Original article

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Seizure-related adverse events during video-electroencephalography monitoring

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ABSTRACT – *Aim*. The aim of this study was to characterise seizure-related adverse events during video-electroencephalography (vEEG) monitoring. *Methods*. Our study evaluated adverse events in 230 epilepsy patients during vEEG monitoring while patients were awake and asleep. *Results*. A total of 588 seizures were recorded and 231 adverse events were identified including electrode displacement (14.5%), aspiration risk (8.5%), urinary incontinence (7.5%), postictal psychosis (5.8%), tongue biting (5.3%), and patient falls (0.5%). No severe types of adverse events were observed, such as choking or aspiration pneumonia. Of the seizures recorded, 39.1% occurred while patients were sleeping and 38.5% of adverse events occurred during this time, which included electrode displacement (48.2%), aspiration risk (28.0%), tongue biting (60.0%), postictal psychosis (16.7%), patient falls (66.7%), and urinary incontinence (38.6%). *Conclusion*. The occurrence of seizure-related adverse events during vEEG monitoring is mild. vEEG is an acceptably safe procedure for epilepsy research and precautions should be put in place to prevent these events.

Key words: video-electroencephalography, seizure, adverse events, epilepsy, risk, injury

Video-electroencephalography (vEEG) is now widely applied to diagnose epilepsy and classify seizures in children and adults (Nordli, 2006). Due to economic development, vEEG monitoring is now much more common and is present in a variety of clinical settings, including tertiary hospitals, general hospitals, outpatient centres, and doctors' surgeries.

Previous studies reported that patients with epilepsy show an increased risk for physical injury with the following primary injuries: head injury, dental injury, soft tissue injuries, and fractures (Appleton, 2002; Beghi and Cornaggia, 2002; Lees, 2010). However, surprisingly little is known about the frequency of these complications during vEEG monitoring. During monitoring, the risk of harm due to seizures may be lower than in the community because safety precautions are in place to address increased seizure activity and avoid falls. Furthermore, many potentially dangerous situations faced in daily life, such as driving, cooking, bathing, and

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swimming, are of course absent in the hospital setting. However, during diagnostic and pre-surgical evaluations, medication is often withdrawn and this, as well as other provocative measures used, may exacerbate the frequency and severity of seizures and the risk of associated injury may be increased (Arzy *et al*., 2010). These procedures may therefore place the patient at a greater risk of prolonged or recurrent seizures leading to a higher rate of seizure-related injuries (Sanders *et al*., 1996). Additionally, environmental changes may also increase the rate of seizures, including events such as electrodes lodged in patients or when patients are restrained.

Despite dedicated staff in many epilepsy monitoring units and the use of constant observation by health care professionals, some seizure-related adverse events (AEs) still occur during vEEG monitoring. The aim of this study was therefore to characterise the seizure-related AEs during vEEG monitoring.

Materials and methods

Subjects

We retrospectively reviewed a series of 230 patients registered in our database. All of these patients underwent vEEG monitoring in the Military General Hospital of Beijing People's liberation Army between October of 2010 and April of 2011. Only patients who had seizures were included in this study. Patients with exclusively psychogenic, non-epileptic events or who had undergone intracranial EEG studies were excluded. The patient population included 116 males and 80 females and the ages of the patients ranged from eight months to 85 years (mean: 32 years).

Monitoring and observation methods

Our centre is equipped with nine monitoring beds with digital vEEG systems (Nicolet), including two beds with 128 channels, two beds with 64 channels, one bed with 40 channels, and four beds with 32 channels. The centre is continuously staffed by registered nurses, vEEG technicians and physicians with specialised epilepsy training. The centre provides full 24-hour care by dedicated technicians or physicians during the week days and nurses during night-time and weekends.

The scalp electrodes were placed according to the international 10-20 system. All vEEG recordings included a single-channel electrocardiogram monitor. Collodion was used to enhance the attachment of electrodes to the scalp. Bandages and elastic hats were used to fix the electrodes to the head, and electrodes were attached to the ears and chest wall using adhesive plasters. To increase the likelihood of capturing events in a timely fashion, it is standard practice to use activating procedures such as reduction of antiepileptic drugs, sleep deprivation, hyperventilation, or photic stimulation. Antiepileptic medications were tapered or discontinued on a case-by-case basis, according to the judgment of physicians and not according to protocol. Usual practice involves tapering of medication during the course of several days.

In our epilepsy centre, a family member was required to remain in the room with the patient. Before the vEEG monitoring, the purpose of the procedure and its potential risks were explained. In addition, patients were provided access to a portable alarm system and were asked to record any events on the nursing staffs' observation chart. While monitoring, the patients were permitted to drink and eat normally, but chewing gum or other non-essential foods was not allowed. A private bathroom was located in each of the monitoring rooms, however, urine and stools were collected in bed or beside the bed. The use of the bathroom was only permitted when accompanied by a nurse. In our monitoring centre, the beds were protected by side rails covered with thick sponge.

