Long-term Video-EEG Monitoring for Paroxysmal Events

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Background: Long term video-electroencephalography monitoring (VEM) has been widely used for the diagnosis, classification, and management of seizures. Few studies have systemically examined its safety issues and clinical utility. This prospective study investigates the general clinical application of long term VEM in the management of paroxysmal events.

Methods: This study cohort consisted of patients admitted to the inpatient VEM unit at Chang Gung Memorial Hospital (Lin-Kou). Standard 19 channel scalp electroencephalography (EEG), electrocardiography (ECG), and simultaneous video images were recorded continuously for 2 full days. Patient characteristics, and clinical, video-EEG and safety data were obtained and analyzed. The diagnosis and management of paroxysmal events before VEM were compared with those after VEM.

Results: Habitual events were recorded in 54.3% of the 129 patients, and VEM had a yield rate of 76% (events recorded or newly recorded interictal discharges) in determining the nature of the events. Eleven patients had seizure clusters, but there was no status epilepticus or electrode-related injury. After VEM, the diagnostic categories were changed in 41.1% of the patients, and 40.3% had revisions in management.

Conclusions: Long term VEM is a safe diagnostic tool providing a high diagnostic yield rate and directing adjustment of management for patients with paroxysmal events.

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Key words: video-EEG, epilepsy, nonepileptic seizure

Epilepsy is characterized by spontaneous recurrent seizures resulting from transient neuronal hypersynchronization of the cerebral cortex. Approximately two-thirds of epilepsy patients can be treated properly by medication.[1] Therapy based on an inaccurate diagnosis of seizures or estimation of seizure frequency contributes to failure of medical treatment for epilepsy.[2,3] A detailed clinical description of epileptic events is the basis for a diagnosis of epilepsy or other paroxysmal disorders. However, the clinical history may not be sufficient because of inaccurate or incomplete information from untrained witnesses.[4] Routine scalp electroencephalography (EEG) may provide objective evidence for diagnosis

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but is limited due to the short recording time and lack of concomitant video images.[5]

A video-EEG (VEEG) examination correlating electro-clinical features is useful in determining the seizure classification and clarification of nonepileptic attacks.[4,6-8] Long term video-EEG monitoring (VEM), initially reserved only for evaluation before epilepsy surgery, is now in widespread use. In addition to surgical localization and identification of candidates for epilepsy surgery, prolonged VEM can also be used to diagnose the nature of paroxysmal events, diagnose epilepsy syndrome, quantify seizure frequency or interictal epileptiform discharges, and assess precipitating factors.[9-17] However, only a few studies have comprehensively examined the overall utility of VEM.[4,6,7,18-22] Its efficacy, cost effectiveness, and safety need to be further clarified. This prospective study investigated the general clinical application of long term VEM for the management of paroxysmal events.

METHODS

Patients

We systematically collected the clinical and VEM data of patients admitted to the VEM unit in Chang Gung Memorial Hospital (Lin-Kou Medical Center) from June 2006 to January 2007. VEM was done for the following reasons: (1) differential diagnosis of paroxysmal events; (2) classification of seizure types or epileptic syndromes; (3) localization of epileptic foci and/or presurgical evaluation for epilepsy surgery; and (4) assessment for discontinuing antiepileptic drugs (AEDs). All patients were followed up until November 2007.

Video-EEG monitoring

Patients were admitted and received VEM continuously for a period of 2 full days (at least 48 hours). The VEEG equipment was housed in a 2-bedroom inpatient procedure unit. The VEEG recording consisted of a digitized 10-20 system 19-channel EEG, a 1-channel electrocardiogram, and simultaneous digital audiovisual data using the Nicolet-BMSI 6000 system (Nicolet Biomedical, Inc., Madison, WI, U.S.A.). The time of onset and features of the paroxysmal events were separately recorded by nursing personnel and patients/families. Safety issues related to VEM, including electrode-related injuries, seizure clusters, status epilepticus, and seizure-related trauma, were carefully monitored.[21-23] Sphenoid electrodes were added for patients with ictal or interictal discharges recorded during VEM. Additional channels (electrooculogram, electromyogram, thermistor, plethysmography, and pulse oximeter) were added for polysomnography in patients having nocturnal events exclusively.[24,25] A dosage reduction protocol was applied for patients with few seizures (except for patients planning to discontinue AED). The AEDs were reduced to a half dose on the first day, and stopped on the second day if no events were recorded. Once the targeted events were recorded twice, the patients were asked to take an additional dose of AEDs, and resume the usual AED regimen. All patients were closely observed in the ward for a period of at least 24 hours to determine if they were seizure-free. Seizure precipitants such as sleep deprivation, exercise, and flashing lights were applied when appropriate.[26]

