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Subjective and objective characteristics of altered consciousness during epileptic seizures

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ABSTRACT

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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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.

3. Results

The following patients were included: 35 patients (16 women) of whom 19 had temporal lobe epilepsy and 16 had extratemporal epilepsy. The patients presented with a total of 104 seizures during their video-EEG monitoring: 52 temporal lobe-onset seizures and 52 extratemporal seizures. The mean age was 30.52 ± 10.88 years. The mean duration of epilepsy was 18.87 ± 9.6 years. No significant difference was found between the temporal lobe-onset group and extratemporal group for these variables: age, duration of epilepsy, or sex. We omitted laterality analysis because more than half of the seizures in the extratemporal group were left-sided; furthermore, one-third of the seizures were left-sided and one-third could not be lateralized in the temporal group (Table 1).

3.1. Survey results

3.1.1. The CSS

The CSS revealed that more than half of the seizures caused profound AOC (62 seizures). The temporal lobe-onset group had significantly greater presence of AOC. Only four seizures in this group (in patients 7 and 35) showed no AOC.

We did not observe a significant difference in the degree of AOC when considering the sleep–wake cycle in relation to the presence of seizures ($p = 0.135$). However, four seizures without AOC occurred when the patients woke up.

3.1.2. The ICI

The self-reported information on the level (ICI A) and content (ICI B) of consciousness showed that the level of consciousness was more affected in the temporal group than in the extratemporal group without statistical significance (4.47 ± 0.877 vs. 7.1 ± 0.93; $p = 0.068$; Fig. 1). The content of consciousness was greater in the extratemporal group, without statistical significance (temporal group: 1.21 ± 0.29; extratemporal group: 1.81 ± 2.14; $p = 0.184$; Fig. 1).

Regarding the sleep–wake cycle, seizures during sleep affected the level of consciousness more than those during wakefulness ($p = 0.0001$). Since some patients were asleep, this finding should be considered carefully because we cannot rule out that sleep affected consciousness. We did not detect a statistically significant difference between the content of consciousness and the time point of occurrence ($p = 0.253$), although both groups showed a low score.

3.1.3. The SPS

With the SPS, we found a correlation between the subjective perception of the duration of a seizure and its objective duration ($\rho = 0.281$; $p = 0.003$). This correlation was observed both during sleep and during wakefulness and was stronger even when the seizures caused more profound AOC ($\rho = 0.381$, $p = 0.002$) (Fig. 2). Seizures that occurred during wakefulness were associated with better recall of ictal onset than those that occurred during sleep, regardless of the EZ, laterality, and the level of AOC ($p < 0.0001$).

Likewise, the recovery of memory at the end of seizures took more time when AOC was greater ($p = 0.019$) and when seizures were associated with lesser content of consciousness ($\rho = -0.476$, $p = 0.0001$).

Table 1
Demographic characteristics of patients.

	Temporal group n = 19 patients	Extratemporal group n = 16 patients	p
Age (years, mean ± DS)	30.79 ± 10.16	30.31 ± 11.9	0.89
Epilepsy duration (years, mean ± DS)	18.08 ± 8.64	19.89 ± 11.0	0.60
Female (%)	42.1	50.0	0.64
Laterality left (%)	63.4%	82.7%	0.033
No laterality (%)	26.9%	1.9%	0.001

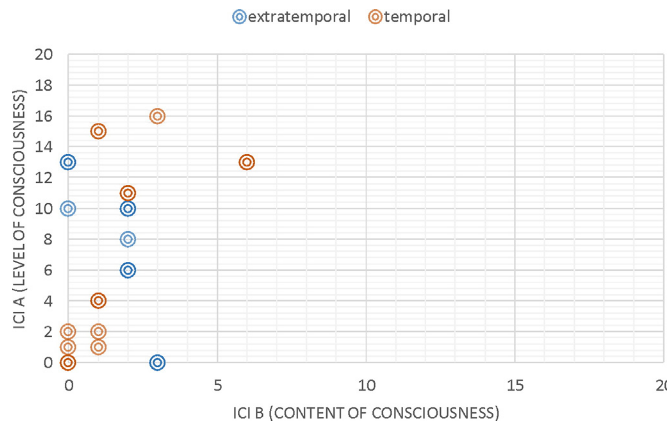

Fig. 1. Content (ICI B) and level (ICI A) of consciousness of seizures in temporal and extratemporal groups.

We found that memory recovery was delayed when the seizures lasted longer ($\rho = 0.436$, $p = 0.002$). As for the sleep–wake cycle, the seizures during the wakefulness period were associated with better recovery of memory when they ended; however, the difference in time necessary to recover memories was not statistically significant between sleep (268.75 ± 123.25) and wakefulness periods (209.81 ± 29.63; $p = 0.61$).

