Video and ambulatory EEG monitoring in the diagnosis of seizures and epilepsy

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INTRODUCTION

It can be difficult to make a diagnosis of epilepsy, and misdiagnosis is not rare [1]. In most cases, a detailed history and a reliable account of the event by an eyewitness is sufficient to make a diagnosis, but this may not always be available. In addition, certain types of nonepileptic events can be difficult to distinguish from seizures, and certain types of seizures can be misdiagnosed as nonepileptic events [1].

This topic discusses the use of electroencephalography (EEG) monitoring in the diagnosis of seizures and epilepsy. More detailed discussions of routine EEG, and the use of other diagnostic tests in the evaluation of patients with seizures and epilepsy are presented separately. The differential diagnosis of seizures is also presented separately. (See "Electroencephalography (EEG) in the diagnosis of seizures and epilepsy" and "Neuroimaging in the evaluation of seizures and epilepsy" and "Evaluation and management of the first seizure in adults" and "Nonepileptic paroxysmal disorders in adolescents and adults".)

INDICATIONS

An interictal EEG can provide evidence that helps to confirm or refute the diagnosis of epilepsy but has many limitations. The most helpful finding on EEG is interictal epileptiform discharges (IEDs), but this finding has imperfect sensitivity and specificity.

EEG monitoring, which can be performed in the outpatient setting (ambulatory-EEG [aEEG] monitoring) or combined with continuous video monitoring in the inpatient setting (video-EEG monitoring), overcomes some of these shortcomings. The most common uses of EEG monitoring include [2,3]:

- **Evaluation of paroxysmal events** – EEG monitoring is often used to help distinguish epileptic seizures from nonepileptic events (table 1) in patients with recurrent events and nondiagnostic interictal EEG findings or lack of expected response to treatment. (See 'Differential diagnosis' below.)

- **Seizure classification and quantification** – Extended monitoring may be required in some cases to determine whether seizures and epilepsy are focal or generalized, which can in turn affect antiseizure medication selection. Monitoring is also used to quantify seizures when the clinical history is unreliable or there are concerns about subclinical seizure activity. (See 'Seizure classification' below and 'Seizure quantification' below.)

- **Epilepsy surgery evaluation** – EEG monitoring, especially video-EEG, is an essential component of a comprehensive epilepsy surgical evaluation in patients with drug-resistant focal epilepsy. EEG monitoring is used both for localization of the seizure-onset zone and for performing ictal single photo emission computed tomography (SPECT). (See "Surgical treatment of epilepsy in adults", section on 'Routine and video-EEG'.)

- **Medication adjustment in a monitored setting –** Some patients require admission to a video-EEG monitoring unit to help manage medication adjustment, particularly patients with a history of status epilepticus, those with frequent or severe seizures, or those with severe medication reactions requiring abrupt discontinuation (eg, due to an allergic reaction).

AMBULATORY-EEG MONITORING

Ambulatory-EEG (aEEG) monitoring allows prolonged EEG recording outside the hospital or clinic setting. The technology has evolved such that portable recordings of up to 36 channels, over several days are possible [4]. Typically, computer software designed to detect electrographic seizures and interictal epileptiform discharges (IEDs) assists in interpretation. However, no program has high specificity and sensitivity, and prolonged segments of the study, ideally the entire study, should be reviewed in their entirety as resources allow. Patients and observers also have the opportunity to "tag" portions of the recording during clinical events using a push button device.

Some systems have the added capability of simultaneous electrocardiogram, pulse oximetry, polysomnography, and audio-video recording and opportunities for real-time monitoring, review, and troubleshooting. Guidelines published in 2022 by the American Clinical Neurophysiology Society provide minimum technical requirements to perform aEEG for adults and children (except the very young), recognizing that these are based on low-level evidence [5].

aEEG is less expensive than inpatient video-EEG monitoring, with costs that are 51 to 65 percent lower than a 24-hour inpatient admission for video-EEG monitoring [6,7]. However, inpatient video-EEG has several advantages that make it the gold standard test in differentiating epileptic from nonepileptic seizures. (See 'Video-EEG monitoring' below.)

Interictal epileptiform discharge detection — Because of its longer recording time that generally includes one or more periods of sleep, aEEG can increase the yield of interictal epileptiform discharge (IED) detection compared with a routine EEG. One study found that the yield of IED detection after an initially normal routine EEG was greater with a 24-hour aEEG than a sleep-deprived EEG (33 versus 24 percent) [8]. In another series, aEEG monitoring for seven days revealed IEDs in 81 percent of 100 adult patients with confirmed epileptic seizures [9]. A later retrospective cohort study of 104 patients with an unprovoked first seizure and a normal routine EEG found that a follow-up sleep-deprived EEG had a sensitivity of 45 percent and a specificity of 91 percent for detecting IEDs, while an aEEG had a sensitivity of 63 percent and a specificity 95 percent [10].

The yield of capturing IEDs in aEEG also appears to be time-dependent: one study of 57 aEEGs showed that in adult patients with a clinical history suggestive of seizures or epilepsy, the yield of capturing new IEDs was 9 percent in the first 30 minutes of recording, 22 percent in a time interval from 31 minutes to 8 hours, and lower thereafter, with the yield not increasing beyond 13 hours [11].

However, the sensitivity and specificity of IED detection on aEEG has not been extensively evaluated. Computer algorithms may miss a substantial proportion of IEDs, and many computer-detected "spikes" are not true IEDs [12]. In one study of 159 adult volunteers without epilepsy, overnight aEEG monitoring revealed spikes in four individuals, two of whom had a family history of epilepsy [12]. Migraine was also a risk factor for spikes in this population. Advanced computer algorithms are improving performance of automated spike detection [13].

