

Minimum Standards for Long-term Video-EEG Monitoring

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Summary

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Highlights

1. This clinical practice guideline seeks to recommend the current standards to be used during long-term video-EEG monitoring.
2. There existing high-level evidence for the utility and performance of long-term video-EEG monitoring is limited.
3. Comprehensive recommendations addressing minimum standards for performing long-term video-EEG monitoring are needed.
4. Clinicians, hospital administrators, and insurance company representatives will benefit from understanding standards for video-EEG monitoring as it applies to patient management.

Summary

The objective of this clinical practice guideline is to provide recommendations on the indications and minimum standards for long-term video-EEG monitoring (LTVEM). The Working Group of the International League Against Epilepsy and the International Federation of Clinical Neurophysiology have developed the guidelines aligned with the Epilepsy Guidelines Working Group. We reviewed the published evidence using the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement. We found limited high levels of evidence aimed at specific aspects of LTVEM performed to diagnose patients with seizures and nonepileptic events. For classification of evidence, we used the Clinical Practice Guideline Process Manual of the American Academy of Neurology. In the absence of high-level evidence, we used the modified Delphi method. We used GRADE to formulate the recommendations for the clinical indications for LTVEM in the evaluation of patients with suspected epilepsy. Further research is needed to establish long-term outcomes from LTVEM, that will enhance evidence for direct clinical utility.

1. Introduction

With more than 70 million cases of epilepsy are reported world-wide, objective measures are needed to evaluate people for seizures.¹⁻⁴ Seizures impart safety risk,⁵ affect people of all ages, gender, ethnic background, and cultures,^{2, 4} with one-third of people who are uncontrolled by antiseizure medication (ASM).^{6, 7} Practice guidelines and quality measures are available providing national and international standards for diagnosis and treatment of patients.⁸⁻¹⁰ Because the manifestations of epilepsy are intermittent, a standard EEG often fails to reveal the epileptiform activity necessary to support the diagnosis of epilepsy. Long-term video-EEG monitoring (LTVEM) is therefore the most robust reference standard for recording epileptiform activity and seizures.¹¹ In this clinical practice guideline, LTVEM refers to scalp EEG monitoring using the 10-20 system of electrode placement and a single channel of electrocardiogram (ECG). Video-EEG remains the best technique to evaluate people with recurrent paroxysmal events with and without impaired consciousness when routine evaluation is unrevealing^{5, 12-20} Position papers and standards¹⁶, services²¹ and guidelines^{11, 14, 22-25} exist for specific indications and certain aspects of LTVEM, though an international guideline to identify minimum performance standards is needed. The International League Against Epilepsy (ILAE) and the International Federation of Clinical Neurophysiology (IFCN) are developing clinical practice guidelines for application of neurophysiological methods in people with epilepsy. The target audience for this clinical practice guideline are clinicians and allied healthcare personnel. The objective of this guideline is to provide recommendations on standards performance of LTVEM.

2. Study Methods

We extracted, reviewed and evaluated published evidence on standards of practice in LTVEM and used the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement for a breakdown of article selection (**Figure 1**).²⁶ Data sources included PubMed and EMBASE supplemented with articles from Ovid Medline, CINAHL (Cumulative Index of Nursing and Allied Health Literature), and Cochrane databases including conference proceedings. The search was restricted to human subjects, but no language restriction was applied during article inclusion. The search strategy included broad search terms ("epilepsy AND seizures AND video-EEG) and synonyms ("epilepsy AND Seizures AND telemetry) pertaining to LTVEM and subtopics evaluated (i.e., "epilepsy AND standards/guidelines"). Article search took place before Oct 16, 2019 and additional relevant articles were selected thereafter for inclusion when high-level evidence was identified. Neonates and continuous EEG monitoring during critical illness were excluded. Two independent reviewers screened titles and abstracts and full text articles were examined for eligibility.

Due to the large heterogeneity in study design and the use of different LTVEM outcomes quantitative synthesis (meta-analysis) was not possible. Therefore, we conducted a qualitative synthesis of high-level studies that are listed in **Table 1**. We posed questions to address patient populations, interventions, comparators, and measured outcome (PICO) aimed at answering the following questions

(Table 2): (1) What are the indications for LTVEM that influence outcome? (2) What are the technical requirements for LTVEM? (3) What are the essential practice elements for performing LTVEM?