For 85% of the patients, this was the first time they had viewed their seizure. Only two patients had negative feelings viewing their own seizures. Others seemed surprised and had no negative feelings. The majority of the patients requested to view their seizures again because this approach allowed them to verify their own memories and feelings during seizures and the true duration of their seizures. Moreover, most patients had a positive opinion about the experience because they could compare their perceptions with whatever their families and friends had told them. The following are examples of answers to item 7 of the SPS (Do you think your seizure was like that?): most of the answers were "yes, I thought that my seizures were more or less like what I saw". Some patients said "I did not imagine that my seizures were like that", "my family described them more or less like this", or "I thought they involved more movement like a colleague of mine at school had". The following are examples of answers to item 8 of the SPS (What did you feel when you saw the seizure?): most of the subjects said that they were surprised by the sight of their seizures ("I feel surprised, puzzled", "I want to view them again because they

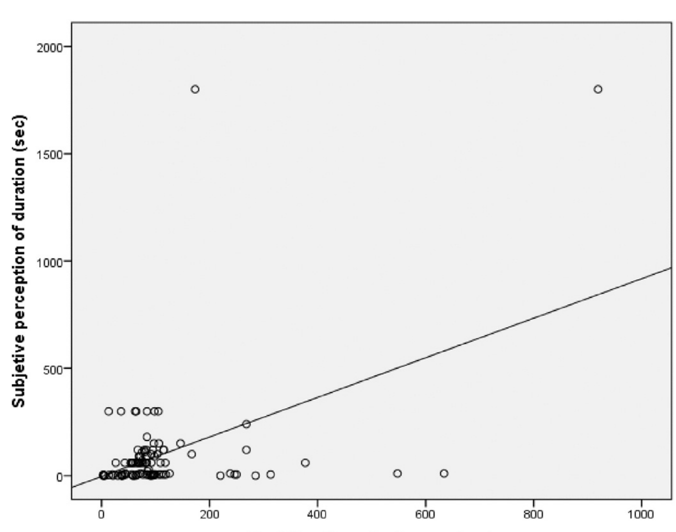

Fig. 2. Correlation between the subjective perception of the duration of a seizure and its objective duration.

surprised me"). Only two patients did not want to continue watching the recordings because this procedure shocked and distressed them.

3.2. Comparison of the different tests

We found that the results of the CSS were consistent with those of the ICI: consciousness that was more affected as measured by the CSS showed a lower value of the level (ICI A) and content (ICI B). Among cases of profound AOC, we found that temporal lobe-onset seizures were associated with worse ICI A ($p = 0.045$) and ICI B ($p = 0.001$) than extratemporal seizures. Among moderate AOC cases, the levels of consciousness were not different between the different EZ groups ($p = 0.80$; Table 2).

In the SPS results, the duration of seizures among different levels of AOC according to the CSS did not differ significantly. The subjective perception of duration of the seizures did not show a significant difference either (Fig. 3).

The SPS allowed the patients to objectively compare their experience and imagine the characteristics of their seizures with what happens during a seizure.

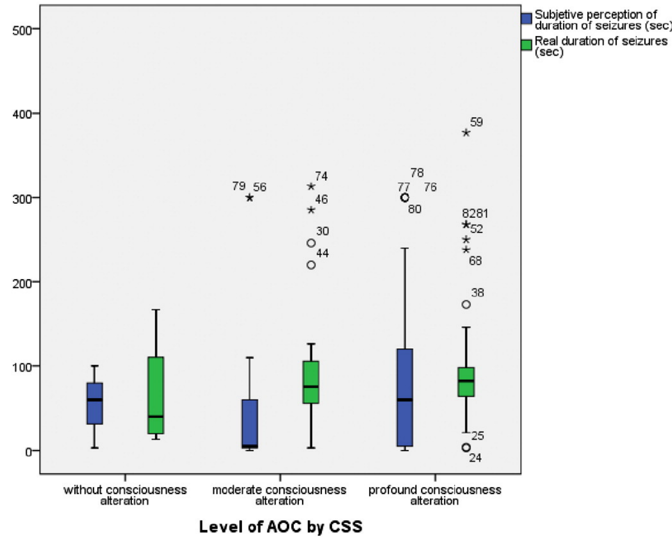

Fig. 3. Subjective perception of duration and real duration of seizures in different levels of alteration of consciousness (AOC) using a Consciousness Seizure Scale (CSS) [8]. No differences were found.

4. Discussion

After the evaluation of a patient population with drug-resistant epilepsy, most of them presented with AOC, which is one of the features that impairs quality of life. First, we evaluated the degree of the AOC using the CSS, which allowed us to subdivide the seizures in three groups according to the level of consciousness: no AOC, moderate AOC, or profound AOC. We found that more than half of the seizures caused profound AOC. Seizures that originated in the temporal lobe caused significantly more profound AOC than those caused by seizures with onset outside the temporal lobe, in line with other studies [17–20]. Those studies showed more profound AOC in the dominant temporal lobe, mostly the left one, but we could not analyze the laterality because most patients in our study had left temporal epilepsy. Future research should include more patients for analysis of laterality.

