

# Electroclinical Characteristics of Status Epilepticus and Clustered Seizures Observed During Video-EEG Monitoring

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## Abstract

**Objective:** Video-electroencephalography (EEG) monitoring (VEM) has critical importance in epilepsy for exact diagnosis, differential diagnosis, and determination of surgical candidacy. However, reduction of antiseizure medications (ASMs) may trigger status epilepticus (SE) and clustered seizures, creating a safety risk. In this study, the frequency, electroclinical characteristics, acute treatment approaches, intubation requirements, and long-term outcomes of SE (convulsive/non-convulsive) and clustered seizures, as observed during VEM, were evaluated.

**Methods:** In a retrospective cohort study, 34 adult patients who developed SE or clustered seizures during VEM between 1994 and 2025 and who had complete emergency intervention records were analyzed. Demographic data, epilepsy type, provocation methods, EEG findings, seizure patterns, acute treatment strategies, and long-term management approaches were recorded.

**Results:** A total of 34 patients, 17 of whom were female, were included (mean age: 27.9±7.1 years). The most common type of epilepsy was temporal lobe epilepsy (n=13; 38.2%). SE or clustered seizures occurred around day 3 (range, 1-9) of hospitalization and followed an average ASM reduction of 60.0% in 70.0% of patients. The most frequent pattern was clustered seizures (41.2%), followed by postconvulsive non-convulsive SE (29.4%), isolated convulsive SE (20.6%), and isolated non-convulsive SE (8.8%). Seizure patterns showed a statistically significant difference according to electroclinical epilepsy localization; clustered seizure events were more frequently observed in extratemporal epilepsies, whereas postconvulsive non-convulsive SE was more common in temporal lobe epilepsy (p<0.05). SE patterns were more frequently associated with the presence of structural lesions on magnetic resonance imaging (p<0.05). During acute treatment, benzodiazepines and intravenous levetiracetam were sufficient for most patients; only 2 patients (5.9%) required intubation. During long-term follow-up, 52.9% of patients underwent surgery or neuromodulation.

**Conclusion:** SE and clustered seizures that develop early, and those that occur following marked ASM reduction, can be safely controlled with appropriate acute management. The association between seizure patterns and electroclinical localization of epilepsy indicates that data obtained during VEM play a major role in surgical and neuromodulatory decision-making and thereby improve the clinical value of VEM.

**Keywords:** Electroencephalography, epilepsy, status epilepticus, seizure, clustered, patient safety

## INTRODUCTION

During video-electroencephalography (EEG) monitoring (VEM), controlled reduction of antiseizure medications (ASMs), hyperventilation, sleep deprivation, and photic stimulation are frequently used to capture ictal events.<sup>1</sup> However, these interventions may increase the risk of status epilepticus (SE) and clustered seizures, particularly in patients with drug-resistant epilepsy, leading to patient safety concerns.<sup>2,3</sup> SE and clustered seizures may cause morbidity and mortality due to trauma, aspiration, hypoxia, and cardiorespiratory events.<sup>4</sup>

The contemporary classification of SE, based on defined time thresholds (t1/t2), has standardized diagnostic and therapeutic approaches and enabled rapid intervention algorithms in clinical practice.<sup>5</sup> However, non-convulsive SE (NCSE), particularly following convulsive seizures, may present with minimal clinical findings and prolonged confusion, making it easily overlooked. Continuous EEG monitoring during VEM is critical for detecting NCSE and preventing permanent neurological injury.<sup>6</sup>

Studies conducted in international centers have demonstrated that properly structured VEM protocols, including 24-hour supervision, seizure safety precautions, early benzodiazepine administration, and stepwise intravenous treatment can maintain serious complication rates at very low levels.<sup>7</sup> In contrast, aggressive use of activation methods or the presence of inexperienced teams are known to increase the risk of complications. Therefore, it is important for centers to present their own safety data and update their protocols in light of scientific evidence.

The objective of this study is to retrospectively examine, among events that developed during VEM hospitalization at the study center, the frequency, electroclinical characteristics, emergency treatment approaches, intubation requirements, and long-term outcomes of surgical or neuromodulatory treatment for convulsive SE, postconvulsive NCSE, isolated NCSE, and seizure clusters.

## METHODS

### Study Design and Population

In this single-center retrospective observational study, patients aged 18 years and older who were monitored in the VEM unit between 1994 and 2025 and developed SE or clustered seizures during the monitoring period were included.

Clinical and EEG data were obtained from the hospital information management system, the video-EEG archive, and the patient files, and recorded in a standardized data form, excluding personal identifiers. The collected variables included age, sex, epilepsy duration and syndrome, seizure type, ASMs and reduction rates, triggering factors (sleep deprivation, hyperventilation, photic stimulation, medication reduction), interictal and ictal EEG findings, day of occurrence during hospitalization, status/seizure type, ictal semiology and EEG pattern, acute treatment approach, intubation requirement, brain magnetic resonance imaging (MRI) findings, clinical response and discharge status, long-term treatment plan (medical follow-up, epilepsy surgery and/or vagus nerve stimulation), and duration of follow-up.

