Usefulness of long-term video-EEG monitoring in children at a tertiary care center

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The value of video-electroencephalographic monitoring (EEG-VM) in evaluating patients with epileptic disorders constitutes a major research field. This study investigates the usefulness of inpatient long-term EEG-VM for pediatric neurology patients under four headings: pre-surgical evaluation; seizure classification; epileptic seizure and non-epileptic paroxysmal event differentiation; and antiepileptic drug (AED) treatment modification. A retrospective study of 101 patients over a one-year period was carried out. The results showed that following EEG-VM, 57.4% of the patients were referred for discussion to the epilepsy surgery conference regarding resective surgery, and of these, 31% were deemed to be surgical candidates. The seizure classification assigned to the patients before EEG-VM changed in 73.3% of the patients after EEG-VM. Regarding the differentiation between epileptic seizure and non-epileptic paroxysmal events, a diagnosis of psychogenic non-epileptic seizure (PNES) was made in 4% of the patients after EEG-VM. EEG-VM outcomes led to the modification of AED treatment in 68.3% of the patients. These significant alterations demonstrate the usefulness of EEG-VM in the management of pediatric neurology patients.

Key words: epilepsy, long-term video-EEG monitoring, children.

Video-electroencephalographic monitoring (EEG-VM) is a valuable tool in evaluating patients with epileptic disorders[1-8]. This retrospective study of 101 pediatric neurology patients over a one-year period investigated the usefulness of inpatient long-term EEG-VM in evaluating candidates for resective surgery; classifying seizures; differentiating between epileptic seizure and non-epileptic paroxysmal events; and in modifying antiepileptic drug (AED) treatment.

Material and Methods

This study was conducted in the EEG-VM Unit of Hacettepe University Children's Hospital, a tertiary care teaching hospital in Ankara, Turkey.

Medical records of 101 children admitted as inpatients for long-term EEG-VM between 3 January 2012 and 3 January 2013 were analyzed. Age range was from 6 months to 17 years (mean: 9.4±4.8 years). Fifty-seven patients (56.4%) were male. The average duration of monitoring was 4.2±2.7 days (range: 1-17 days). Additional patient information is provided in Table I.

The data sources included the Pediatric Neurology Unit's patient charts, Nurse Diaries of events during EEG-VM, EEG-VM Reports, and Epilepsy Surgery Conference Outcome Reports.

In the EEG-VM Unit, data are digitally recorded using Grass-Telefactor equipment. A 32-channel EEG is evaluated using longitudinal and transverse bipolar montages and reference montage. Scalp electrodes are placed using collodion according to the international 10-20 system of placement.

Statistical Analysis

Descriptive analysis, data tabulations, z-test, and t-tests were performed using STATA 10 and Microsoft Excel. A value of $p<0.05$ was taken as statistically significant.

Table I. Additional Patient Information

Patient		N	%
Age at first seizure (years) *Data from 100 patients as the information was not available for 1 patient.*	0-2	43	43.0
	3-6	29	29.0
	7-12	23	23.0
	>12	4	4.0
	No clinical seizures	1	1.0
Age at start of repetitive seizures (years) *Data from 76 patients as the information was not available for 25 patients.*	0-2	27	35.5
	3-6	23	30.3
	7-12	20	26.3
	>12	3	3.9
	No repetitive seizures	3	3.9
Frequency of seizures *Data from 92 patients as the information was not available for 9 patients.*	Daily	53	57.6
	Weekly	16	17.4
	Monthly	8	8.7
	< Monthly	8	8.7
	Irregular	5	5.4
	No clinical seizures	2	2.2
Antiepileptic drugs	Monotherapy	18	17.8
	Polytherapy	70	69.3
	None	13	12.9
History of trauma	Yes	56	55.4
	No	45	44.6

Results

Aim of EEG-VM and Surgical Conference Outcome

The aim of EEG-VM was categorized as shown in Table II. The results show that 45.5% of the patients were admitted for phase 1 pre-surgical evaluation.