In our centre, nursing staff could provide bedside assessment and supplementary oxygen as well as suction apparatus, lateral decubitus positioning (per standardised protocols), and assessment of need. A staff member would stay with the patients during the seizure.

The number, type, and timing of recorded seizures were assessed according to the international classification of seizures (Engel, 2001). We also recorded whether the patients were sleeping when the seizure occurred.

All the seizure-related events, reported by patients or objectively visualised by our investigators when monitoring, were recorded. AEs were considered as events which could jeopardise patient safety, have a significant effect on vEEG monitoring or inconvenience patients. Other seizure-related events, such as the destruction of monitoring beds or side rails, were excluded. AEs were finally summarised and classified. Because all patient data were anonymous, this research study did not require ethical approval.

Data analysis

Categorical variables were summarised using frequencies and percentages.

Results

A total of 230 patients were admitted for vEEG monitoring. No seizures were recorded in 15.0% (34/230) of patients. Seizures were recorded in 85.0% (196/230) of patients who met the criteria for inclusion of this study. For these 196 patients, the mean time to first seizure was 1.59 days (ranging from 1-5 days). Mean monitoring duration was three days (standard deviation ±1, ranging from 1 to 9 days). Over the assessment period, a total of 588 seizure episodes were recorded in 196 patients; a median of three seizures per subject (standard deviation ±2, ranging from 1 to 20). Of these seizures, 8.5% (50/588) were simple partial seizures, 21.1% (124/588) were complex partial seizures, and 58.7% (345/588) were primary or secondary generalised tonic-clonic seizures. Because other types of seizures were less frequent, all other categories of seizures were combined into one category, which showed an incidence of 11.7% (69/588); 60.9% (358/588) of seizures occurred when patients were awake, while 39.1% (230/588) occurred when patients were sleeping.

Adverse Events

Overall, 231 AEs were recorded in 588 episodes of seizures. The seizure-related injuries were rare. No complications of aspiration pneumonia or neurogenic pulmonary oedema were noted. No patient required intubation, cardiopulmonary resuscitation, or transfer to the intensive care unit. No deaths occurred. We divided all AEs into two types; those that jeopardised patient safety including aspiration risk, tongue biting, and patient falls, and those that were simple inconveniences including electrode displacement, postictal psychosis, and urinary incontinence (*table 1*).

Type 1 Adverse Events

Because AEs such as aspiration risk, tongue biting, and patient falls are harmful to patients, we combined these into one category. Seizures can occur while patients are eating or drinking and emesis may sometimes occur ictally or postictally. These events may compromise airways or lead to aspiration risk. We therefore considered these factors as a single AE. In our study, these events were recorded in 50 seizures (39 whilst eating and 11 with emesis). The incidence of these seizures was 8.5% (50/588) and the frequency of this AE was 21.6% (50/213), the second most common AE. However, in our series, no severe AEs, such as chocking or aspiration pneumonia, were observed.

Of all the episodes, patients bit their tongues in 2.6% (15/588) of seizures, with an incidence of 6.4% (15/213), relative to all AEs. The incident was ascertained by recording by the patients and checking by our staff. In our study, this event was not severe. There was no need for surgery and only iodophors were used to sterilise wounds.

In our study, only three falls were observed with an incidence of 0.5% (3/588), which was the least common event with an incidence of 1.2% (3/213). These falls all occurred during the onset of generalised tonic-clonic seizures. Due to the severity of these seizures, the patients fell off their beds, but only caused minor soft tissue injuries which did not require any special medical treatment.

Type 2 Adverse Events

In our study, we also observed some AEs which did not compromise the safety of patients, but hampered the quality of the EEG, such as electrode displacement, postictal psychosis, or urinary incontinence. Electrode displacement was the most frequently recorded AE, which was caused by a severe seizure in 14.5% (85/588) of all seizures. Likewise, the incidence of electrode displacement was 36.8% (85/231), relative to all AEs. The electrodes attached to the patients' ears or on their chest walls were most easily displaced, as was the part of the electrodes attached to the patients'

Table 1. Adverse events of all seizure types.

Adverse events	**GTC**	**CPS**	**SPS**	**Other seizures**	**Sum *n* (%)**
Aspiration risk	31	10	3	6	50 (21.6)
Tongue biting	11	2	0	2	15 (6.4)
Urinary incontinence	31	8	0	5	44 (19.1)
Postictal psychosis	22	7	1	4	34 (14.7)
Electrode displacement	51	28	1	5	85 (36.8)
Patient falls	3	0	0	0	3 (1.2)
Sum *n* (%)	149 (64.5)	55 (23.8)	5 (21.7)	22 (9.5)	231

GTC: generalised tonic-clonic seizures; CPS: complex partial seizures; SPS: simple partial seizures.

heads. Nearly all of the electrodes attached to the head were displaced and it was necessary to reattach these electrodes in 5.9% (5/85) of these AEs.