ASM tapering was performed in a patient-specific manner, taking into account seizure frequency, epilepsy type, and safety considerations. Dose reductions were implemented gradually during the first days of hospitalization. GABAergic ASMs (such as benzodiazepines and barbiturates) were reduced with greater caution because of their potential to lower the seizure threshold and to cause withdrawal-related seizure exacerbation.

Epilepsy types were classified as focal (temporal and extratemporal-frontal, parietal, or occipital, if clearly localized) or generalized. In focal epilepsies, cases in which the epileptogenic zone was considered to predominantly involve the temporal lobe, with extension to adjacent regions, were categorized as temporal-plus epilepsy.

SE was evaluated according to the International League Against Epilepsy 2015 definition and time thresholds; NCSE was confirmed based on the Salzburg criteria and continuous EEG findings.<sup>5,8</sup>

### MAIN POINTS

- Status epilepticus and clustered seizures that develop during video-electroencephalography monitoring most commonly occur around the third day of hospitalization and following reduction of antiseizure medication.
- Acute management with benzodiazepines and intravenous antiseizure medications allows successful control of most cases without the need for intubation.
- Seizure patterns vary with electroclinical localization; clustered seizures predominate in extratemporal epilepsies, whereas postconvulsive non-convulsive status epilepticus is more frequently observed in temporal lobe epilepsy.

Clustered seizures were defined as recurrent, brief seizure episodes occurring within a period of less than four hours.<sup>6</sup>

Approval from the Hacettepe University Health Sciences Research Ethics Committee was obtained for the study, and the research was conducted in accordance with the principles of the Declaration of Helsinki (decision no: SBA 25/972, date: 01.12.2025).

### Statistical Analysis

Statistical analyses were performed using SPSS software (IBM Corp., version 25). Categorical variables were presented as numbers and percentages, and continuous variables were presented as mean±standard deviation or median (minimum-maximum), as appropriate. The Kruskal-Wallis test was used for between-group comparisons, and exact tests were used for categorical variables. A *p*-value <0.05 was considered statistically significant.

## RESULTS

### Patient Characteristics

Among 2339 patients admitted for VEM between 1994 and 2025, a total of 34 adult patients who developed SE or clustered seizures and had complete emergency intervention records were analyzed; these included 17 females and 17 males.

The mean age of the 34 patients was 27.9±7.1 years, and the mean epilepsy duration was 18.0±9.0 years. Patients were using a median of 3 ASMs (range, 1-7) prior to admission.

In the electroclinical classification of the study population (n=34), temporal lobe epilepsy was the most frequent diagnosis (n=13; 38.2%). Extratemporal epilepsy was identified in 16 patients (47.1%), including frontal lobe epilepsy (n=4, 11.8%) and parietal lobe epilepsy (n=2, 5.9%). In addition, temporal-plus epilepsy was observed in 4 patients (11.8%), and generalized epilepsy was identified in 1 patient (2.9%).

Epileptogenic lesions on brain MRI were present in the majority of patients (76.5%; n=26), and hippocampal sclerosis and cortical dysplasia were the most common findings.

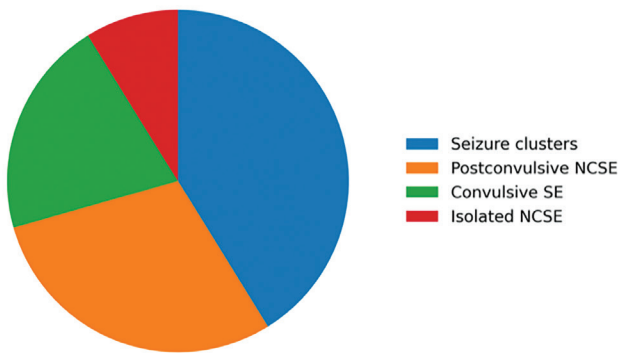
The clinical and electrophysiological characteristics of the patients are summarized in Supplementary Table 1.

### Characteristics of Status Epilepticus and Seizure, Clustered Events

The distribution of seizure patterns was as follows: clustered seizures in 41.2% (n=14), postconvulsive NCSE in 29.4% (n=10), convulsive SE in 20.6% (n=7), and isolated NCSE in 8.8% (n=3) (Figure 1).

SE or clustered seizures developed at a median of 3 days (range, 1-9) during VEM hospitalization. In 74.0% of patients, ASM dose reduction had been performed at the time of event onset, and in these patients, the mean reduction rate was 60.0% (range, 16.7-87.5%).