Ictal recording — The ability of aEEG to record clinical events may be an even more important contribution of the technology than IED detection. Clearly, the baseline frequency of clinical events contributes to the yield of aEEG in this regard. In one study of 157 children whose parents reported at least three spells per week, 140 patients (89 percent) had a typical event during aEEG (mean duration 1.9 days); 76 percent of these were suspected to be nonepileptic based on the lack of an EEG correlate on aEEG [14].

Other studies in both children and adults have reported a similar yield of aEEG in distinguishing epileptic from nonepileptic events [15-17]. In a large retrospective study of prolonged (up to 96 hours) aEEG recordings (without video), the findings resulted in a significant change in the pre-study diagnosis in 26 percent of patients, and an overall diagnostic yield of 68 percent [18]. In most cases, changing the diagnosis from epilepsy to probable nonepileptic phenomena, such as syncope or psychogenic nonepileptic attacks.

An important point is that a definitive diagnosis of psychogenic nonepileptic attacks can only be made with expert review of video-EEG recordings. Caution should be used when making a diagnosis of nonepileptic phenomena on the basis of EEG findings alone; the majority of focal seizures without impairment of consciousness and a portion of those with impairment of consciousness have no definite scalp EEG correlate. Thus, a negative aEEG study, especially one with events with no definite EEG correlate, should lead to a definitive inpatient video-EEG monitoring session in most cases.

A finding that has been repeatedly observed in aEEG studies is that patients with epilepsy are often unaware of seizures [8,14,19-21]. In one study, 18 (38 percent) of 47 computer-assisted aEEG recordings contained focal seizures that were not identified by the patient; only 7 of these 18 patients also had self-reported clinical seizures during the study [21]. As a result, both ambulatory and video-EEG monitoring may have diagnostic utility despite a low frequency of seizure events reported by a patient. We often use aEEG to help quantify seizure frequency, particularly in patients who are not always aware of their seizures. In addition, we often use 24 to 72 hours of aEEG to confirm lack of seizures before allowing patients to resume driving after a period of apparent seizure freedom. (See "Driving restrictions for patients with seizures and epilepsy".)

When electrographic seizures are recorded, the tracing can also help distinguish focal versus generalized seizures [16]. Some studies suggest that aEEG can also help localize the focus of focal epilepsies in patients being considered for surgery and may provide prognostic information in patients being considered for antiseizure medication withdrawal [22].

Reports documenting non-synchronized video recording with ambulatory EEG suggest that video can help with diagnosis of paroxysmal events in some patients [23]. One study evaluated 41 adult patients with video-ambulatory EEG and showed that typical attacks were detected in 71 percent, similar to the rate of detection (62 percent) among 64 patients evaluated with conventional inpatient video monitoring; likewise, diagnostic questions were answered by video-ambulatory EEG and by inpatient video monitoring at a similar rate (73 percent for both) [24].

While in-hospital video-EEG monitoring is safer and more accurate, home video-EEG monitoring may be useful for diagnosing or quantifying paroxysmal spells in patients who have frequent events, are unable or unwilling to come to the hospital if there is a long wait for inpatient monitoring, or if the cost of inpatient monitoring is prohibitive [25,26]. Home video-EEG monitoring is now a standard practice, one that grew in popularity during the coronavirus disease 2019 (COVID-19) pandemic when elective hospital admissions were restricted [27].

Duration of recording — There is no accepted standard for the duration of aEEG recording, which can range from 24 hours to a week or more if periodic downloads of information are made. In one large study of prolonged aEEG monitoring, 95 percent of the patients with IEDs were identified within the first 48 hours [28]. Generalized epileptiform discharges were identified much earlier than focal discharges (median latency 43 minutes for generalized IED versus 576 minutes for focal IED). Another report analyzed over 3500 in-home EEG recordings from an anonymized database and concluded that 72 hours was the optimal duration for detecting spells in adults, capturing >97 percent of first events, and 48 hours was optimal for children, capturing 98 percent of first events [29].

These findings suggest that 48 to 72 hours is likely sufficient for detection of IED. For other indications, such as characterization of clinical events and detecting seizures of which the patient is unaware, the duration of recording may be longer or shorter, and should be individualized based on the patient's history.

VIDEO-EEG MONITORING

Video-EEG monitoring is the synchronous recording and display of EEG patterns and video-recorded clinical behavior. Short recordings of several hours can be performed as an outpatient in an EEG laboratory. Longer recordings of 24 hours or more are either done at home, as discussed above, or in a hospital inpatient setting.

Inpatient video-EEG is preferred when:

- Medication may need to be withdrawn
- Interacting/testing the patient is necessary in the peri-ictal setting
- Localization is needed for an epilepsy surgical evaluation
- Evaluating and managing a patient for suspected psychogenic nonepileptic seizures (PNES), also known as functional seizures

A survey from the National Association of Epilepsy Centers (NAEC) reported that the availability of specialty epilepsy care increased from 2012 to 2019, including in-hospital video-EEG monitoring admissions to the epilepsy monitoring unit (EMU) (41 percent), EMU beds (26 percent), and epileptologists (109 percent) [30]. However, there is broad variation in practices in EMUs throughout the world. As a result, there has been a growing desire in the epilepsy community to establish consensus guidelines for all aspects of video-EEG monitoring, such as those from the National Association of Epilepsy Centers (NAEC) in the United States [2] and the Children's Epilepsy Surgical Service (CESS) in the United Kingdom [3]. A Canadian group has identified quality indicators for video-EEG monitoring, related to equitability, efficiency, safety, and effectiveness, and these can serve as a basis for standardizing the quality and safety of care provided in epilepsy monitoring units [31].

