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Review

The quantitative measurement of consciousness during epileptic seizures

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ABSTRACT

The assessment of consciousness is a fundamental element in the classification of epileptic seizures. It is, therefore, of great importance for clinical practice to develop instruments that enable an accurate and reliable measurement of the alteration of consciousness during seizures. Over the last few years, three psychometric scales have been specifically proposed to measure ictal consciousness: the Ictal Consciousness Inventory (ICI), the Consciousness Seizure Scale (CSS), and the Responsiveness in Epilepsy Scale—versions I and II (RES-I and RES-II). The ICI is a self-report psychometric instrument which retrospectively assesses ictal consciousness along the dimensions of the level/arousal and contents/awareness. The CSS has been used by clinicians to quantify the impairment of consciousness in order to establish correlations with the brain mechanisms underlying alterations of consciousness during temporal lobe seizures. The most recently developed observer-rated instrument is the RES-I, which has been used to assess responsiveness during epileptic seizures in patients undergoing video-EEG. The implementation of standardized psychometric tools for the assessment of ictal consciousness can complement clinical observations and contribute to improve accuracy in seizure classification.

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1. Introduction. Assessment of ictal consciousness and calssification of epileptic seizures.

The classification of seizures has the twofold function of assisting the clinical assessment of patients with epilepsy and facilitating communication between health professionals. The history of seizure classification systems has largely relied upon accurate clinical observations and expert opinions, which converged in the dichotomy between generalized seizures (characterized by loss of consciousness and other clinical correlates of synchronous spike–wave discharges occurring in both hemispheres) and partial seizures (occasionally associated with complex alterations of consciousness and other clinical correlates of focal cortical disturbances) [1]. This was already formally established in the first classification of epileptic seizures proposed by Gastaut in 1970, which based the assessment of ictal consciousness on the clinical evaluation of 'loss of contact' with the external environment, in line with the approach of the French epileptology school [2]. When the International League Against Epilepsy (ILAE) formalized the first classification system [3,4], partial seizures were further divided into *simple partial seizures* (in which conscious awareness is preserved) and *complex partial seizures* (in which conscious awareness is disrupted) [5].

As new scientific information was acquired through the refinement of neurophysiology research and the development of neuroimaging and genetic and molecular biology, the ILAE put forward proposals to revise the classification system [6–8]. Within this new conceptual framework, partial seizures were termed focal and are still categorized into seizures 'without impairment of consciousness or awareness' (corresponding to the classical category of simple partial seizures) and seizures 'with impairment of consciousness or awareness' (corresponding to the classical category of complex partial seizures). Recently, this approach was further developed by Blumenfeld and Jackson [9], who proposed two categories of focal seizures which build on both the old and new classification systems: 'focal aware consciousness seizures' (FACS) and 'focal impaired consciousness seizures' (FICS). Thus, alterations of consciousness continue to be a widely accepted distinguishing feature of focal seizures.

Over the last few years, a few psychometric instruments have been developed to measure alterations of consciousness which are specific to epileptic seizures. In this article, we review the first three scales proposed for the measurement of consciousness in epilepsy, focusing on their development and validation process, clinimetric characteristics, and practical use (Table 1): the Ictal Consciousness Inventory (ICI), the Consciousness Seizure Scale (CSS), and the Responsiveness in Epilepsy Scale—versions I and II (RES-I and RES-II).

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Table 1
Summary of the clinimetric characteristics of the scales specifically developed to assess consciousness in epilepsy.

Scale	ICI	CSS	RES-I/RES-II
Authors	Cavanna et al.	Arthuis et al.	Yang et al./Bauerschmidt et al.
Year	2008	2009	2012/2013
Country	Italy	France	USA
Rater	Patient	Assessor	Assessor
Items	20	8	12/10 + 1
Direct observation of seizure	No	Yes	Yes
Administration/scoring burden[a]	+	+	±
Psychometric testing	Yes	No	Yes
Used in nonepileptic attacks	Yes	No	No

Abbreviations: ICI, Ictal Consciousness Inventory; CSS, Consciousness Seizure Scale; RES, Responsiveness in Epilepsy Scale.
[a] Administration burden was rated as follows: "+" (easy) and "±" (moderate).

2. Ictal Consciousness Inventory (ICI)

The ICI is a self-report psychometric instrument specifically developed in 2008 to measure ictal consciousness as reported by patients with epilepsy [10]. This scale consists of 20 items which evaluate both the level of general awareness/responsiveness (items 1–10) and the "vividness" of ictal subjective experiences (items 11–20) during epileptic seizures. The scale was originally proposed by its authors as a guide within the bidimensional model for the evaluation of ictal consciousness. The model addresses both the level of awareness and the subjective content of conscious experience [11]. Within this theoretical framework, patients with generalized seizures present with complete unresponsiveness and the absence of any ictal subjective conscious experience (i.e., cluster around the 0 level and 0 contents point). By contrast, during complex partial seizures, both the level and content of consciousness can be reported with different degrees of intensity. In particular, complex partial seizures originating in the temporal lobe are often associated with specific subjective feelings (so-called experiential phenomena). The ICI has specifically been developed and validated to quantify the vividness of these experiential phenomena during ictal consciousness.