Individual studies were rated using predefined criteria to evaluate the evidence reflecting risk of bias given the paucity of high-level evidence.^{11, 27, 28} Category I studies were composed of prospective trials, with either a control group or with two patient groups from a broad spectrum cohort one with and other without the disease. Broad spectrum studies described important confounders in their baseline population. Category II were narrow-spectrum prospective trials or large broad-spectrum retrospective trials. Category III were narrow-spectrum retrospective trials or case-control studies. Category IV was all other studies including small retrospective studies. The most relevant articles were identified, rated, and linked to recommendations predicated on category I and II rated studies. Pre-existing guidelines, consensus/position statements, and task force proposals were incorporated when applicable. Studies had to specify key outcome metrics (diagnosis and management) according to the STARD (Standards for Reporting Diagnostic Accuracy Studies) criteria.^{29, 30} High-level evidence was classified, rated, and subjected to a second rating. We used the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system to formulate recommendations.

We developed this clinical practice guideline as evidence-based and consensus-driven modeled after the Epilepsy Guidelines Working Group.³¹ The ILAE Commission on Diagnostic Methods and the Executive Committee of the IFCN each appointed members of the Working Group. The Working Group and the guideline development protocol was approved by the Guidelines Task Force before starting the literature search. Two face-to-face meetings were held. Where relevant high-level evidence was absent, we used the Delphi process³² to obtain blind consensus when majority agreed.²³

3. Indications

Epilepsy and neurology communities have produced 11 references to LTVEM in the form of guidelines and position papers, though limited comprehensive assessment outside individual topics exists¹⁶. Principal clinical indications for LTVEM include: (1) differential diagnosis between epileptic seizures and nonepileptic attacks (2) classification and (3) quantification of seizure types and epilepsy syndromes, and (4) electroclinical characterization of focal seizures during presurgical evaluation in patients with drug-resistant epilepsy^{14, 16, 22, 33}.

3.1 Differential Diagnosis

LTVEM is most used for differential diagnosis of epileptic and non-epileptic attacks with compelling evidence from 143 LTVEM papers (no category I, 6 category II) for clinical usefulness to distinguish between them.^{17, 34-38} One category II study viewing samples of video and EEG to categorize diagnoses demonstrate good inter-rater reliability for epilepsy, but only moderate reliability for psychogenic nonepileptic attacks (PNEA), and only fair inter-rater reliability for physiologic nonepileptic events.^{39, 40} Overall, some reports reveal PNEA in approximately 20-30% of patients admitted for diagnostic LTVEM^{35, 37} but others note a wider prevalence between 5% and 50%.^{41, 42} Misinterpretation of an EEG has been one reason leading to misdiagnosis.⁴¹⁻⁴⁶ A meta-analysis of 135 VEM studies found 60% of referrals were for diagnostic reasons.⁴⁷ Another reason for misdiagnosis are due to spells

demonstrating generalized motor activity.⁴⁸ These may be challenging to distinguish from epileptic seizures based on clinical grounds alone.⁴⁹ In 181 consecutive patient LTVEM recordings, the clinical diagnostic question was answered in 67%.⁵⁰ In older adults (mean age 51 years), LTVEM was useful in 93.5% of 31 patients with pure PNEA.³⁴ Standards for diagnosis of PNEA include use of LTVEM developed by an international consensus group of clinician-researchers.⁵¹ A diagnostic LTVEM outcome study in 230 people resulted in a change in diagnosis in 133 (58%) and refinement of a diagnosis in 29 (13%) to provide overall diagnostic value in 87% of patients. It was particularly useful to differentiate epileptic seizures from non-epileptic attacks as well as frontal lobe seizures from generalized seizures.³⁶ Similarly, another study found 58% of 131 patients had their diagnosis altered by LTVEM, with the greatest change being an increase from 7 to 31% of patients with nonepileptic attacks.¹⁷ Following LTVEM the diagnosis was reversed in 29 (24%) out of 121 patients and 4 diagnoses changed from nonepileptic to epileptic seizures.³⁷ Overall, LTVEM identified patients with pure PNEA to be more common than patients with a dual diagnosis^{38, 52} and physiological non-epileptic events.¹⁹ One category II controlled study of 1083 patients from Poland evaluating PNEA in 85 (7.8%) on clinical grounds: 48 patients were believed to manifest only PNEA and 37 patients were suspected of both PNEA and epileptic seizures.³⁸ When LTVEM was performed only 9/230 (3.9%) patients had a dual diagnoses demonstrating the pitfall for a dual diagnosis based on clinical grounds alone. Another retrospective comparative cohort of 49 patients with PNEA noted 18.2% manifested pseudostatus.⁵³

