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Review

Epilepsy and driving: Potential impact of transient impaired consciousness

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ABSTRACT

Driving is an important part of everyday life for most adults, and restrictions on driving can place a significant burden on individuals diagnosed with epilepsy. Although sensorimotor deficits during seizures may impair driving, decreased level of consciousness often has a more global effect on patients' ability to respond appropriately to the environment. Better understanding of the mechanisms underlying alteration of consciousness in epilepsy is important for decision-making by people with epilepsy, their physicians, and regulators in regard to the question of fitness to drive. Retrospective cohort and cross-sectional studies based on surveys or crash records can provide valuable information about driving in epilepsy. However, prospective objective testing of ictal driving ability during different types of seizures is needed to more fully understand the role of impaired consciousness and other deficits in disrupting driving. Driving simulators adapted for use in the epilepsy video-EEG monitoring unit may be well suited to provide both ictal and interictal data in patients with epilepsy. Objective information about impaired driving in specific types of epilepsy and seizures can provide better informed recommendations regarding fitness to drive, potentially improving the quality of life of people living with epilepsy.

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1. Introduction

Loss of driving privileges can have a profound impact on the quality of life of individuals diagnosed with epilepsy [1]. For most adults, driving is a primary means of transportation and is necessary for employment, maintaining social ties, and performing other tasks essential to independent living.

Regulations restricting people with epilepsy (PWE) from obtaining or keeping a driving license seek to limit the risk that drivers with epilepsy might pose to themselves and others. Driving risk in PWE has two components: 1) general driving ability may be affected by antiepileptic drug (AED) side effects and/or by the underlying pathology generating the individual's seizures causing interictal cognitive or sensorimotor deficits [2–4] and 2) intermittent risk of loss of consciousness or motor control due to a seizure while driving. In this review, we will focus on transient impairment that may occur due to loss of consciousness during seizures. We will review mechanisms, consequences, and future directions to better understand and prevent this important comorbidity of epilepsy.

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2. Epilepsy and driving

The literature on epilepsy and driving consists largely of cohort studies based on analysis of government and medical databases or surveys of PWE which attempt to determine if PWE are at an elevated risk of motor vehicle accidents (MVAs) [5]. One disadvantage of these studies is the inability to causally link specific MVAs to the occurrence of a seizure while driving; as a result, most studies have made no distinction between MVAs occurring with or without seizures.

Studies have generally reported moderate [6–12] or, rarely, no [13] increases in overall MVA rates for PWE (Table 1). A 2012 analysis by Classen et al. [5] of studies published between 1994 and 2010 not only determined that, based on 4 studies [9,14–16] which met their criteria, epilepsy is likely not predictive of increased MVAs but also noted a lack of consistency in the literature. On the other hand, a meta-analysis conducted by the Department of Transportation Federal Motor Carrier Safety Administration as part of a 2007 comprehensive evidence report estimated PWE to have an accident rate of between 1.13 and 2.16 times that of healthy subjects [17], based on 8 studies [6,7,9–13,16]; heterogeneity in reported data was again noted. Conflicting results from different large sample studies may point to important differences in study methods, population samples, geographical locations, and time periods (see Table 1).

Although overall risk of driving accidents in PWE may be only minimally or moderately increased compared with that of controls, another important question is the severity of damage in accidents that do occur. Several studies have reported that crashes in PWE are more likely to cause injury, death, or property damage than those in controls (Table 1) [9,11,13,15,18]. Two studies which reported a lower risk of serious fatal MVAs in PWE may have been biased by the difficulty of determining an epilepsy diagnosis from death certificates [16] or by the small sample size [19]. In any case, the rate of fatal accidents in PWE has been reported to be lower than that in the highest-risk groups such as young drivers and those who abuse alcohol [6,16,20].

Few studies have attempted to stratify driving risk based on levels of ictal impairment or types of seizures [21]. The beliefs that auras provide sufficient warning of seizures and that PWE are able to drive safely through auras or simple partial seizures have not been well studied [5], although some studies (based on self-report) indicate that PWE who experience warnings before their seizures may be less likely to crash [21,22]. The difficulty of making case-by-case decisions on fitness to drive is compounded by the fact that the self-report of PWE and their family and friends on the frequency and level of impairment of seizures can be unreliable [23].

Objective evidence on driving and epilepsy is crucial for decision-making of physicians, patients, and regulators. A mosaic of regulatory procedures currently exists in the United States. More than half of US states require PWE to demonstrate a seizure-free interval of between 3 and 24 months before being allowed to drive [24,25]. Some states have adopted more flexible procedures in place of or in addition to seizure-free intervals: fitness to drive can be determined by a medical advisory board or by the individual's physician [24,26]. In many states, physicians are legally liable for the driving advice they give to PWE [24,26]. International regulations are similarly variable, with a number of countries banning PWE from ever driving [27].