We did not find correlations between AOC and a specific time point of the sleep–wake cycle according to the SPS. Nevertheless, it is noteworthy that all seizures without AOC occurred while the patients were awake. The relation between AOC and the sleep–wake cycle has not been thoroughly analyzed in other studies. Detyniecki and Blumenfeld showed that seizures during sleep tend to be longer and more frequently generalized [21].

Second, we used the ICI for the evaluation of the level and contents of consciousness. We did not find significant differences in the level of consciousness between temporal and extratemporal seizures, in agreement with other reports [12,22]. With regard to the content of consciousness, we again did not observe a significant difference between temporal and extratemporal seizures. Nonetheless, both groups showed low scores, in line with other studies [12,22]. When considering the time points of the sleep–wake cycle, seizures during sleep were associated with a worse level of consciousness; however, we found no differences in the content of consciousness. The latter finding was not reported separately in other studies.

The results of more objective evaluation of AOC by the CSS and the subjective experience during a seizure according to the ICI correlated well. This finding shows the usefulness of the analysis of subjective perception of seizures; this analysis has been disregarded for a long time.

Finally, we extensively analyzed the subjective component of consciousness using our SPS survey. We found a correlation between the subjective perception and the objective duration of the seizures. This result surprised us, because in clinical practice, we typically only consider the information on the duration of seizures presented by the witnesses and disregard the patient's opinion. Although we did not conduct a specific analysis, in most cases, the patients' assessment was more precise than that of their relatives'. This pattern was slightly more pronounced when seizures caused lesser AOC and lasted for a lesser duration. In addition, we found that the perception of ictal duration was more accurate when it was associated with lower content of consciousness. This finding could be explained as follows: the memory of internal experiences could "trick" the perception of time. In relation to memory, using the SPS survey, we found that patients had better recall of ictal onset during wakefulness than during sleep, regardless of the EZ, laterality, and level of AOC. Nevertheless, the recovery of memory at the end of seizures took more time with greater AOC and smaller content of consciousness and when seizures lasted longer.

We were surprised by the excellent attitude among the patients toward the viewing of their own seizures (video-EEG recordings), which was the first time ever for most of the patients. After viewing their own seizures, nearly all patients stated that they were surprised and glad to view what really happened, without expressing negative opinions. In seizures with AOC, the patients relied on witnesses of the episodes to find out what happened. In general, the witnesses were their relatives. In particular, epilepsy creates complex relationships between

Table 2
Values of ICI in seizure with different AOC by CSS — level of consciousness (ICI A) and content of consciousness (ICI B) were statistically different between moderate and profound AOC. Also in profound AOC, the temporal group had less level (ICI A) and less content of consciousness (ICI B). In moderate AOC, there were no differences in level and content of consciousness considering different epileptogenic zones.

	Moderate AOC				Profound AOC			
	All patients	Temporal group	Extratemporal group	p	All patients	Temporal group	Extratemporal group	p
ICI A	9.7 ± 4.5				1.33 ± 2.2			0.0001
		2.71 ± 5.58	9.46 ± 2.68	0.80		0.92 ± 1.59	2.86 ± 3.62	0.042
ICI B	2.1 ± 1.9				0.73 ± 1			0.003
		2.71 ± 2.34	1.38 ± 0.96	0.066		0.23 ± 0.43	2.57 ± 0.53	0.0001

people, often dependent and negative relations. Our experience with showing patients the video recordings of their seizures has been extremely positive. Most patients corroborated the symptoms and signs that were successfully recalled until AOC and after recovery of memory. We believe that our method (SPS) improves what had been a weak point in several studies: postictal amnesia can alter the memory of some symptoms at the start of the seizure. This problem seems to be corrected by viewing one's own seizures.

The main limitations of this study are as follows. The small number of patients with right-sided epilepsy limited our conclusions about the influence of laterality on consciousness. In addition, both ictal and postictal amnesia could affect the accuracy of a retrospective self-report just as the individual's interpretation of ictal subjective experiences can, depending on the linguistic proficiency and level of insight. In the future, we will enroll more patients to analyze the variability in seizure phenomenology and to increase the reliability of findings.

We believe that this work makes an important contribution to the field of AOC research because we used different instruments to evaluate different dimensions of consciousness. The inclusion of subjective characteristics of AOC into the analysis, especially those related to the time point when consciousness deteriorated, provides new insights into consciousness and enables a more complete understanding thereof.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.yebeh.2015.12.003.

Ethical publication statement

We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

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Disclosure of conflicts of interest

None of the authors has any conflict of interest to disclose.

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