We observed urinary incontinence in 0.8% (44/588) of all episodes with an incidence of 19.1% (44/213), relative to all AEs.

We observed postictal psychoses in 5.8% (34/588) of all episodes and in 4.6% (9/196) of all patients; the incidence of this event was 14.7% (34/213), relative to all AEs. Of 196 patients with epilepsy referred for vEEG monitoring, 36 patients had a history of psychiatric complications. Of the patients with psychiatric comorbidity, 22.2% (8/36) developed psychiatric complications during vEEG monitoring, whereas only 0.6% (1/160) patients without a history of psychiatric disorders developed psychiatric complications. All postictal psychoses lasted from two minutes to three hours, in both cases, and the psychosis resolved without intervention and did not delay hospital discharge.

In our study, we distinguished between seizure-related AEs in patients that were either awake or asleep. We found that 61.5% of AEs occurred when patients were awake (*table 2*), while 38.5% occurred when patients were asleep (*table 3*). However, the type of AE was different when patients were sleeping or awake. While patients were awake, electrode displacement was the most common event (31.0%), which was followed by aspiration risk (25.4%), postictal psychosis (19.7%), urinary incontinence (19.0%), tongue biting (4.2%), and patient falls (0.7%). When patients were sleeping, electrode displacement was also the most common event (46.1%) and was followed by urinary incontinence (19.1%), aspiration risk (15.7%), tongue biting (10.1%), postictal psychosis (6.7%), and falls (2.2%). Of all seizures, 39.1% occurred while patients were sleeping. In addition, 48.2% of all electrode displacement, 38.6% of all urinary incontinence, 28.0% of all aspiration risk, 60.0% of all tongue biting, 17.6% of all postictal psychosis, and 66.7% of all patient falls occurred while patients were sleeping.

Discussion

Successful diagnostic vEEG monitoring requires a balance between seizure-associated risk and the need to gain diagnostic information in a timely fashion. Previous work has largely focused on the efficacy and outcomes of vEEG, including studies on the risk of invasive EEG (Simon *et al*., 2003) and long-term monitoring (Haut *et al*., 2002). Few studies have reported AEs in detail (Angus-Leppan, 2007; Hui *et al*., 2007; Rose *et al*., 2003). This study provides a systematic assessment of the safety and seizure-related AEs of vEEG monitoring in a large population of consecutive patients.

When monitoring, there are some events which may be harmful to patients which we consider as AEs. Aspiration risk is the most dangerous adverse event. Noe *et al*. (2010) noted that 5.6% of seizures occurred while patients were eating or drinking, and 0.6% were followed by postictal emesis. The aspiration pneumonia rate was 0.2% for subjects with generalised tonic-clonic seizures (DeToledo *et al*., 2004). Mortality due to aspiration has been associated with long-term care facilities (Day *et al*., 2005). In order to avoid this event, non-essential eating such as chewing gum was not allowed in our centre. If this event occurred, the patients and their family were instructed to provide simple protection, such as cleaning the mouth quickly and maintaining the lateral decubitus position. We also provided protection for the patients including supplementary oxygen, suction apparatus, *etc*.

Tongue biting is classically considered to favour a diagnosis of epileptic seizure (Benbadis, 1995). Lateral tongue biting is also a lateralising sign in partial epilepsy (Benbadis, 1996). Tongue biting is common

Table 2. Adverse events of seizures in patients during wakefulness.

Adverse events	**GTC**	**CPS**	**SPS**	**0ther seizures**	**Sum *n* (%)**
Aspiration risk	22	7	3	4	36 (25.4)
Tongue biting	5	0	0	1	6 (4.2)
Urinary incontinence	19	5	0	3	27 (19.0)
Postictal psychosis	19	5	1	3	28 (19.7)
Electrode displacement	27	14	0	3	44 (31.0)
Patient falls	1	0	0	0	1 (0.7)
Sum *n* (%)	93 (65.5)	31 (21.8)	4 (2.8)	14 (9.9)	142

GTC: generalised tonic-clonic seizures; CPS: complex partial seizures; SPS: simple partial seizures.

Table 3. Adverse events of seizures in patients during sleep.