Event determination

First, a trained EEG technician and an epileptologist visually scanned all VEEG data and marked specific events. Special attention was paid to the onset of events recorded by patients or caregivers. All events identified were condensed and further reviewed by 2 of the authors independently. The targeted events were classified into one of the following three categories: (1) epileptic seizure, when a concurrent ictal EEG pattern was demonstrated; (2) psychogenic nonepileptic seizure (PNES), defined as an event mimicking an epileptic seizure but devoid of concurrent ictal or post-ictal EEG changes; and (3) other nonepileptic event, defined as a physiologic event (cardiogenic or metabolic cause) or event related to other neurological diseases (such as sleep disorders, movement disorders, migraine, or transient ischemic attack).

Consensus diagnosis

A "consensus diagnosis" was made at a comprehensive meeting of the staff of the epilepsy section (6 attending epileptologists, a neurosurgeon, pediatric neurologist, and radiologist) after the patient history, seizure semiology, VEM data, and neuroimaging modalities were compiled. The diagnosis was categorized as (1) epileptic seizures, including partial

epilepsy, idiopathic generalized epilepsy, or symptomatic generalized epilepsy, identified by the criteria proposed by the Commission on Classification and Terminology in 1989;[27] (2) nonepileptic diseases, including PNES with or without epilepsy, sleep disorders, movement disorders, and others; and (3) uncertain diagnoses. The pre-admission diagnosis and management were compared with that after VEM examination. Patients who had been seizure free for more then 3 years were advised to continue AEDs if residual epileptic or epileptiform discharges were detected during VEM.

RESULTS

Patients and clinical data

A total of 129 consecutive patients were enrolled for VEM over the period of study. Patient characteristics, referral sources, and indications for VEM are summarized in Table 1. Previous routine EEGs revealed epileptiform discharges in 40 (31.0%) patients. Twenty-one of the 129 patients had a confirmed diagnosis of epilepsy, and were admitted for epileptogenic foci localization or evaluation for tapering an AED; the remaining 108 patients were admitted for differential diagnosis of paroxysmal events and classification of seizure types.

Table 1. Data of 129 Patients Admitted for VEM

Mean age (years)	38.3 (7-89)
Female	57 (44.1%)
Mean disease duration (years)	7.2 (0-42)
Referral source	
Epileptologist	110 (85.3%)
General neurologist	16 (12.4%)
Others	3 (2.3%)
Aims for VEM	
Differential diagnosis of paroxysmal events	69 (53.5%)
Classification of seizure types	39 (30.2%)
Presurgical evaluation	12 (9.3%)
Planning to discontinue AEDs	9 (7.0%)
Epileptiform discharges on routine EEG	40 (31.0%)

Abbreviations: VEM: video-electroencephalography monitoring; AED: antiepileptic drug.

VEM findings

Habitual events were recorded in 70 (54.3%) of the 129 patients. Fig. 1 summarizes the identified events. Epileptic events were recorded in 22 (17.1%) patients, and 3 of them also had PNES. Sixteen (12.4%) patients had PNES only. Interictal discharges (IDs) were identified in 51 (39.5%) patients. In 28 of the 51 patients, previous EEG did not demonstrate any IDs. Overall, the VEM had a positive yield (events or IDs recorded) rate of 76% in 129 patients. Eleven patients had clustered seizures (more than 3 events in 24 hours), but no status epilepticus ensued. No seizure-related trauma or electrode-related injury was noted in these 129 patients receiving VEM.