Advantages of video-EEG — While considerably more expensive than ambulatory-EEG (aEEG), there are several advantages to this test, including the continuous video-monitoring that allows for analysis of both the clinical and electrographic features of a recorded event [32]:

- Staff trained in EEG monitoring may detect seizure activity on remote viewing of the video or EEG at the nursing or monitoring station. They can interact with and test the patient during a spell or seizure aura and push the event button. This can be very important for characterizing impairment of awareness and subtle lateralizing features, including postictal aphasia or hemiparesis.

- Both video and EEG quality are usually superior with inpatient, monitored recordings. Video cameras in inpatient units usually allow infrared viewing of patients in the dark, as well as remote control of the camera, including zooming in as needed, from the nursing or monitoring station. As a result, when a seizure occurs, subtle clinical features with lateralizing importance can be better appreciated, such as dystonic posturing, eye deviation, facial clonus, postictal nose-wiping, brief Todd's paresis, etc. Video can also help identify artifacts produced by nonseizure-related rhythmic movements (eg, blinking, chewing, toothbrushing, scratching) that can mimic seizures on EEG.

- Electrode application can be more frequently monitored and maintained, limiting artifact. Additional electrodes, such as inferior temporal electrodes, are impractical in the outpatient setting, and can be more easily monitored and maintained in the inpatient setting. These electrodes can provide information that would be unavailable from the standard electrode array. (See "Electroencephalography (EEG) in the diagnosis of seizures and epilepsy", section on 'Special electrode placement'.)

- The inpatient setting is a safer environment in which to withdraw antiseizure medications or use other measures designed to induce clinical events [33]. (See 'Safety' below.)

Duration of recording — The likelihood of recording an event (and therefore making a diagnosis) increases with the duration of recording. In one case series of 248 adult patients admitted to an epilepsy monitoring unit, the median time to first diagnostic event, whether epileptic seizure or nonepileptic event, was two days; 35 percent of patients required three or more days of monitoring, and 7 percent more than one week [34]. In another series of consecutive patients admitted to a video-EEG monitoring unit for diagnosis of spells, a stay of longer than five days was no less likely to be inconclusive than shorter stays in patients with epileptic seizures [35]. In patients with presumed nonepileptic events, stays longer than five days were more likely to be inconclusive. Similarly, a third retrospective series of 151 patients admitted for video-EEG monitoring concluded that five days of recording was optimal to identify interictal abnormalities and seizures [36]. The EEG detection rate by day 5 was 95 percent among patients who had interictal abnormalities; in addition, 75 percent of patients had a first seizure by day 5. When a first video-EEG study is not diagnostic, repeat testing can be helpful; in one study a second study was diagnostically useful in 35 of 43 cases [37].

The duration of recording will depend on the indication: subjects undergoing presurgical evaluation often require a significantly longer period of long-term monitoring to obtain clinically relevant (and previously unreported) information (mean 3.5 days) compared with patients who are being recorded for diagnosis or classification (2.4 and 2.3 days, respectively) [38].

Provocative techniques — A number of techniques can be used to provoke typical events in the epilepsy monitoring unit:

- Routine activating techniques such as hyperventilation and photic stimulation should be part of any inpatient video-EEG recording session. One group performed hyperventilation for five minutes at a time, every three hours between 6 am and 12 midnight; 25 percent of all recorded focal-onset seizures were activated during hyperventilation [39]. The seizures provoked during hyperventilation did not differ from spontaneous seizures in characteristics or severity. Another video-EEG monitoring study found that hyperventilation had an activating effect on the EEG only in those who were also undergoing antiseizure medication tapering [40]. Overall, 14 out of 80 patients, most of whom had localization-related epilepsy, had seizures activated by hyperventilation. In this series, patients underwent hyperventilation for six minutes at a time, and this was repeated a mean of 3.5 times/day. (See "Electroencephalography (EEG) in the diagnosis of seizures and epilepsy", section on 'Routine activating techniques'.)

- Sleep deprivation can increase the diagnostic yield of routine outpatient EEG recordings. (See "Electroencephalography (EEG) in the diagnosis of seizures and epilepsy", section on 'Sleep and sleep deprivation'.)

  Sleep deprivation is also frequently used as a technique to provoke seizures in patients admitted for video-EEG monitoring, although there is no direct evidence supporting the effectiveness of this technique. In one series, patients who were kept awake every second night during video-EEG monitoring did not have more seizures than patients who were allowed to sleep normally [41].

- Antiseizure medications may be withdrawn in order to provoke seizures. Several studies have shown that the rapid reduction of antiseizure medications during video-EEG monitoring increases the risk of focal seizures and evolution to bilateral convulsive seizures [42,43]. Up to half of all patients who have never had a generalized seizure at baseline will have one in the context of rapid medication withdrawal [42].

  The rate of antiseizure medication withdrawal is variable, and there is no generally accepted standard. While some experts have advocated gradual withdrawal of one antiseizure medication at a time, reducing each antiseizure medication by 25 to 50 percent of the baseline total daily dose each day [44]. More rapid reductions may result in a better diagnostic yield, with earlier time to first seizure and shorter overall duration of video-EEG monitoring [45,46]. In a survey of adult monitoring units, 69 percent reported tapering medications by at least a third each day [47].

  The rate of antiseizure medication taper should be adjusted for each patient based upon risk factors for status epilepticus (eg, frequent seizures at baseline, poor seizure control, frequent generalized seizures, prior status epilepticus) and the risk of adverse outcomes associated with seizure clusters and generalized seizures (eg, low bone density, concurrent cardiovascular disease, history of postictal psychosis). Benzodiazepines and barbiturates should be withdrawn at slower rates than other antiseizure medications because of the high risk of status epilepticus associated with rapid withdrawal of these medications.

- Other techniques used during video-EEG monitoring in order to provoke seizures include physical exercise, alcohol consumption, video games and mental and concentration tasks [48]. While there is no evidence to support the effectiveness of any of these techniques for provoking seizures, physical and mental activity should be encouraged to prevent boredom and deconditioning during long admissions for video-EEG monitoring.