The most frequently reduced ASMs included levetiracetam, valproate, carbamazepine, and lamotrigine. GABAergic medications (benzodiazepines and phenobarbital) were generally



**Figure 1.** Distribution of seizure patterns. The figure shows the percentage distribution of seizure patterns observed during video-EEG monitoring in the study population. Seizure clusters were the most frequently observed pattern, followed by post-ictal NCSE, convulsive SE, and isolated NCSE  
EEG: Electroencephalography, SE: Status epilepticus, NCSE: Non-convulsive SE

tapered more cautiously and often later during monitoring than other ASMs.

In the acute management of SE or clustered seizures, intravenous benzodiazepines (diazepam) were used as first-line treatment, followed by intravenous levetiracetam as second-line therapy in most cases. In selected patients, intravenous valproate, phenytoin, or lacosamide was administered. Only 2 patients (5.9%) required intubation and midazolam infusion due to refractory events. No severe complications were observed.

**Long-term Outcomes**

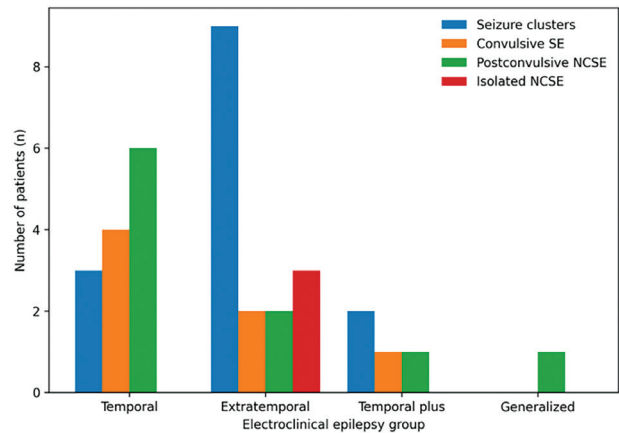
During long-term follow-up, 16 of the 34 patients (47.1%) were managed with medical treatment alone. Anterior temporal lobectomy ± amygdalohippocampectomy was performed in 6 patients (17.6%), and vagus nerve stimulation was implanted in 6 patients (17.6%).

Lesionectomy was performed in 3 patients (8.8%), and vagus nerve stimulation was planned for 3 patients (8.8%) who were awaiting surgery. In 1 patient (2.9%), anterior temporal lobectomy with amygdalohippocampectomy and vagus nerve stimulation were performed; in 1 patient (2.9%), hemispherotomy with amygdalohippocampectomy was performed; and in 1 patient (2.9%), anterior callosotomy was performed. In addition, 1 patient (2.9%) was presented to the surgical council for consideration of vagus nerve stimulation or lesionectomy.

**Distribution of Seizure Patterns According to Electroclinical Epilepsy Groups**

The distribution of seizure patterns noted during VEM across electroclinical epilepsy groups is shown in Figure 2. The distribution of seizure patterns differed significantly between epilepsy groups ( $p < 0.05$ ).

The frequency of clustered seizures was significantly higher in extratemporal epilepsies than in temporal lobe epilepsy (Fisher’s exact test,  $p < 0.05$ ). In contrast, the rate of SE was significantly higher in temporal lobe epilepsy; this difference was particularly



**Figure 2.** Distribution of seizure patterns according to electroclinical epilepsy groups. This figure shows the distribution of seizure patterns observed during video-EEG monitoring across electroclinical epilepsy groups (temporal, extratemporal, temporal plus, and generalized epilepsy). Seizure clusters were more frequent in extratemporal epilepsies, whereas post-ictal NCSE was more commonly observed in temporal lobe epilepsy  
EEG: Electroencephalography, SE: Status epilepticus, NCSE: Non-convulsive SE

prominent for postconvulsive NCSE (Fisher’s exact test,  $p < 0.05$ ). In the temporal-plus epilepsy group, a heterogeneous distribution was observed, with seizure, clustered, and SE patterns present.

Evaluation of MRI findings revealed a statistically significant association between seizure patterns and the presence of structural lesions ( $p < 0.05$ ). Structural lesions were more frequent in SE patterns. In contrast, no statistically significant differences were found between epilepsy groups or between seizure patterns with respect to age, epilepsy duration, day of event onset during VEM, percentage reduction in ASM, EEG propagation patterns, or long-term treatment decisions ( $p > 0.05$ ).