Following EEG-VM, 58 patients (57.4%) were referred to the surgical conference, and 18 (31%) were deemed to be surgical candidates. Of the 46 patients admitted for phase 1 pre-surgical evaluation, 44 (95.7%) were referred to the surgical conference, and 25 (56.8%) were deemed not to be surgical candidates. Of the 55 patients admitted with aims other than phase 1 pre-surgical evaluation, 14 (25.5%) were referred to the conference, and of these, 2 (14.3%) were deemed to be surgical candidates. The surgical conference outcome was undetermined for 4 patients as it was decided that these patients required further tests before a final decision could be made.

Aim of EEG-VM and Age

The majority of patients admitted for phase 1 pre-surgical evaluation were aged 7 years and above. The majority of those admitted for differentiation between epileptic seizure and non-epileptic paroxysmal events were aged 6 years and below (Fig. 1).

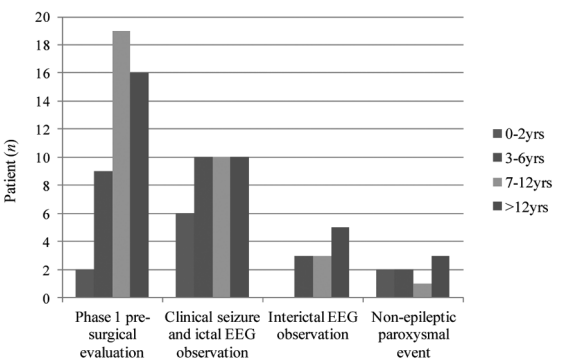

Fig 1. Aim of EEG-VM and patient age upon admission.

Table II. Aim of EEG-VM

Aim	Patient (n)	%
Phase 1 pre-surgical evaluation	46	45.5
Clinical seizure and ictal EEG observation	36	35.6
Interictal EEG observation	11	10.9
Differentiation between epileptic seizure and non-epileptic paroxysmal events	8	7.9
Total	101	100.0

EEG-VM: Video EEG monitoring

Table III. Classification of Seizures after EEG-VM and Surgical Conference Outcomes

Classification of seizures	Surgical conference outcome			Total Patient (n)
	Surgical candidate	Not a surgical candidate	Undetermined	
Simple partial seizure	4	0	1	5
Complex partial seizure	8	21	0	29
Generalized seizure	0	5	2	7
Partial seizure secondarily generalized	2	5	1	8
More than one type of seizure	1	2	0	3
No clinical seizures	3	3	0	6
Total Patient (n)	18	36	4	58

EEG-VM: Video EEG monitoring

Seizure

The mean age at first seizure was 4.4±4.2 years. The mean age at the start of repetitive seizures was 4.7±4.2 years.

In 24 patients (in whom AED tapering/termination was not applied for seizure induction during EEG-VM), the family reported daily seizures before EEG-VM, and of these, 20.8% were observed not to have daily seizures during EEG-VM ($p<0.01$) (t-test).

The classification of seizures before EEG-VM was categorized using the International League Against Epilepsy (ILAE)[9] as a guideline. The largest categories were complex partial seizure (CPS) (35.6%) and generalized seizure (GS) (34.7%). The classification of seizure categories changed after EEG-VM since psychogenic non-epileptic seizures (PNES) were observed. For 73.3% of patients, the seizure classifications assigned before EEG-VM changed after EEG-VM. Before EEG-VM, 2% of patients were reported to have no clinical seizures, whereas after EEG-VM, 32.7% were seen to have no clinical seizures. 34.7% of patients were classified as having GS before EEG-VM, whereas only 11.9% had a GS classification after EEG-VM. A diagnosis of PNES was made in 4% of patients (Fig. 2).