- Techniques for provoking psychogenic nonepileptic seizures are discussed in detail separately. (See "Psychogenic nonepileptic seizures: Etiology, clinical features, and diagnosis", section on 'Event induction'.)

Safety — An inpatient video-EEG monitoring unit is the safest environment in which to diagnose paroxysmal events. In one series of 149 adults monitored for a mean duration of five days, adverse events requiring intervention occurred in 21 percent [49]. In another series of 507 patients, mostly adults, monitored over 596 video-EEG recording sessions, 44 patients (9 percent) experienced 53 adverse events requiring intervention and resulting in prolonged hospital stay [50]. The most common adverse events were status epilepticus (2 percent of all recordings), injuries from falls, vertebral compression fractures, and psychiatric complications including postictal psychosis. Postictal psychosis can present a unique diagnostic challenge in that it may not be evident until well after discharge.

Safety data in children are similar. In a series of 454 pediatric epilepsy monitoring admissions, status epilepticus was the most frequent adverse event, occurring in 3 percent of all admissions and 6 percent of those with epileptic seizures [51]. Additional adverse events in four patients (2 percent) included fall, symptomatic subdural fluid collection associated with grid placement, hip pain from a seizure, and postictal psychosis.

Very rarely, sudden unexpected death in epilepsy (SUDEP) occurs in epilepsy monitoring units. The risk in adult monitoring units has been estimated at 1.2 per 10,000 inpatient video-EEG studies [52]. (See "Sudden unexpected death in epilepsy", section on 'Incidence'.)

In order to minimize adverse events, inpatient video-EEG monitoring units should be staffed by nurses and other health professionals with experience in dealing with seizures, and the layout and furnishings should be designed to minimize the risk of injury and falls [53]. Particular attention should be paid to developing a safety protocol when the patient goes to the bathroom, particularly with invasive video-EEG monitoring studies. In one study, three-quarters of all falls in an epilepsy monitoring unit occurred in the bathroom [54]. One prospective cohort study of 1062 epilepsy monitoring unit (EMU) admissions concluded that allowing ambulation within an EMU room was safe [55]. However, we still require supervision for most patients in our units whenever they are out of bed, especially in the setting of medication lowering.

Nocturnal supervision is an important component of the overall safety plan. This was illustrated by a multicenter study that reviewed 16 SUDEP cases and nine near-SUDEP cases occurring in epilepsy monitoring units, in which SUDEP was much more likely to occur at night (14 out of 16 cases) [52]. In addition, cardiopulmonary resuscitation (CPR) was started within three minutes in all but one of the daytime cardiac arrests but in none of the nighttime arrests. These data emphasize the need for robust nighttime coverage, routine use of oximetry-based alarm systems, and clear CPR contingency plans in inpatient epilepsy monitoring units. One observational study found that early administration of oxygen after a generalized convulsive seizure reduced the likelihood of postictal generalized EEG suppression [56], a pattern that has been associated with an increased risk of SUDEP in some but not all studies. (See "Sudden unexpected death in epilepsy", section on 'Neurogenic cardiopulmonary dysfunction'.)

Diagnostic yield

Differential diagnosis — For patients with recurrent clinical events, video-EEG recording in an epilepsy monitoring unit is the best, and sometimes the only, way to make a definitive diagnosis [57,58]. Approximately 20 percent of patients referred for video-EEG monitoring for medically refractory seizures do not have epilepsy [16,59,60].

In a retrospective review of 213 admissions (from 196 patients) to an inpatient epilepsy monitoring unit, a definitive diagnosis was reached in 88 percent of patients after a median stay of five days [60]. Epilepsy was diagnosed in 71 percent and excluded in 22 percent of admissions. In patients diagnosed with epilepsy, the median time since the onset of symptoms was 18 years. Perhaps more worrisome was that patients determined not to have epilepsy had been treated with antiseizure medications (often multiple medications) for an average of nine years. The National Association of Epilepsy Centers guidelines recommend referral for video-EEG monitoring if spells are uncontrolled after one year, or if the patient has failed treatment with two to three antiseizure medications [53].

The majority of patients misdiagnosed with epilepsy are eventually found to have either psychogenic nonepileptic seizures (PNES), also known as functional seizures, or (much less frequently) syncope [60-64]. It is also well known that some patients with presumed PNES are found to have epileptic seizures on video-EEG [65]. (See "Nonepileptic paroxysmal disorders in adolescents and adults" and "Psychogenic nonepileptic seizures: Etiology, clinical features, and diagnosis".)

Accurate interpretation of video-EEG monitoring requires careful analysis of the clinical events with any changes in the EEG occurring before, during, and after the seizure. Some caution is required for interpretation. While the majority of seizures with impaired awareness reveal an ictal EEG correlate, the tracing may be obscured by muscle artifact. Only 15 to 33 percent of focal seizures without impairment of consciousness or seizure auras, which often involve a limited area of cortex, are associated with surface EEG abnormalities [66]. Some studies suggest that synchronized seizure activity must involve approximately 10 cm^2 of cortex for it to produce a focal pattern on a scalp EEG [67]. Frontal lobe seizures may also not be correlated with electrographic abnormalities on an EEG [68]. Therefore, the absence of an ictal rhythm on EEG does not exclude epilepsy.

A study of interrater reliability of video-EEG found substantial agreement (kappa = 0.7) for epileptic seizures [69]. There was more variability in interpretation for psychogenic and physiologic nonepileptic seizures. Limitations of this study that differ from "real-life" use of this test include a forced choice paradigm based on analysis of a single episode and no access to other clinical data.