**DISCUSSION**

In this study, it was demonstrated that SE or seizure clusters developed in 1.45% of patients monitored during VEM. This rate was lower than those reported in the literature.<sup>9</sup> The gradual tapering and withdrawal of ASMs during hospitalization may have contributed to this finding. Indeed, consistent with our results, previous studies have shown that centers employing slow and controlled ASM reduction protocols, continuous EEG monitoring, and predefined rescue treatment algorithms report lower rates of serious complications and SE during VEM.<sup>10,11</sup>

Seizure clusters and SE in our patients were most frequently observed on the third day of hospitalization, following a reduction in the ASM dose. Previous studies focusing on the timing of seizures and related complications during VEM have similarly reported that most events occur within the first few days of monitoring, with this period generally ranging between 1 and 4 days across centers.<sup>11</sup> These differences are thought to be closely related to center-specific ASM tapering protocols, the speed of medication withdrawal, and the provocation methods used during VEM.<sup>12,13</sup> Indeed, the literature emphasizes that ASM reduction lowers the seizure threshold of epileptic networks, facilitating seizure clustering and potentially creating a substrate for the

development of SE. In this respect, our findings are consistent with previous studies reporting seizure clustering and SE that are related to ASM tapering during VEM.<sup>14</sup>

In addition, seizure clusters were predominant in extratemporal epilepsies, whereas SE—particularly convulsive-onset NCSE—was more frequently observed in temporal lobe epilepsy. The literature reports that in extratemporal epilepsies, especially frontal lobe epilepsy, seizure clusters characterized by brief but frequently recurring seizures, often with nocturnal features, are prominent.<sup>15</sup> In contrast, seizures in temporal lobe epilepsy may have longer durations, and the tendency of limbic networks to sustain epileptic activity has been emphasized as a risk factor for the development of SE.<sup>16,17</sup> Taken together, these findings suggest that seizure patterns are closely associated not only with provocation strategies applied during VEM but also with the electroclinical localization of epilepsy.

In our study, seizure clusters were the most frequently observed pattern (41.2%). The literature has shown that seizure clusters may constitute a threshold for the development of SE.<sup>18</sup> From this perspective, early intervention in seizure clusters is of critical importance. Accordingly, all patients with seizure clusters in our cohort received oral or intravenous medication loading immediately following seizure clustering. In addition, no serious traumatic injuries or cardiac arrest occurred in any patient in the study group. The absence of progression to SE in patients with seizure clusters and the lack of traumatic complications are consistent with literature findings indicating that continuous observation and rapid intervention strategies significantly improve the safety profile during VEM.<sup>6,18</sup> The fact that only two patients required intubation under a benzodiazepine-based rapid intervention strategy further supports the effectiveness of structured safety protocols.

This study also demonstrated a significant association between seizure patterns and the presence of structural lesions on MRI. The higher frequency of structural lesions in SE patterns suggests that epileptic networks may become more easily sustained on a background of structural damage. This finding is consistent with previous studies reporting a higher risk of SE in structural epilepsies.<sup>5</sup>

An important methodological consideration in this study is the heterogeneity of ASM tapering strategies. ASM reduction was individualized for each patient to reflect real-world clinical practice in VEM units; however, this variability limits the ability to standardize the effects of ASM withdrawal on seizure occurrence and may introduce bias into the dynamics of provoked seizures. In particular, withdrawal of GABAergic agents such as benzodiazepines may significantly reduce inhibitory tone and lower the seizure threshold, thereby facilitating seizure clustering or SE. Previous studies have emphasized that both the type of ASM and the rate of withdrawal may influence seizure risk during VEM.<sup>13,14</sup>

### Study Limitations

In addition, the retrospective design of this study entails a risk of information loss due to incomplete clinical records, and the relatively small sample size from a single center may limit the generalizability of the findings. Therefore, prospective, multicenter

studies with standardized protocols and larger patient cohorts are required to confirm these results.

### CONCLUSION

Due to the inherent nature of investigation and monitoring during VEM, the risk of seizure clusters or SE is not negligible. Early intervention strategies, predefined and tailored to the patient's clinical and EEG characteristics, are crucial for reducing morbidity and mortality.

### Ethics

**Ethics Committee Approval:** Approval from the Hacettepe University Health Sciences Research Ethics Committee was obtained for the study, and the research was conducted in accordance with the principles of the Declaration of Helsinki (decision no: SBA 25/972, date: 01.12.2025).

**Informed Consent:** Retrospective study.

### Footnotes

#### Authorship Contributions

Surgical and Medical Practices: F.İ.T., Concept: F.İ.T., Design: F.İ.T., Data Collection or Processing: M.M.Ç., Analysis or Interpretation: M.M.Ç., F.İ.T., Literature Search: M.M.Ç., Writing: M.M.Ç., F.İ.T.

**Conflict of Interest:** No conflict of interest was declared by the authors.

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**Supplementary Table:** <https://d2v96fxpocvxx.cloudfront.net/488590dc-488d-47e2-b626-b249fd4be6fc/content-images/6994d384-22db-4ba8-86c0-a395ad8bdf3c.pdf>

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