Changes in diagnosis and management

Table 2 summarizes the diagnostic categories before and after VEM. Excluding the 21 patients who already had a definite diagnosis of epilepsy (those admitted for presurgical evaluation or planning to discontinue AEDs), 108 patients were admitted for differential diagnosis of paroxysmal events or classification of seizure types or syndromes. The diagnosis was changed in 53 (49.1%) of the 108 patients. The number of patients with partial epilepsy was reduced from 75 (69.4%) to 40 (37.0%), and

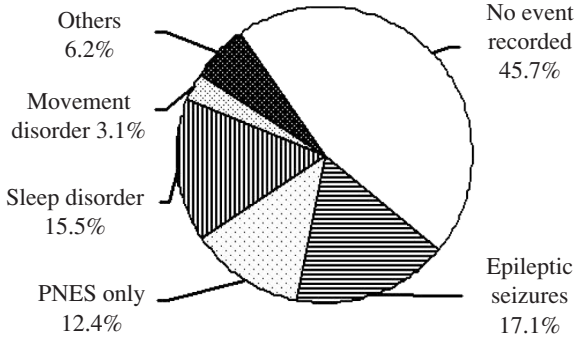

Fig. 1 Patient (n = 129) categories according to events recorded. Habitual events were recorded in 70 (54.3%) of 129 patients. Twenty-two (17.1%) patients had epileptic seizures, and 3 of them also had psychogenic nonepileptic seizures (PNES). Sixteen (12.4%) patients had PNES only. The other 32 (24.8%) patients had events classified as sleep disorders (20 patients), movement disorders (4 patients), and others (1 had sensory symptoms of cervical radiculopathy, 1 had hemifacial spasm, 2 had aura of migraine, and 4 had unclassified events).

Table 2. Diagnostic Categories before and after VEM

Diagnostic category	Total 129 patients		108 patients*	
	before VEM	after VEM	before VEM	after VEM
Partial epilepsy	94 (72.9%)	59 (45.7%)	75 (69.4%)	40 (37.0%)
Idiopathic generalized epilepsy	7 (5.4%)	3 (2.3%)	5 (4.6%)	2 (1.9%)
Symptomatic generalized epilepsy	2 (1.6%)	1 (0.8%)	2 (1.9%)	1 (0.9%)
Nonepileptic neurological diseases†	3 (2.3%)	56 (43.4%)	3 (2.8%)	56 (51.9%)
Uncertain	23 (17.8%)	10 (7.8%)	23 (21.3%)	9 (8.3%)

Abbreviations: *: Patient groups excluding those with definite diagnosis of epilepsy (patient categories of presurgical evaluation and planning to discontinue AEDs) before VEM examination; †: Nonepileptic neurological diseases included psychogenic nonepileptic seizures, movement disorders, and sleep disorders.

uncertain diagnoses from 23 (21.3%) to 9 (8.3%). On the other hand, there was a significant increase in the number of patients (from 2.8% to 51.9%) diagnosed with nonepileptic diseases (including PNES, sleep disorders, movement disorders, and others). After VEM, 56 patients were classified as having nonepileptic diseases, and their final diagnoses are summarized in Table 3. Before VEM, the paroxysmal events of these 56 patients were considered to be partial seizures in 38 (67.9%) patients, idiopathic generalized epilepsy (IGE) in 2 (3.6%) patients, nonepileptic diseases in 2 (3.6%) patients, and uncertain diagnosis in 14 (25.0%) patients.

Fig. 2 demonstrates 52 (40.3%) of the 129 patients had a change in management after VEM. AEDs were initiated in 8 patients whose events were confirmed to be epileptic. Clonazepam for periodic limb movement disorder (PLMD) or a dopamine agonist for restless leg syndrome (RLS) was started in 6 patients. Six patients underwent tapering of AEDs after VEM confirmed the habitual events were nonepileptic (average 2.2 years after AED was initiated). Nine patients were planning to discontinue AEDs and received VEM examination. Four of them had totally normal EEGs and underwent a drug discontinuation program. During the 10-month follow-up period, one patient had seizure relapse in the second month. The other 5 patients with residual epileptiform discharges on VEM were advised to continue AEDs and remained free of seizures.