The ICI was developed in three stages. In the first stage, 20 items measuring alterations of ictal consciousness were derived from patient interviews, expert opinion, and literature review [12]. The first 10 items refer to the level of consciousness and evaluate self-consciousness; general awareness of time, place, and other people's presence; comprehension of other people's words; verbal and nonverbal responsiveness; gaze control; forced attention; and voluntary initiative. Items 11 to 20 concern the contents of consciousness and evaluate the following subjective experiences: dreamy states, symptoms of derealization (with both temporal and spatial features), feeling of the presence of an absent person, illusions, hallucinations, déjà vu/vécu, and unpleasant and pleasant ictal emotions. Overall, each item can be rated by the patient on a 0–2 Likert-type scale. Therefore, the ICI yields two subscores ranging from 0 to 20: the first one for the level and the second one for the contents of ictal consciousness. Higher scores indicate increased alertness and more vivid experiential symptoms, respectively. In the second stage, 110 outpatients, recruited in three secondary referral centers for the diagnosis and management of epilepsy, completed the two ICI subscales along with a battery of standardized psychometric instruments. The diagnosis of epilepsy was made according to the ILAE criteria [4] by at least two different neurologists who were not involved in the development of the scale. All patients younger than 18 years old, with an uncertain diagnosis of epilepsy, a reading level less than sixth grade, a diagnosis of learning disability, or a Mini Mental State Examination score inferior to 24, were excluded from the validation study. As part of the second stage, all the patients were assessed by a neurologist/neuropsychiatrist with experience in epilepsy. Following a thorough clinical interview, each participant was administered standardized psychometric rating scales to evaluate common psychiatric comorbidities, including depression, anxiety, and dissociative disorders. After this evaluation, the patients were asked to think about their witnessed seizures and complete an ICI form for every seizure they could remember. In the third stage, the psychometric properties of the ICI were tested via standard statistical methods, including principal component factor analysis. The ICI performed well in terms of acceptability, validity, and reliability. Ictal Consciousness Inventory scores were in the expected directions: patients diagnosed with generalized epilepsy ($n = 32$) reported low scores on both level and content subscales, whereas patients with partial epilepsy ($n = 78$) reported higher scores, and patients with temporal lobe epilepsy ($n = 67$) scored higher than patients with frontal lobe epilepsy ($n = 11$), especially with regard to the contents subscale.

The results of the development and validation process led the authors to conclude that the ICI is an accurate clinical instrument for collecting retrospective accounts of the complex phenomenology of seizures along the dimensions of the level and contents of consciousness, with focus on the ictal experiential phenomena. The relatively small sample size (especially with regard to the group with frontal lobe epilepsy) and the recruitment from specialist settings (introducing possible referral bias) were the main limitations of the ICI validation study. Finally, both ictal and postictal amnesia could affect the accuracy of retrospective self-report ICI scores [13].

A study by Ali et al. [14] employed the ICI to quantitatively evaluate ictal alterations of consciousness in 95 adult outpatients attending general neuropsychiatry and epilepsy clinics with established diagnoses of either epilepsy ($n = 66$) or nonepileptic attack disorder ($n = 29$), excluding patients with uncertain or dual diagnoses. The scores for ICI-level and ICI-contents were calculated for the 167 questionnaires answered by patients with epilepsy ($n = 119$, of which 58 were patients with temporal lobe epilepsy, 14 with frontal lobe epilepsy, and 47 with idiopathic generalized epilepsy) and patients with NEAD ($n = 48$). The authors found significantly higher scores in both the level and content domains for patients with nonepileptic attack disorder, who reported significantly greater levels of general awareness/responsiveness and more vivid subjective experiences during attacks. The ICI was therefore proposed as a potentially useful self-report instrument to supplement clinical and instrumental tests for the differential diagnosis of epilepsy and nonepileptic attack disorder.

3. Consciousness Seizure Scale (CSS)

The CSS was developed in a study from 2009 originally aimed at analyzing the mechanisms underlying loss of consciousness during temporal lobe seizures [15]. This scale takes into consideration different features of conscious experience, delineating 8 criteria: unresponsiveness (criteria 1 and 2); visual attention (criterion 3); consciousness of the seizure (criterion 4); adapted behavior (criterion 5); amnesia (criteria 6 and 7); and global appreciation of consciousness by an experienced physician (criterion 8). All items are rated by the epileptologist: items 1 to 7 can be scored 0 or 1, while the eighth item from 0 to 2, thus yielding a possible total score of 0 to 9. Higher scores indicate more severe loss of consciousness. Temporal seizures are characterized by neuronal discharges that originate in the temporal lobe and propagate along networks interconnecting both cortical and subcortical regions [16]. The CSS has been proposed to quantitatively assess loss of consciousness within the theoretical framework of the 'global workspace' theory of consciousness [17,18]. According to this model, conscious information becomes available through the synchronized activity of neuronal modules linked to widespread networks within different brain regions. Thalamocortical communication plays a crucial role in this dynamic system [19,20], as the deactivation of thalamic structures, along with