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Review

Consciousness of seizures and consciousness during seizures: Are they related?

Kamil Detyniecki [a,*], Hal Blumenfeld [a,b,c]

[a] Department of Neurology, Yale University School of Medicine, 333 Cedar Street, New Haven, CT 06520, USA
[b] Department of Neurobiology, Yale University School of Medicine, 333 Cedar Street, New Haven, CT 06520, USA
[c] Department of Neurosurgery, Yale University School of Medicine, 333 Cedar Street, New Haven, CT 06520, USA

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ABSTRACT

Recent advances have been made in the network mechanisms underlying impairment of consciousness during seizures. However, less is known about patient awareness of their own seizures. Studying patient reports or documentation of their seizures is currently the most commonly utilized mechanism to scientifically measure patient awareness of seizures. The purpose of this review is to summarize the available evidence regarding the accuracy of patient seizure counts and identify the variables that may influence unreliable seizure reporting. Several groups looking at patient documentation of seizures during continuous EEG monitoring show that patients do not report as many as 50% of their seizures. These studies also suggest that seizures accompanied by loss of consciousness, arising from the left hemisphere or the temporal lobe, or occurring during sleep are associated with significantly reduced reporting. Baseline memory performance does not appear to have a major influence on the accuracy of seizure report.

Further prospective studies using validated ictal behavioral testing as well as using correlation with newer electrophysiological and neuroimaging techniques for seizure localization are needed to more fully understand the mechanisms of underreporting of seizures.

Better methods to alert caregivers about unrecognized seizures and to improve seizure documentation are under investigation.

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1. Introduction

The definition of consciousness has long been debated by philosophers, and consciousness can have different meanings in different contexts. In order to study consciousness, it is important to distinguish two important components, namely, the content and the level of consciousness [1]. The content of consciousness includes all the information encoded in organized sensory and motor systems as well as in other systems such as memory and emotion/drives. The level of consciousness regulates the maintenance of an alert, attentive, and aware state [1]. Recent neuroimaging, intracranial EEG, and animal models demonstrate that seizures and other disorders of consciousness converge on the same group of cortical and subcortical structures, termed the "consciousness system" [2–4].

Elucidating the mechanisms of impaired consciousness in epilepsy has major clinical implications, as this impaired consciousness is often the cause of motor vehicle accidents, drowning, falls, and social stigmatization [5–7]. It is important to distinguish loss of consciousness during seizures from lack of awareness of having a seizure. Precise scientific methods that would investigate how conscious a person is of his/her seizures at the time of their occurrence are currently lacking. Several tools have been developed to objectively test ictal behavior and responsiveness during seizures [8–13]; however, none of these methods provide a measure of a patient's awareness of having the seizure. To date, the most scientific way to measure a patient's awareness of seizures is their report. The accuracy of patient report about their seizures has been studied in the form of diaries or seizure counts mostly during inpatient video-EEG monitoring. Surprisingly, overall, patients do not report 30–50% of their seizures [14–18]. This has obvious consequences for patient care and the accuracy of clinical drug trials.

There are several factors that can potentially influence seizure report. These include the following: seizure localization by hemisphere and lobe, preictal vigilance state at time of seizure onset, memory function, and seizure type [14–18]. Seizure type, in turn, determines whether patients are conscious during seizures. Knowledge of the effects of these factors can help clinicians ascertain whether a given patient is at higher risk for underreporting of seizures.

The effect of any of these individual variables on seizure report likely depends on additional factors as well and is, thus, not independent. For

* Corresponding author. Fax: +1 203 737 2799.
E-mail address: kamil.detyniecki@yale.edu (K. Detyniecki).

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example, the occurrence of certain seizure types or localization is highly dependent on the sleep/wake state.

Impairment of consciousness can affect seizure report in many ways. The phenomenon of underreporting of seizures could have two possible explanations: either the patients were not aware of their seizures at the time of occurrence or they were aware at some point during the seizure but did not report them later because of poor memory. Impairment in any of the components that maintain the level of consciousness such as being alert, attentive, or aware could influence the recognition of the seizure at the time of its occurrence. In addition, seizures that impair certain substrates of the content of consciousness such as memory, language, or body awareness could affect the subsequent report.

In this review, we summarize previous investigations of seizure counts, discuss the factors that influence underreporting of seizures including the role of impairment of consciousness, and suggest directions that would eventually provide for the better understanding of this problem.

2. Side and lobe of seizure onset

As discussed later in this review, the level of consciousness during seizures plays an important role for seizure recognition and subsequent reporting. However, different aspects of the content of consciousness such as language or visual–spatial attention may also be altered to a different degree if the seizure originates in the dominant vs. the nondominant hemisphere, thereby affecting the subsequent report. For example, one would expect more verbal memory deficits in seizures originating in the dominant hemisphere which would subsequently impair verbal reporting. Left hemisphere seizures are reported to be more commonly associated with loss of consciousness possibly related to impaired verbal abilities in particular if originating in the dominant temporal lobe [19,20]. However, it is also theoretically possible that seizures arising from the right hemisphere might, more often, cause underreporting since lesions of the right hemisphere are well known to cause anosognosia or the reduced awareness of neurological deficits [21–24].