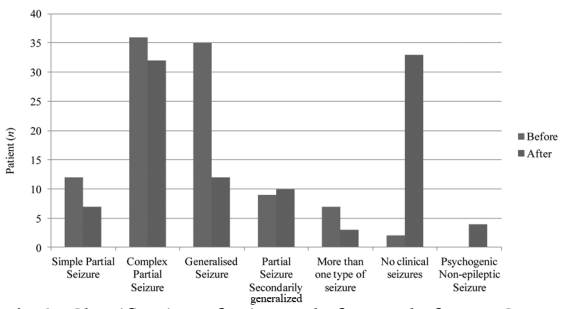

Fig 2. Classification of seizures before and after EEG-VM.

Moreover, seizure classification before and after EEG-VM was compared for each patient ($p<0.001$) (z-test). Patients in whom clinical seizures were observed during EEG-VM: Of 22 patients with CPS before EEG-VM, the classification changed in 8; of 24 patients with GS before EEG-VM, the classification changed in 18; of 6 patients with more than one type of seizure before EEG-VM, the classification changed in 6 patients.

The classification of seizures after EEG-VM and the surgical conference outcomes were compared for the 58 patients referred to the conference. Of the 29 patients classified as having CPS, 72.4% were deemed not to be

Table IV. EEG-VM Activity

EEG-VM	Total patient population (n)	%	Patients deemed not to be surgical candidates (n)	%
Background abnormality	4	4.1	1	2.9
Focal EA	26	26.5	9	26.5
Multifocal EA	18	18.4	11	32.4
Generalized EA	14	14.3	5	14.7
Secondary bilateral synchrony	12	12.2	6	17.6
Normal	24	24.5	2	5.9
Total	98		34	
	Data from 98 patients as the information could not be accessed for 3 patients.	100.0	*Data from 34 patients as the information could not be accessed for 2 patients.*	100.0

EEG-VM: Video EEG monitoring EA: epileptiform activitiy monitoring

surgical candidates. Of the 7 patients with GS classification, 71.4% were not surgical candidates (Table III).

Anti epileptic drug (AED) Treatment

Eighty-eight (87.1%) patients were on AEDs (20.5% monotherapy, 79.5% polytherapy) when admitted for EEG-VM. For 69 patients (68.3%), a modification in their AEDs was made after EEG-VM. Of the 88 patients on AEDs before EEG-VM, AEDs were terminated in 4.5%. Of the 13 patients not on AEDs before EEG-VM, AEDs were *initiated* in 23.1%.

EEG-VM and Surgical Conference

EEG-VM activities were categorized as shown in Table IV. 26.5% of the patients had focal epileptiform activity (EA), and 24.5% had normal findings. Among patients deemed not to be surgical candidates at the surgical conference, 32.4% had multifocal EA (Table IV).

Routine EEG

Routine EEG (rEEG) reports were brought by the family of 95 patients. rEEG findings were categorized as for EEG-VM activities. rEEG reports showed that 24.2% had generalized EA, and 24.2% had normal findings. A comparison between EEG-VM activity and rEEG findings showed that in 69.9%, the results were incompatible ($p<0.001$) (z-test). Moreover, EEG-VM activity and rEEG findings were compared for each patient. Best compatibility was for the normal category (Fig. 3).

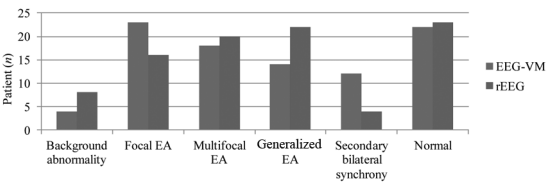

Fig 3. Comparison between EEG-VM activity and rEEG findings for each patient

EEG-VM and Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) scan findings of 93 patients were evaluated. Of these, 25 had normal findings, and half of the pathological findings were focal/unilateral. A comparison between EEG-VM activity and MRI scan findings showed that in 35.6%, the results were incompatible ($p<0.001$) (z-test).

Trauma

A comparison between history of trauma and surgical conference outcomes was done for the 58 patients referred to the conference. Of the 18 patients deemed to be surgical candidates, 61.1% had a history of trauma.

