized to either the right or left hemisphere. Inclusion criteria were as follows: age between 18 and 65 years and full-scale intellectual ability (IQ ≥ 80). Magnetic resonance imaging was performed on each patient and revealed various lesions in some patients (e.g., hippocampal sclerosis, dysplasia, or a tumor). Prolonged video-EEG monitoring was performed during 5 days on an average. Semiological and electrophysiological ictal changes allowed us to focalize and lateralize the seizure origin to distinct cortical structures. Long-term scalp EEG recordings were obtained from all patients during in-patient video-EEG monitoring by means of digital equipment (Bioscience Vector and Stellate Harmonie equipment) at a 200-Hz sample rate, using 20 or 32 electrodes of simultaneous registration in accordance with the international 10–20 system. In some patients, additional temporal electrodes of the 10–10 system were used. We followed the guidelines of the American EEG Society [14] for long-term monitoring. Referential montages as well as longitudinal–bipolar and transverse–bipolar montages were used for the analysis.

We reviewed the ictal clinical semiology in the videos of seizures (video-EEG recordings) of the patients. For the purpose of this study, two experts trained and experienced in video-EEG interpretation reviewed all video-EEG recordings. Each seizure was reviewed 3 to 4 times in its entirety to identify every pathological sign. Seizure onset was defined as the first electrographic change in the background or any clinical sign indicating seizure onset or when a patient indicated either verbally or gesturally that he or she was experiencing an aura. End of the seizure was identified when rhythmic activity finished, the EEG showed a diffused attenuation or slowing, or more than 90% of the EEG channels were slow and the patient's stereotyped behavior ended, and/or the patient began to interact with his or her surroundings in a way different from that during the seizure. We used systematic patient assessment during the ictal and postictal period; the assessment was performed by a qualified staff member (i.e., a technician, nurse, or physician). The patients were instructed to promptly inform the staff whenever they experienced an aura. Postictally, after the patients regained consciousness and were able to follow commands, they were again interviewed to verify whether they recalled having an aura prior to the seizure and could describe it and whether they had any memory of what happened during the seizure. We evaluated postseizure language deficits by asking the patients to name various objects. The definition of an EZ was based on our diagnostic protocol including anamnesis and results of video-EEG and MRI [11,15,16].

Patients with a diagnosis of convulsive nonepileptic seizure (CNES) or those who did not agree to participate in this study were excluded. All patients signed a written informed consent form before the study.

2.1. The protocol for evaluation of conscious states

We used a protocol that included three tests:

2.1.1. Consciousness Seizure Scale (CSS)

The CSS [8] is an instrument used during the analysis of video-EEG recordings and contains 8 items for evaluation of the level of consciousness during the ictal and postictal periods. The seizures are subdivided into three groups according to the degree of AOC: without AOC (score ≤ 1), moderate AOC (score ranging from 2 to 5), and profound AOC (score ≥ 6).

2.1.2. Ictal Consciousness Inventory (ICI)

The ICI [12] is a self-report 20-item instrument specifically developed to quantify (ICI A) the level of general awareness/responsiveness (items 1–10; level of consciousness) and (ICI B) the "vividness" of ictal experiential phenomena (items 11–20; content of ictal consciousness) during epileptic seizures. First, we conducted a pilot study with a healthy control group ($n = 15$) to verify that the translation of the instrument was correctly understood; thereafter, we used the instrument with the patients.

2.1.3. The Seizure Perception Survey (SPS)

The SPS is a structured survey that was developed by our group (see Supplementary material) as a way for patients to describe the subjective experience of their seizures before and after viewing them in video-EEG recordings. The survey was subdivided into two parts. Part A: Before the patients viewed their seizures, the patients were individually asked about the subjective duration of their seizures, what they remembered about their last seizure, and whether they had viewed their seizures before. Part B: The examiner viewed the video-EEG together with the patient within a six-hour time frame after a seizure, with the exception of night seizures, when this was done the next morning. During the review of the video-EEG, the patients were asked to refer to their last memory from the beginning of the seizure. If there was AOC, the patients were also asked what they remembered after the seizure. Finally, the patients were asked what they felt after viewing their seizure.

2.2. Ethics committee approval

Approval by the ethics committee of the Ramos Mejia Hospital was obtained for the study. All the patients signed a written informed consent form before their voluntary participation in this study.

2.3. Statistical analysis

We analyzed the following variables: age, education, epilepsy onset, epilepsy duration, localization, and laterality using Student's t-test for independent variables, chi-squared test, and logistic regression analysis. We performed all consciousness tests for every seizure for each patient, and the results were then compared. We analyzed the results of the tests in relation to the patient's EZ. We used an ANOVA test and Pearson's and Spearman's correlation analyses for quantitative variables. Statistical significance levels were set at $p \leq 0.05$. The SPSS 20.0 for Windows was used for all the statistical analyses.