Seizure classification — Video-EEG monitoring can also help with seizure classification, which in turn impacts the most appropriate selection of an antiseizure medication [16,58,59,70-74]. The clinical history can be misleading in this regard. As examples, a patient with staring spells may have absence seizures or focal seizures with impairment of consciousness, and a patient with generalized convulsions may have focal or generalized epilepsy. Although the presence of an aura strongly suggests partial-onset seizures, one study reported that symptoms interpreted by the patient as a seizure aura (often brief, nonspecific dizziness) occurred in up to 70 percent of those with primary generalized epilepsy [75].

In two case series that compared seizure classification based on an informant's description versus video-EEG monitoring, reclassification occurred in 12 to 20 percent of patients [76,77]. However, it was not clear that this reclassification led to an alteration of treatment strategy in these patients. By contrast, in a study of 40 patients who underwent video-EEG monitoring, newly recognized epileptic seizure types were identified in eight patients [71]. Monitoring led to altered treatment regimens in some patients and was associated with a reduced seizure frequency in 24 patients over a six-month follow-up.

Seizure quantification — Video-EEG also has an instrumental role in quantifying seizures. As with aEEG, case series of video EEG studies reveal that many patients with epilepsy have more events than they are aware of [19,78]. In one series of 31 patients admitted to an epilepsy monitoring unit, 23 had epileptic seizures, but only 26 percent of patients were aware of all their seizures and 30 percent were not aware of any [19]. Similarly, another study of 91 video-EEG-monitored inpatients found that 56 percent (323/582) of seizures were not documented by patients [79]. Focal seizures with impairment of consciousness in particular were underreported; only 25 percent of patients with such seizures were aware of all seizures; 51 percent failed to document any focal seizures with impairment of consciousness; and 73 percent of all such seizures were unreported. Even focal seizures evolving to bilateral convulsive seizures were often (42 percent) unreported. Only 38 percent of patients documented all their seizures.

Another study found no correlation between self-reported outpatient seizure frequency and time-to-first-seizure during inpatient video-EEG monitoring [78]. These data demonstrate that reports of seizure frequency obtained from patients are often unreliable and that a low self-reported seizure frequency should not deter referral of a patient for monitoring.

Epilepsy surgery planning — Video-EEG monitoring is performed in individuals with drug-resistant focal epilepsy for surgical localization [4,15,80-82]. (See "Surgical treatment of epilepsy in adults".)

Emerging methods of outpatient monitoring — As many (or most) people now carry a smartphone with them most of the time, it is not difficult to capture infrequent clinical events on home smartphone videos. The utility of such videos (without EEG of course) has been demonstrated by comparing impressions from reviews of these videos with those of subsequent inpatient video/EEG monitoring [83]. Expert review was accurate in 89 percent of cases, especially for convulsive spells. Accuracy for determining whether spells were epileptic was much greater when adding review of smartphone videos to the standard history and physical.

For capturing videos of infrequent spells, especially nocturnal ones, systems have been devised for automated detection of abnormal movements based purely on video and audio via home cameras, without EEG [84]. These may be helpful for determining the nature of such spells and for quantifying them.

Lastly, methods for ultra-long-term ambulatory EEG monitoring are being developed, mostly involving electrodes implanted between the scalp and the skull (subscalp) via simple outpatient surgical procedures [85]. Some of these have been approved in Europe, and at least one is being considered for US FDA approval. These devices can be used to capture infrequent spells, for discovering long-term patterns such as circadian and longer (multiday) cycles, and for seizure forecasting [86].

SOCIETY GUIDELINE LINKS

Links to society and government-sponsored guidelines from selected countries and regions around the world are provided separately. (See "Society guideline links: Seizures and epilepsy in adults" and "Society guideline links: Seizures and epilepsy in children".)

INFORMATION FOR PATIENTS

UpToDate offers two types of patient education materials, "The Basics" and "Beyond the Basics." The Basics patient education pieces are written in plain language, at the 5th to 6th grade reading level, and they answer the four or five key questions a patient might have about a given condition. These articles are best for patients who want a general overview and who prefer short, easy-to-read materials. Beyond the Basics patient education pieces are longer, more sophisticated, and more detailed. These articles are written at the 10th to 12th grade reading level and are best for patients who want in-depth information and are comfortable with some medical jargon.

Here are the patient education articles that are relevant to this topic. We encourage you to print or e-mail these topics to your patients. (You can also locate patient education articles on a variety of subjects by searching on "patient info" and the keyword(s) of interest.)

- Basics topic (see "Patient education: EEG (The Basics)")

SUMMARY AND RECOMMENDATIONS

Electroencephalography (EEG) is one of the most important diagnostic tests in evaluating a patient with possible epilepsy, providing evidence that helps confirm or refute the diagnosis. EEG also assists in classifying the underlying epileptic syndrome and thereby guides management.

- Because of its longer duration of recording that typically includes one or more periods of sleep, ambulatory-EEG (aEEG) monitoring can increase the yield of routine EEG in detecting interictal epileptiform discharges (IEDs). (See 'Interictal epileptiform discharge detection' above.)

- Ambulatory EEG is most helpful in quantifying or capturing clinical events and associating these with the presence or absence of electrographic seizures. However, absence of an EEG correlate does not exclude epilepsy and aEEG cannot "rule out" epileptic seizures. (See 'Ictal recording' above.)

- While relatively inexpensive and convenient to perform, ambulatory EEG monitoring has significant disadvantages compared with inpatient video-EEG recording, including the inability to interact and test the patient during a spell or withdraw medications safely and the higher potential for artifact and misinterpretation. (See 'Ambulatory-EEG monitoring' above.)

- Inpatient video-EEG monitoring facilitates ongoing maintenance of video and EEG quality, permits interaction with the patient during or after an event, and allows medication withdrawal in a safer, monitored setting. (See 'Advantages of video-EEG' above.)