Discussion

The patient population in this study had a high seizure burden, with the majority having daily seizures (57.6%). 87.1% were on AEDs upon admission for EEG-VM, and of these, 79.5% were on polytherapy, reflecting the refractory nature of the seizures.

Seizure onset was at an early age (mean: 4.4±4.2 years), and 96% had repetitive seizures. The mean age at the start of repetitive seizures

was 4.7±4.2 years.

The mean age upon admission was 9.4±4.8 years. This is relatively high when compared to previous pediatric studies[2-4].

A comparison between age at first seizure and age upon admission showed an average delay of 5.2±4.5 years, which is long considering that patients continue suffering a high seizure burden[10-12].

The average duration of monitoring in this study was 4.2±2.7 days, longer than the averages reported by other pediatric studies[4,5,12,13]. Longer duration is associated with more conclusive EEG-VM outcomes[2].

Video electroencephalographic monitoring (EEG-VM) enables the selection of patients for referral to the surgical conference, and hence, the determination of those who are surgical candidates. In this study, 58 patients were referred to the conference, and 62.1% were deemed not to be surgical candidates. This is because the most severe cases, whom other tertiary centers failed to help, are referred to Hacettepe University Hospital for a comprehensive appraisal.

On the other hand, 50% of the patients who had no clinical seizures during EEG-VM were deemed to be surgical candidates because EEG-VM enabled the recognition of a focus in these patients.

An assessment of the relationship between the aim of EEG-VM and referral to the surgical conference has shown that the majority (95.7%) of those referred to the conference were those admitted for EEG-VM with the aim of phase 1 pre-surgical evaluation. This group also had the highest number of patients (36.4%) deemed to be surgical candidates. Among those admitted for EEG-VM with the aim of clinical seizure and ictal EEG observation; interictal EEG observation; and differentiation between epileptic seizure and non-epileptic paroxysmal events, 25.5% were referred to the surgical conference. Of these, 14.3% were deemed to be surgical candidates. This indicates the usefulness of EEG-VM in selecting candidates for surgery even when the main aim for monitoring is not pre-surgical evaluation.

The results revealed that the aim of EEG-VM is related to the age of the patients. For patients aged between 0-2 years, clinical seizure and ictal EEG observation is a priority because of the relative difficulty in classifying seizures based solely on family descriptions in this age group; hence the need for EEG-VM. On the other hand, the majority of patients monitored for phase 1 pre-surgical evaluation were aged 7 years and above. This is because AEDs are the first-line treatment in trying to decrease seizure burden, and a period of time is allowed to observe their effects. Should AEDs fail, it can be said that the seizures are intractable [6,11]. In this case, the next available option is surgery, by which time the patients are older.

Video electroencephalographic monitoring (EEG-VM) allows the accurate classification of seizures[7,12,14-17]. Before EEG-VM, classifications were largely based on seizure descriptions reported by the family[6,13]. In this study, 34.7% of patients were classified as having GS before EEG-VM, whereas only 11.9% of patients were found to have GS after EEG-VM. Family descriptions are subjective and carry the likelihood of exaggerating, overlooking, or misinterpreting certain symptoms, and hence can be misleading, resulting in inaccurate seizure classifications[6,13]. This highlights the value of EEG-VM for the correct classification of seizures.

The change in seizure classification before and after EEG-VM was analyzed for each patient. The classification changed in 82.9% of patients classified as having GS before EEG-VM. The greatest change was for patients classified as having more than one type of seizure (85.7%). This could be because some patients were discharged when sufficient information was obtained, and thus they did not stay long enough for the observation of multiple seizure types. On the other hand, the families might have described different symptoms of the same seizure as distinct seizure types. EEG-VM allows these distinctions to be made[1,15,16].

Video electroencephalographic monitoring (EEG-VM) is also crucial in distinguishing between epileptic seizure and non-epileptic paroxysmal events[3-5,13], and a diagnosis of PNES[7,18-20], leading to important modifications in the management of patients[12,18]. In this study, 4% of patients were diagnosed with PNES.