Several studies point toward a higher proportion of unreported seizures if the side of seizure onset was in the left hemisphere, particularly when comparing seizures arising from the left vs. the right temporal lobe [15,17]. It has been noted that seizures arising from the left hemisphere are particularly associated with an alteration of the level of consciousness [19,25]. However, it is important to recognize that there may be a bias towards the demonstration of impaired consciousness in seizures arising from the left hemisphere since most behavioral tests used during seizures depend on verbal function. Another factor which could influence seizure reporting depending on the side of onset is the possibility that there is a greater proportion of generalized seizures in patients whose seizure onset is in the dominant hemisphere, particularly in the dominant temporal lobe [26]. As we recently observed, seizures associated with impairment of consciousness are less frequently reported compared to seizures where consciousness is preserved [18]. Another important aspect is the possibility that focal seizures originating in the dominant hemisphere may cause transient dysfunction affecting the isolated aspects of the content of consciousness such as verbal memory. This may affect subsequent report.

The effect of seizure localization by lobe on seizure report is incompletely elucidated in most studies. Some studies suggest that patients with extratemporal foci are more likely to report their seizures [15]. Possible explanations could include the fact that temporal lobe seizures more commonly cause impairment in both the level of consciousness and memory around the time of seizures and are, therefore, expected to more severely disrupt subsequent seizure report.

However, the conclusions that can be drawn from these studies are limited by the small numbers of patients, particularly in the extratemporal group. In addition, most studies based their localization on scalp recording which at times is suboptimal for detailed lobar localization.

In summary, while several studies have examined the potential role of side and lobe of onset in seizure reporting, this remains an open question. Further studies using better methods for seizure localization such as invasive intracranial monitoring and/or localization based on postsurgical outcomes are needed.

3. Sleep/wake state at time of seizure onset

There is a known link between sleep and epilepsy. Several studies have shown that seizures during sleep are longer and more often secondarily generalized [27,28]. In addition, seizures tend to occur in particular patterns during sleep and wakefulness depending on the site of onset [27,29–31]. Moreover, since the level of arousal and memory are reduced during sleep even when seizures are not occurring, it is not unreasonable to believe that seizure documentation is dependent on the vigilance state of the patient at the time of the seizure occurrence. In fact, two studies that examined this question [16,17] found a larger percentage of unrecognized seizures if the patients were asleep at the time of seizure onset. The reason for the difference in seizure report could be, in part, attributed to the fact that seizures occurring during sleep are more often secondarily generalized [31,32], therefore, possibly affecting the ability of patients to be aware of their seizures. However, one study showed that 86% of simple partial seizures occurring during sleep were undocumented by patients [16]. Another possible reason for the discrepancy in documentation is the increased occurrence of certain seizure types during sleep depending on localization [30,31,33], which in turn may have an influence on seizure reporting. Finally, there is a fair amount of evidence that points to the importance of sleep before and after learning for encoding and consolidation of hippocampal dependent memories [34,35]. Therefore, it is possible that sleep before and after nocturnal seizures may disrupt the memory of a seizure.

The true mechanisms of seizure underreporting are not yet clear. The abovementioned studies showed a very strong correlation between seizures occurring during sleep and underreporting of seizures. However, they failed to control for other variables such as site of onset and seizure type which, as previously mentioned, are likely not independent variables.

Knowledge of a circadian pattern of seizures can help predict the risk of underreporting. There has been recent interest in the timing of antiepileptic drug regimens based on circadian rhythms [36]. This, as well as other approaches for better seizure detection at nighttime, may help improve patients' documentation of seizures.

4. Memory function

As we have already discussed, patients may be unable to document their seizures as a result of lack of awareness of the seizure itself or because of poor memory. Inability to recall a seizure could be the result of an ictal- or postictal-induced amnestic phenomenon. It is also possible that poor baseline memory plays a role.

Some patients demonstrate awareness of seizures at the time of occurrence by pushing an event button located at the bedside during video-EEG monitoring. When patients “notified” their seizures at the time of occurrence, most of them were successful at subsequently reporting them [16,18].

The presence of an aura was also associated with better seizure documentation [17]. However, for those patients who were initially “aware” of their seizures but subsequently did not report them, a memory problem would be a logical explanation. To assess whether chronic memory problems may affect seizure report, a number of studies looked at baseline cognitive performance. Overall performance on a baseline neuropsychological test did not affect subsequent report of seizures [15,16,37]. However, in a study by Hoppe et al., patients who documented all of their seizures had a tendency for better baseline verbal memory scores [16].

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