Adverse events	**GTC**	**CPS**	**SPS**	**Other seizures**	**Sum *n* (%)**
Aspiration risk	9	3	0	2	14 (15.7)
Tongue biting	6	2	0	1	9 (10.1)
Urinary incontinence	12	3	0	2	17 19.1)
Postictal psychosis	3	2	0	1	6 (6.7)
Electrode displacement	24	14	1	2	41 (46.1)
Patient falls	2	0	0	0	2 (2.2)
Sum *n* (%)	56 (62.9)	24 (27.0)	1 (1.1)	8 (9.0)	89

GTC: generalised tonic-clonic seizures; CPS: complex partial seizures; SPS: simple partial seizures.

and is often not considered as a physical injury in most articles. It is harmful to patients and if the injury is severe, medical treatment may be required, potentially leading to a medical dispute or lawsuit. We therefore considered tongue biting to be an adverse event. Generally, most patients bite their tongues during seizure onset, thus a quick response and appropriate first aid is essential in order to help prevent this injury.

Soft tissue injuries were reported to be common when seizures appeared outside of the hospital (Wirrell, 2006). Sanders *et al*. (1996) noted that falls are an important potential source of injury during vEEG monitoring. Shafer *et al*. (2011) conducted a survey of 70 epilepsy centres and found that patient falls were the most frequent AEs, affecting 68.6% of all centres. However, statistical analysis was not performed on the frequency. Dobesberger *et al*. (2010) evaluated 507 consecutive patients and found that the overall fall rate was 6 per 1000 days, as an inpatient. Of a total of 19 falls, three falls led to severe injuries resulting in one acute epidural haematoma (in the bathroom) and two common fractures of lumbar vertebrae. In new hospitals, most rooms have a private bathroom, which has been singled out as a high risk area for falls (Morgan *et al*., 1985). Patient falls were the least common event in our study, which only caused mild soft tissue injuries. We believe that the lower incidence was due to our management strategy, such as a protected bed, restraint of non-essential movement outside of the bed, and restraint of using the bathroom.

When monitoring, there are also some events which are unlikely to compromise patient safety, but have a significant effect on vEEG monitoring We therefore consider these events to be AEs, of which electrode displacement was the most common. In previous studies, only events where patients using intracranial electrodes pulled out or dislodged electrodes were considered as AEs (Shafer *et al*., 2010). In order to avoid this adverse event, scalp electrodes must be carefully applied. Our patients were observed for 24 hours and the electrodes could be quickly reattached.

Potential risk factors unique to the vEEG monitoring setting may include increased seizure frequency and clustering, increased seizure generalisation, and psychiatric AEs associated with antiepileptic drug withdrawal (Devinsky *et al*., 1995). Postictal psychosis may increase the risk of developing chronic psychosis and is associated with increased mortality (Logsdail and Toone, 1988). This event has been described in 6% of patients undergoing vEEG monitoring (Alper *et al*., 2001). Preparations should be made to manage developing psychosis, agitation, and combativeness during vEEG monitoring. Necessary interventions may include simple reassurance, reduction of environmental stimuli, use of restraints, or administration of sedative or antipsychotic medications.

Urinary incontinence was also a common adverse event. Utilising a urethral catheter could effectively prevent this event, however, since the incidence of this event was low, we believed this to be unnecessary.

In other studies, Noe and Drazkowski (2009) reported three (2.75%) of 109 patients with recorded seizures to have potentially serious cardiac abnormalities. Orthopaedic injuries occurred in 3.7% of the patients. All were vertebral compression fractures presenting with acute thoracic back pain that developed after a generalised tonic-clonic seizure. Interestingly, no severe AEs were observed in our study, as mentioned by Noe and Drazkowski (2009) and Shafer *et al*. (2011). In addition to our management strategy, some other reasons may have contributed to these differences, for example, most patients were in our centre for presurgical evaluation. The results of our study may not be representative of all epilepsy patients.

Safety measures should be put in place to avoid AEs. vEEG monitoring requires highly specialised interdisciplinary staff, who should be well aware of the risks of seizures (Buelow *et al.*, 2009). Likewise, the staff should be trained in order to appropriately assess and respond to any unusual or uncontrolled behaviour.

Any type of seizure may cause AEs and certain types carry a higher risk during vEEG monitoring. Tonic-clonic and myoclonic seizures are the seizure types reported to cause the most injuries (Appleton, 2002) and this is consistent with our study.

Increasing evidence suggests that considerable information can be obtained by vEEG recording while the patient is asleep (Halasz *et al.*, 2002). Our study is unique in that we recorded AEs while patients were sleeping. According to our statistics, the rate of electrode displacement during sleep was nearly the same as when patients had seizures during wakefulness. Because patients did not eat when asleep, the risk of aspiration was lower. The risk of postictal psychosis was also lower, however, the risk of falls and tongue biting was much higher, most likely because the patients' family members were also asleep.

Conclusion

The occurrence of seizure-related AEs during vEEG monitoring is mild indicating that vEEG is an acceptably safe procedure for epilepsy research. □

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

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