An assessment of the relationship between classification of seizures after EEG-VM and

referral to the surgical conference has shown that patients with CPS comprised the largest population referred to the conference (50%). The highest surgical candidate results are expected for CPSs; however, 72.4% of these patients were deemed not to be surgical candidates possibly because of the need for further investigations owing to extratemporal localization, the absence of a lesion, or the lesion being in an elegant cortex. On the other hand, 80% of those referred with simple partial seizure (SPS) were deemed to be surgical candidates presenting the highest surgical candidate results. AED treatment may have given rise to the transformation of CPS to SPS, which may be why SPS had the highest surgical candidate results.

Video electroencephalographic monitoring (EEG-VM) guides AED modifications for better control of seizures[21]. In this study, modifications were made in 68.3% of the patients. AEDs were initiated in 23.1% of patients not on any AEDs before EEG-VM, and were terminated in 4.5% of the patients on AEDs before EEG-VM. Interictal EEG observation through EEG-VM is particularly helpful in reducing the number and/or decreasing the dosage of AEDs. This was achieved in 7.9% of the patients.

A comparison between reported and observed seizure frequencies showed that daily seizures were not observed in 20.8% of patients during EEG-VM, despite being reported by the family. The constant care in the hospital environment may be a factor in reducing seizure frequency.

To further investigate the reason why 58.6% of those referred to the surgical conference were deemed not to be surgical candidates, the EEG-VM activity of these patients was evaluated. Multifocal EA and focal EA comprised the largest group. Unsuitability of multifocal EA for surgery, localization of the focal EA, absence of a lesion, or the young age of the patient are possible reasons why these patients were deemed not to be surgical candidates at the conference.

Compatibility between EEG-VM activity and rEEG findings was investigated, and 69.9% were incompatible. rEEG recordings last approximately 20-40 minutes[22]. This, when compared to long-term EEG-VM, is a limited time frame and might be insufficient to detect all abnormalities, which might explain the discrepancy[3]. Furthermore, rEEGs are interpreted by one trained observer, whereas during EEG-VM, there is continuous observation by trained nurses, interpretation by EEG technicians, and evaluation by professors, enabling a higher abnormality detection rate. Moreover, the compatibility results between EEG-VM activity and rEEG findings for each patient have shown that normal findings were the most compatible; incompatibilities occur for pathological findings[16].

encephalographie

Video electroencephalographic monitoring (EEG-VM) are often compared with MRI scans when planning patient management. In this study, 35.6% of EEG-VM and MRI scans were incompatible. Those patients with focal EA in EEG-VM, but exhibiting bilateral findings such as HIE in MRI scans, formed the incompatible group. This suggests that MRI scans alone are not sufficient in planning patient management, and should be considered together with EEG-VM recordings[8].

Finally, an interesting relationship was observed between history of trauma and surgical conference outcomes. In this study, 18 patients were deemed to be surgical candidates after EEG-VM, and 61.1% of these had a history of trauma. Considering the long waiting lists due to the limited availability of long-term EEG-VM units in Turkey and that one of the aims of EEG-VM is phase 1 pre-surgical evaluation, this finding raises the question as to whether patients with a history of trauma could be assigned a certain priority.

This retrospective study carries the limitation of a predetermined patient population consisting of the most severe cases with intractable epilepsy. There were no specific inclusion-exclusion criteria for the patients reviewed. This could restrict the application of the findings to other specific pediatric neurology populations.

A prospective study would be beneficial in verifying the validity of the findings in the long- term through patient follow-up.

In conclusion, this study is original in the specific categories it investigates for evaluating the usefulness of inpatient long-term EEG-VM in pediatric neurology patients. The findings support the usefulness of long-term EEG-VM in determining eligibility for resective

surgery; correcting the seizure classifications; identifying non-epileptic paroxysmal events; and guiding modifications in AED treatment, hence enhancing the management of epilepsy and leading to a better control of seizures, and at best, achieving freedom from seizures, thereby improving the patients' quality of life.

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