- Video-EEG is used most commonly to determine whether epilepsy is the cause of recurrent seizure-like events. (See 'Differential diagnosis' above.)

- Video EEG can also aid in seizure classification, quantification, and determination of patient awareness of their seizures. It is also vital for presurgical evaluation of epilepsy patients. (See 'Seizure classification' above.)

- Smartphone videos, automated home video camera systems, and emerging subscalp EEG electrodes are helping to advance diagnosis in the outpatient setting. (See 'Emerging methods of outpatient monitoring' above.)

REFERENCES

1. Kanner AM. Common errors made in the diagnosis and treatment of epilepsy. Semin Neurol 2008; 28:364.
2. Shih JJ, Fountain NB, Herman ST, et al. Indications and methodology for video-electroencephalographic studies in the epilepsy monitoring unit. Epilepsia 2018; 59:27.
3. Pressler RM, Seri S, Kane N, et al. Consensus-based guidelines for Video EEG monitoring in the pre-surgical evaluation of children with epilepsy in the UK. Seizure 2017; 50:6.
4. Cascino GD. Use of routine and video electroencephalography. Neurol Clin 2001; 19:271.
5. Tatum WO, Halford JJ, Olejniczak P, et al. Minimum Technical Requirements for Performing Ambulatory EEG. J Clin Neurophysiol 2022; 39:435.
6. Schomer DL. Ambulatory EEG telemetry: how good is it? J Clin Neurophysiol 2006; 23:294.
7. Foley CM, Legido A, Miles DK, et al. Long-term computer-assisted outpatient electroencephalogram monitoring in children and adolescents. J Child Neurol 2000; 15:49.
8. Liporace J, Tatum W 4th, Morris GL 3rd, French J. Clinical utility of sleep-deprived versus computer-assisted ambulatory 16-channel EEG in epilepsy patients: a multi-center study. Epilepsy Res 1998; 32:357.
9. Walczak T, Scheuer M, Resor S, Pedley T. Prevalence and features of epilepsy without interictal epileptiform discharges. Neurology 1993; 43:287.
10. Geut I, Weenink S, Knottnerus ILH, van Putten MJAM. Detecting interictal discharges in first seizure patients: ambulatory EEG or EEG after sleep deprivation? Seizure 2017; 51:52.
11. Siddiqi M, Ahmed SN. No Further Yield of Ambulatory EEG for Epileptiform Discharges Beyond 13 Hours. Neurodiagn J 2017; 57:211.

12. Schachter SC, Ito M, Wannamaker BB, et al. Incidence of spikes and paroxysmal rhythmic events in overnight ambulatory computer-assisted EEGs of normal subjects: a multicenter study. J Clin Neurophysiol 1998; 15:251.
13. Nhu D, Janmohamed M, Shakhatreh L, et al. Automated Interictal Epileptiform Discharge Detection from Scalp EEG Using Scalable Time-series Classification Approaches. Int J Neural Syst 2023; 33:2350001.
14. Olson DM. Success of ambulatory EEG in children. J Clin Neurophysiol 2001; 18:158.
15. Morris GL 3rd, Galezowska J, Leroy R, North R. The results of computer-assisted ambulatory 16-channel EEG. Electroencephalogr Clin Neurophysiol 1994; 91:229.
16. Yogarajah M, Powell HW, Heaney D, et al. Long term monitoring in refractory epilepsy: the Gowers Unit experience. J Neurol Neurosurg Psychiatry 2009; 80:305.
17. Lawley A, Evans S, Manfredonia F, Cavanna AE. The role of outpatient ambulatory electroencephalography in the diagnosis and management of adults with epilepsy or nonepileptic attack disorder: A systematic literature review. Epilepsy Behav 2015; 53:26.
18. Faulkner HJ, Arima H, Mohamed A. The utility of prolonged outpatient ambulatory EEG. Seizure 2012; 21:491.
19. Blum DE, Eskola J, Bortz JJ, Fisher RS. Patient awareness of seizures. Neurology 1996; 47:260.
20. Gotman J. Automatic seizure detection: improvements and evaluation. Electroencephalogr Clin Neurophysiol 1990; 76:317.
21. Tatum WO 4th, Winters L, Gieron M, et al. Outpatient seizure identification: results of 502 patients using computer-assisted ambulatory EEG. J Clin Neurophysiol 2001; 18:14.
22. Koepp MJ, Farrell F, Collins J, Smith S. The prognostic value of long-term ambulatory electroencephalography in antiepileptic drug reduction in adults with learning disability and epilepsy in long-term remission. Epilepsy Behav 2008; 13:474.
23. Goodwin E, Kandler RH, Alix JJ. The value of home video with ambulatory EEG: a prospective service review. Seizure 2014; 23:480.
24. Kandler R, Ponnusamy A, Wragg C. Video ambulatory EEG: A good alternative to inpatient video telemetry? Seizure 2017; 47:66.
25. Jamal Omidi S, Hampson JP, Lhatoo SD. Long-term Home Video EEG for Recording Clinical Events. J Clin Neurophysiol 2021; 38:92.
26. Brunnhuber F, Slater J, Goyal S, et al. Past, Present and Future of Home video-electroencephalographic telemetry: A review of the development of in-home video-electroencephalographic recordings. Epilepsia 2020; 61 Suppl 1:S3.