3. Impaired consciousness in epilepsy and driving

The diverse semiology of epileptic seizures includes motor convulsions or other motor impairments, sensory impairment in vision, audition and proprioception, hallucinations, emotional distress, memory impairment, aphasia, as well as alterations of overall level of responsiveness or consciousness. While any one or a combination of these symptoms potentially jeopardizes safe driving, some, such as motor and visual impairments and especially loss of consciousness, may pose greater risk than others.

Recurrent episodes of alteration of consciousness during epileptic seizures are a cause of significant disability in PWE [28]. Seizures that alter consciousness interfere with a specialized network of cortical and subcortical brain structures, termed the consciousness system, crucial to the maintenance of the waking state, attentiveness to and awareness of memory, sensory and motor systems, emotions, and drives, all of which comprise normal consciousness [29]. The components of the consciousness system include the higher-order frontal and parietal association cortices (Fig. 1), as well as subcortical arousal systems in the upper brainstem, thalamus, basal forebrain, hypothalamus, and other structures [29]. Cortical and subcortical structures interact strongly through reciprocal connections to produce a great variety of states (including seizures) differing in levels of wakefulness, attention, and awareness.

Not surprisingly, brain structures related to alert, attentive driving overlap with many of the same structures necessary for consciousness [30–32]. Parietooccipital cortices and other brain regions important for perception and motor control were found to be activated during driving in one neuroimaging study [32]. Avoidance of collisions was found to involve the mid- and anterior cingulate, precuneus, posterior parietal cortex, and bilateral ventrolateral prefrontal cortex [32]. Information processing, sensory–motor integration based on visual, proprioceptive, and auditory input, coordination, attention, memory, and decision-making are all critical components of consciousness and driving that are at risk of being impaired during seizures.

Seizures which cause loss of consciousness include three types: generalized tonic–clonic seizures (GTCs), complex partial seizures, and absence seizures. Generalized tonic–clonic seizures, or *grand mal* seizures, are perhaps the most widely known to the general public because of their association with convulsions. Generalized tonic–clonic seizures cause severe impairment of consciousness for the duration of the seizure and for a significant postictal period [29,33,34]. The impairment is likely caused by abnormal electrical activity in the brain affecting specific brain structures in the ictal and postictal periods [35–37]. Single photon emission computed tomography imaging during secondarily generalized complex partial seizures showed the involvement of regions of the brain important for consciousness [36]. In general, GTCs last about 2 min and cause profound impairment of consciousness along with convulsions; lasting impairment is found postictally for a significant duration as the patient recovers [29,33,34,38]. Patients are unable to remember events around the time of the seizure [34,38] and cannot perform simple tasks such as grasping a ball and visual tracking [33]. These seizures pose catastrophic risk if occurring during driving [21,39].

Complex partial seizures affect a focal region of the brain, often the temporal lobe, but are associated with loss or alteration of consciousness. An explanation for this mismatch, in effect, in temporal lobe epilepsy has been proposed and studied by our lab and others. The network inhibition hypothesis offers the following mechanism: focal seizure discharges in the temporal lobe are carried to subcortical structures via known anatomical connections and activate GABA-ergic neurons, causing powerful inhibition of subcortical arousal structures in the upper brainstem, thalamus, basal forebrain, and hypothalamus [29,40]. This results in the deactivation of the neocortex and impairment of consciousness. Intracranial electroencephalography (EEG) during complex partial seizures shows slow wave activity similar to that recorded during deep sleep and coma; on the other hand, simple partial seizures do not exhibit strong slow wave activity in the neocortex [41,42]. The network inhibition hypothesis is borne out by animal and human studies linking activity in subcortical regions to slow wave activity and decreased blood flow in the neocortex [40]. Cutting the fornix prevented the spread of seizures to subcortical regions and spared behavioral arrest in rats [41], and other recent work showed that subcortical neurons important for arousal are inactivated during limbic seizures in rats [43]. Complex partial seizures last 1–2 min and are associated with an alteration of consciousness but sometimes spare automatic or simple functions such as grasping a ball and visual tracking [33]. It is unclear whether a more challenging task such as driving might be spared, even partly, during some complex partial seizures.

Absence seizures are most commonly found in children and are associated with abrupt onset and offset of brief (5–20 s) behavioral arrest. Abnormal hypersynchronous oscillations in thalamocortical networks are thought to be central to the generation of the characteristic spike–wave discharge seen on EEG and to ictal impairment of consciousness [44–46]. Behavioral testing during absence seizures shows that simple tasks such as repetitive tapping are relatively spared compared with more complex tasks involving higher-order processing [45,46]. It is unclear whether the short duration and sparing of simple behaviors during absence seizures would lead to partial sparing of driving ability.

Perhaps, seizures that do not impair consciousness, including auras and simple partial seizures, are the most important to characterize in relation to driving. These seizures are focal but vary greatly in the regions of the brain affected and, therefore, cause symptoms which may have variable effects on driving. Whether ictal effects of simple partial seizures or interictal effects of brief epileptiform discharges are benign during driving has not been fully studied.