DISCUSSION

Accurate diagnosis of paroxysmal events is

Table 3. Diagnosis of 56 Patients with Nonepileptic Diseases after VEM

Diagnosis	No.
Psychogenic nonepleptic seizures (PNES)	19
Sleep disorders	22
NREM parasomnia	11
Periodic limb movement disorder	4
Restless leg syndrome	2
REM sleep behavior disorder	1
Rhythmic movement disorder	1
Obstructive sleep apnea syndrome	1
Psychophysiological insomnia	1
Nocturnal behavioral spells	1
Movement disorders	4
Paroxysmal kinesigenic dystonia	1
Paroxysmal nonkinesigenic dystonia	1
Segmental dystonia	1
Cortical myoclonus	1
Other nonepileptic disorders	11
Sensory symptoms from peripheral neuropathy	1
Hemifacial spasm	1
Syncope	1
Episodic vomiting	1
Aura of migraine	2
Metabolic encephalopathy	2
Not clarified	3

Abbreviations: NREM: non-rapid eye movement; REM: rapid eye movement.

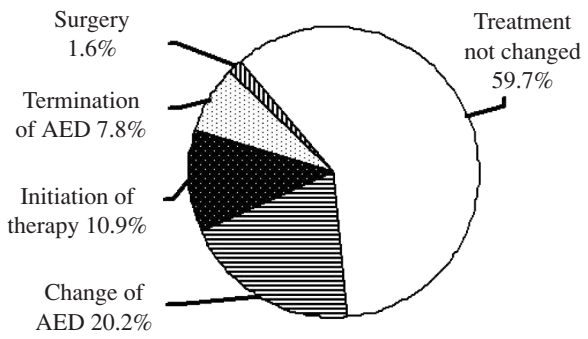

Fig. 2 Management changes after VEM (n = 129). Management was changed in 52 (40.3%) of 129 patients as demonstrated in each category.

essential for proper treatment. However, a clinical history with a routine scalp EEG may not be sufficient for a precise diagnosis. Simultaneous video-recording of habitual episodes with ongoing EEG offers an unequivocal diagnosis of paroxysmal events. This electro-clinical correlation has been achieved by video-EEG examination. Using VEM, the present study recorded habitual events in 54.3% of the 129 patients. The overall yield rate (events or new IDs recorded) was 76%, which is similar to previous studies (72% to 74.8%).[4,7,13] A higher recorded event rate of 69% in the study of Ghougassian et al. was probably related to a longer duration of VEM (mean 5.6 days).[7] This relationship was further supported by another VEM study in 1000 children.[13] The detection of IDs in an EEG, in addition to recording habitual events, provides valuable evidence that an event is epileptic. Although repeated or prolonged scalp EEG increases the detection rate of IDs,[5] the current study suggests a 2-day duration of VEM is sufficient to provide a high yield of recording events or IDs. Only 7.8% of the 129 patients had uncertain diagnoses after VEM.

At least 20% of patients referred to comprehensive epilepsy programs do not have epilepsy.[17,28-30] Previous studies reported 14% to 42% of patient populations with paroxysmal events had PNES or events secondary to physiologic conditions.[3,4,13,31-33] Confirmation of the correct diagnosis may eliminate unnecessary AEDs and lead to appropriate treatment.[17] An 84% reduction in medical costs was reported in patients whose diagnoses of habitual events were revised to PNES after VEM.[34] In one study, the clinician's predictive accuracy in identifying PNES prior to inpatient VEM was approximately 50%,[35] and another study reported that patients with PNES were diagnosed 7.2 years after manifestation.[36] Even for epilepsy specialists, the misdiagnosis rate when diagnosing seizure disorders before VEM was also higher than 20%.[33] Simultaneous video and EEG monitoring is the gold standard in differentiating epileptic and nonepileptic events. In the current study, the application of VEM identified the target paroxysmal event as nonepileptic in 56 patients. The target events were diagnosed as sleep disorders in 22 patients, PNES in 19 patients, movement disorders in 4 patients, and other nonepileptic disorders in 11 patients. Seventeen of the 56 patients had been previously diagnosed with epileptic seizures; the background epilepsy history and appearance of IDs in routine EEG may have led to a misdiagnosis of the target habitual events. PNES and sleep disorders were the common concomitant neurological conditions in these 17 patients with epilepsy. This is consistent with the previous VEM studies which reported that staring episodes in the pediatric population, and PNES in the elderly were the most commonly encountered nonepileptic paroxysmal events.[17,28,30,37] Overall, 53 (41.1%) of the 129 patients had a change in diagnosis after VEM, which is similar to previous reports in which 24% to 47.5% of patients had a diagnosis change.[3,7,33] As a result, 52 (40.3%) of the current 129 patients had a management change, which is similar to the study of Chen in which 45% of 230 patients had alteration in management.[6] AEDs were eliminated in 6 patients whose habitual events were nonepileptic (average 2.2 year delay after misdiagnosis). Clonazepam or dopamine agonists for sleep disorders were prescribed for 6 patients with restless leg syndrome or periodic limb movement disorder.