27. Brunnhuber F, Slater JD, Goyal S, et al. The unforeseen future: Impacts of the COVID-19 pandemic on home video-EEG telemetry. Epilepsia 2023; 64 Suppl 4:S12.
28. Faulkner HJ, Arima H, Mohamed A. Latency to first interictal epileptiform discharge in epilepsy with outpatient ambulatory EEG. Clin Neurophysiol 2012; 123:1732.
29. Klein H, Pang T, Slater J, Ramsay RE. How much time is enough? Establishing an optimal duration of recording for ambulatory video EEG. Epilepsia Open 2021; 6:569.
30. Ostendorf AP, Ahrens SM, Lado FA, et al. United States Epilepsy Center Characteristics: A Data Analysis From the National Association of Epilepsy Centers. Neurology 2022; 98:e449.
31. Sauro KM, Wiebe S, Macrodimitris S, et al. Quality indicators for the adult epilepsy monitoring unit. Epilepsia 2016; 57:1771.
32. Worrell GA, Lagerlund TD, Buchhalter JR. Role and limitations of routine and ambulatory scalp electroencephalography in diagnosing and managing seizures. Mayo Clin Proc 2002; 77:991.
33. Moien-Afshari F, Griebel R, Sadanand V, et al. Safety and yield of early cessation of AEDs in video-EEG telemetry and outcomes. Can J Neurol Sci 2009; 36:587.
34. Friedman DE, Hirsch LJ. How long does it take to make an accurate diagnosis in an epilepsy monitoring unit? J Clin Neurophysiol 2009; 26:213.
35. Moseley BD, Dewar S, Haneef Z, Stern JM. How long is long enough? The utility of prolonged inpatient video EEG monitoring. Epilepsy Res 2015; 109:9.
36. Goldstein L, Margiotta M, Guina ML, et al. Long-term video-EEG monitoring and interictal epileptiform abnormalities. Epilepsy Behav 2020; 113:107523.
37. Muniz J, Benbadis SR. Repeating video/EEG monitoring: why and with what results? Epilepsy Behav 2010; 18:472.
38. Alving J, Beniczky S. Diagnostic usefulness and duration of the inpatient long-term video-EEG monitoring: findings in patients extensively investigated before the monitoring. Seizure 2009; 18:470.
39. Guaranha MS, Garzon E, Buchpiguel CA, et al. Hyperventilation revisited: physiological effects and efficacy on focal seizure activation in the era of video-EEG monitoring. Epilepsia 2005; 46:69.
40. Jonas J, Vignal JP, Baumann C, et al. Effect of hyperventilation on seizure activation: potentiation by antiepileptic drug tapering. J Neurol Neurosurg Psychiatry 2011; 82:928.
41. Malow BA, Passaro E, Milling C, et al. Sleep deprivation does not affect seizure frequency during inpatient video-EEG monitoring. Neurology 2002; 59:1371.

42. Marciani MG, Gotman J, Andermann F, Olivier A. Patterns of seizure activation after withdrawal of antiepileptic medication. Neurology 1985; 35:1537.
43. Marks DA, Katz A, Scheyer R, Spencer SS. Clinical and electrographic effects of acute anticonvulsant withdrawal in epileptic patients. Neurology 1991; 41:508.
44. Fisch BJ, So EL. Activation Methods. In: Current practice of Clinical Electroencephalography, Third, Ebersole JS, Pedley TA (Eds), Lippincott Williams & Wilkins, Philadelphia 2003.
45. Rizvi SA, Hernandez-Ronquillo L, Wu A, Téllez Zenteno JF. Is rapid withdrawal of anti-epileptic drug therapy during video EEG monitoring safe and efficacious? Epilepsy Res 2014; 108:755.
46. Kumar S, Ramanujam B, Chandra PS, et al. Randomized controlled study comparing the efficacy of rapid and slow withdrawal of antiepileptic drugs during long-term video-EEG monitoring. Epilepsia 2018; 59:460.
47. Jehi L. Antiepileptic Drug Management in the Epilepsy Monitoring Unit: Any Standards? Epilepsy Curr 2016; 16:116.
48. Millett CJ, Johnson AL, Thompson PJ, Fish DR. A study of the relationship between participation in common leisure activities and seizure occurrence. Acta Neurol Scand 2001; 103:300.
49. Noe KH, Drazkowski JF. Safety of long-term video-electroencephalographic monitoring for evaluation of epilepsy. Mayo Clin Proc 2009; 84:495.
50. Dobesberger J, Walser G, Unterberger I, et al. Video-EEG monitoring: safety and adverse events in 507 consecutive patients. Epilepsia 2011; 52:443.
51. Arrington DK, Ng YT, Troester MM, et al. Utility and safety of prolonged video-EEG monitoring in a tertiary pediatric epilepsy monitoring unit. Epilepsy Behav 2013; 27:346.
52. Ryvlin P, Nashef L, Lhatoo SD, et al. Incidence and mechanisms of cardiorespiratory arrests in epilepsy monitoring units (MORTEMUS): a retrospective study. Lancet Neurol 2013; 12:966.
53. Labiner DM, Bagic AI, Herman ST, et al. Essential services, personnel, and facilities in specialized epilepsy centers--revised 2010 guidelines. Epilepsia 2010; 51:2322.
54. Pati S, Kumaraswamy VM, Deep A, et al. Characteristics of falls in the epilepsy monitoring unit: a retrospective study. Epilepsy Behav 2013; 29:1.
55. Cox F, Reus E, Widman G, et al. Epilepsy monitoring units can be safe places; a prospective study in a large cohort. Epilepsy Behav 2020; 102:106718.
56. Surges R, Strzelczyk A, Scott CA, et al. Postictal generalized electroencephalographic suppression is associated with generalized seizures. Epilepsy Behav 2011; 21:271.