Safety issues related to VEM include frequent seizures (clustered seizures and status epilepticus), seizure- related behavior (ictal or post-ictal aggression, self-injury, and psychosis), falls, and electrode-related injury (pulling out scalp or surgically implanted electrodes).[23] There were no electrode-related injuries in the current study, but 11 episodes of clustered seizures (more than 3 events in 24 hours) were recorded in 22 patients with epileptic events. This is comparable with previous reports of clustered seizures in 48.3% and 61.5% of patients

receiving VEM.[20-22] There was no status epilepticus or seizure- related trauma. Patients receiving VEM in the current study followed a strict drug reduction protocol and an adequate hedge against seizures evolving to status epilepticus. A well-planned AED reduction and reinstitution protocol resulted in safe recordings in the 2-day VEM, as suggested in a previous study.[20]

Whether and when to withdraw AEDs are common issues for which there is still no consensus. Nine patients were admitted for VEM to evaluate the possibility of AED discontinuation after being seizure-free for more than 3 years. Five patients had interictal epileptiform discharges and were advised to continue their AEDs without dosage adjustment, and remained seizure free. Four patients received an AED tapering protocol after VEM. Three patients were seizure free during 10 months follow-up, and their brain magnetic resonance images (MRI) were negative. One patient had seizure recurrence during the second month. Brain MRI study showed left hemicerebral atrophy, and an EEG revealed focal slow waves over the left temporo-occipital area and no epileptiform discharges. This is consistent with a previous report stating that symptomatic epilepsy (compared to idiopathic epilepsy) and adolescent onset epilepsy (compared to that of childhood onset) were relative risk factors for seizure recurrence.[38] The prognostic value of VEM in AED discontinuation needs further clarification in a larger patient group.

In conclusion, 2-day VEM provides a high yield rate in recording paroxysmal events and identifying IDs. A strict AED reduction and reinstitution protocol helps to reduce the occurrence of seizure clustering or status epilepticus. Long-term VEM is a safe diagnostic tool that guides treatment appropriate for individual patients with episodic events. Further study is undergoing to clarify the application of VEM in a patient plan to taper AED.

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長時間影像腦波監測在陣發症狀之臨床應用

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背 景： 長時間影像腦波監測已被廣泛運用於癲癇的診斷、分類以及治療之選擇，目前僅少數研究有系統地檢測其安全性議題與臨床效用。本前瞻性研究探討長時間影像腦波監測在“陣發症狀”之實際應用。

方 法： 2006 年 6 月至 2007 年 1 月住院接受長期監測的患者，同步記錄其標準 19 頻道腦波、心電圖與影音資料，連續記錄二整天。統合分析臨床、影像腦波與安全性資料，比較住院前與腦波監測後病症的診斷及治療處置。

結 果： 腦波監測 129 位患者中，有 54.3% 記錄到慣常之陣發症狀。腦波監測於陣發症狀有 76% 診斷率。長時間影像腦波監測是一項安全的檢查，僅 11 位患者發生無傷害之叢發性發作，未有癲癇重積狀態或監測過程相關之傷害。腦波監測後診斷類別有更動者有 41.1%，其中以非癲癇性發作這項診斷的改變最爲顯著。依據腦波監測結果，有 40.3% 患者改變其治療方式。

結 論： 長時間影像腦波監測是安全的腦電生理學檢查，對臨床“陣發症狀”具有高診斷價值，同時能導正此類患者之治療方向。

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關鍵詞：影像腦波，癲癇，非癲癇性發作

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