57. Cuthill FM, Espie CA. Sensitivity and specificity of procedures for the differential diagnosis of epileptic and non-epileptic seizures: a systematic review. Seizure 2005; 14:293.
58. Nordli DR Jr. Usefulness of video-EEG monitoring. Epilepsia 2006; 47 Suppl 1:26.
59. Binnie CD, Rowan AJ, Overweg J, et al. Telemetric EEG and video monitoring in epilepsy. Neurology 1981; 31:298.
60. Smolowitz JL, Hopkins SC, Perrine T, et al. Diagnostic utility of an epilepsy monitoring unit. Am J Med Qual 2007; 22:117.
61. Scheepers B, Clough P, Pickles C. The misdiagnosis of epilepsy: findings of a population study. Seizure 1998; 7:403.
62. Eirís-Puñal J, Rodríguez-Núñez A, Fernández-Martínez N, et al. Usefulness of the head-upright tilt test for distinguishing syncope and epilepsy in children. Epilepsia 2001; 42:709.
63. Oto M, Russell AJ, McGonigal A, Duncan R. Misdiagnosis of epilepsy in patients prescribed anticonvulsant drugs for other reasons. BMJ 2003; 326:326.
64. Zaidi A, Clough P, Cooper P, et al. Misdiagnosis of epilepsy: many seizure-like attacks have a cardiovascular cause. J Am Coll Cardiol 2000; 36:181.
65. LaFrance WC Jr, Benbadis SR. Differentiating frontal lobe epilepsy from psychogenic nonepileptic seizures. Neurol Clin 2011; 29:149.
66. Devinsky O, Kelley K, Porter RJ, Theodore WH. Clinical and electroencephalographic features of simple partial seizures. Neurology 1988; 38:1347.
67. Tao JX, Baldwin M, Ray A, et al. The impact of cerebral source area and synchrony on recording scalp electroencephalography ictal patterns. Epilepsia 2007; 48:2167.
68. Verma A, Radtke R. EEG of partial seizures. J Clin Neurophysiol 2006; 23:333.
69. Benbadis SR, LaFrance WC Jr, Papandonatos GD, et al. Interrater reliability of EEG-video monitoring. Neurology 2009; 73:843.
70. Dreifuss FE. Role of intensive monitoring in classification. Adv Neurol 1987; 46:13.
71. Sutula TP, Sackellares JC, Miller JQ, Dreifuss FE. Intensive monitoring in refractory epilepsy. Neurology 1981; 31:243.
72. Benbadis SR, O'Neill E, Tatum WO, Heriaud L. Outcome of prolonged video-EEG monitoring at a typical referral epilepsy center. Epilepsia 2004; 45:1150.
73. Asano E, Pawlak C, Shah A, et al. The diagnostic value of initial video-EEG monitoring in children--review of 1000 cases. Epilepsy Res 2005; 66:129.
74. Cascino GD. Video-EEG monitoring in adults. Epilepsia 2002; 43 Suppl 3:80.

75. Boylan LS, Labovitz DL, Jackson SC, et al. Auras are frequent in idiopathic generalized epilepsy. Neurology 2006; 67:343.
76. Heo JH, Kim DW, Lee SY, et al. Reliability of semiology description. Neurologist 2008; 14:7.
77. Hirfanoglu T, Serdaroglu A, Cansu A, et al. Semiological seizure classification: before and after video-EEG monitoring of seizures. Pediatr Neurol 2007; 36:231.
78. Eisenman LN, Attarian H, Fessler AJ, et al. Self-reported seizure frequency and time to first event in the seizure monitoring unit. Epilepsia 2005; 46:664.
79. Hoppe C, Poepel A, Elger CE. Epilepsy: accuracy of patient seizure counts. Arch Neurol 2007; 64:1595.
80. Cambier DM, Cascino GD, So EL, Marsh WR. Video-EEG monitoring in patients with hippocampal atrophy. Acta Neurol Scand 2001; 103:231.
81. Porter RJ, Sato S, Long RL. Video recording. Electroencephalogr Clin Neurophysiol Suppl 1985; 37:73.
82. Quesney LF, Gloor P. Localization of epileptic foci. Electroencephalogr Clin Neurophysiol Suppl 1985; 37:165.
83. Tatum WO, Hirsch LJ, Gelfand MA, et al. Assessment of the Predictive Value of Outpatient Smartphone Videos for Diagnosis of Epileptic Seizures. JAMA Neurol 2020; 77:593.
84. Basnyat P, Mäkinen J, Saarinen JT, Peltola J. Clinical utility of a video/audio-based epilepsy monitoring system Nelli. Epilepsy Behav 2022; 133:108804.
85. Haneef Z, Yang K, Sheth SA, et al. Sub-scalp electroencephalography: A next-generation technique to study human neurophysiology. Clin Neurophysiol 2022; 141:77.
86. Viana PF, Pal Attia T, Nasseri M, et al. Seizure forecasting using minimally invasive, ultra-long-term subcutaneous electroencephalography: Individualized intrapatient models. Epilepsia 2023; 64 Suppl 4:S124.

Topic 2235 Version 29.0

GRAPHICS

Imitators of epilepsy: Nonepileptic paroxysmal disorders

Neonates
Apnea
Jitteriness
Benign neonatal sleep myoclonus
Hyperekplexia
Infants
Breath-holding spells
Benign myoclonus of infancy
Shuddering attacks
Sandifer syndrome
Benign torticollis in infancy
Abnormal eye movements (eg, spasmus nutans, opsoclonus-myoclonus)
Rhythmic movement disorder (head banging)
Children
Breath-holding spells
Vasovagal syncope
Migraine
Benign paroxysmal vertigo
Staring spells
Tic disorders and stereotypies
Rhythmic movement disorder
Parasomnias
Adolescents and young adults
Vasovagal syncope
Narcolepsy
Periodic limb movements of sleep
Sleep starts
Paroxysmal dyskinesia

Tic disorders
Hemifacial spasm
Stiff-person syndrome
Migraine
Psychogenic nonepileptic seizures
Hallucinations
Older adults
Cardiogenic syncope
Transient ischemic attack
Drop attacks
Transient global amnesia
Delirium or toxic-metabolic encephalopathy
Rapid eye movement sleep behavior disorder

Graphic 81289 Version 7.0

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