A systematic review involving 33 papers on diagnostic procedures including seizure induction, Minnesota multiphasic personality inventory, prolactin levels, single photon emission computed tomography (SPECT), and clinical metrics (i.e., pre-ictal pseudosleep, ictal, and post-ictal characteristics) found no procedure attained reliability equivalent to VEM.⁵⁴ Overall, specificity was better than sensitivity ranging from 56-100% compared with 23-96% with none of the tests investigated demonstrating both high sensitivity and specificity. In one pediatric retrospective diagnostic accuracy study, chart review found superior sensitivity of 54% and comparable specificity of 88% for LTVEM compared to standard EEG even in the absence of a typical seizure or spell.⁵⁵ LTVEM sessions were significantly shorter in a group of 221 patients undergoing LTVEM for diagnosis (mean: 2.4 days) than for those admitted for presurgical evaluation (3.5 days).³⁷ In a series of 148 consecutive patients evaluated with LTVEM over approximately 3 years there was a significant reduction in ASM usage in people with epilepsy and PNEA after the procedure.³⁴ By providing a definitive diagnosis, potential adverse consequences of unnecessary ASM and invasive procedures may be averted by LTVEM⁵⁶.

The highest-level studies in this area included 6 level II studies which are downgraded due to unexplainable inconsistencies between these studies but upgraded due to the magnitude of effects. The overall confidence in evidence for these studies is therefore moderate for LTVEM to provide differential diagnostic utility in differentiating epileptic from non-epileptic events.

Recommendation: LTVEM monitoring should be used to differentiate between epileptic and non-epileptic events, in patients where the diagnosis is in question (strong recommendation).

3.2 Classification

Classification of seizures and epilepsy syndromes is essential for appropriate selection of ASM.^{43, 57, 58} The International Classification of Epileptic Seizures divides seizure types into focal and generalized.⁵⁹ LTVEM-proven epilepsies support a continuum of disease^{11, 58, 60-62} providing definite diagnosis beyond history, clinical seizure types, neurophysiologic, and neuroimaging features.^{13, 19, 24, 59, 63, 64} A prospective study of inpatient LTVEM (at least 3 hours) clarified the epilepsy syndrome in 93% of patients, one-third of whom were eligible for epilepsy surgery.⁶⁵

Alternative classification systems based purely on semiology have been proposed⁶⁶. A prospective comparison (category II) between ILAE and semiological seizure classification systems in 78 consecutive patients found seizure classification changed significantly from baseline following LTVEM using the ILAE more than the semiological classification.⁴⁰ Another adult semiology study (category IV) of 90 patients found some seizure types (e.g., myoclonic and hypermotor seizures) had excellent consistency between historical description and a LTVEM confirmed diagnosis while other types (focal seizures) were less reliable.⁶⁷ In a study (category IV) of 323 children (mean age of 7 years), episodes of staring, myoclonic jerking, abnormal eye movements, and posturing, 53% were correctly reclassified by new information derived from LTVEM.⁶⁸ Other retrospective (category IV) studies involving patients with juvenile myoclonic epilepsy reported focal clinical and generalized EEG features in about one-half of patients blurring the clinical diagnosis.^{69, 70}

Most studies on the role of LTVEM to classify seizures are category III and IV. They proved useful in distinguishing between focal and generalized epilepsy in 47/230 (35%) in one study.³⁶ A large retrospective LTVEM-based surgical series classifying patients by EEG found a focal EEG in two-thirds, generalized abnormality in 22%, lateralized features in 4%, and 6% that were mislocalized or mislateralized.⁷¹ Sleep-related seizures may be diagnosed and correctly classified (focal vs generalized) by overnight LTVEM.^{72, 73} A small retrospective study found a significant increase in the percentage of generalized epilepsy diagnoses (more than double) after LTVEM.¹⁷ Genetic Generalized Epilepsies (GGE) have not found gene defects to be a reliable classification method,⁷⁴ and IEDs are neither seizure type nor epilepsy syndrome specific.^{75, 76} LTVEM is able to classify and subclassify GGE,⁷⁷ and reclassify seizure types to select appropriate ASM.⁴³

There was a single class II study and the overall confidence in evidence is low to utilize LTVEM for purposes of classifying patients with epilepsy.

Recommendation: LTVEM may help classify patients with epilepsy in whom the seizure type or epilepsy syndrome is undetermined (weak recommendation).

3.3 Seizure Quantification

Thirty articles (category III and IV) addressed seizure quantification and LTVEM. LTVEM studies demonstrate fewer than 50% of seizures (47-63%), on average, are correctly represented by patients with accuracy of reporting varying over time.⁷⁸ One (category IV) questionnaire study of patient's subjective self-awareness of a seizure found 44.2% of LTVEM-proven seizures went unnoticed.⁷⁹ Still, self-reporting is the foundation for clinical decision-making of seizure patients including regulatory trials leading to approval of ASM.⁸⁰ Long-term ambulatory EEG and LTVEM studies reveal 20-25% of patients are always unaware of seizures.⁸¹⁻⁸⁵ At risk groups include patients with temporal lobe epilepsy (TLE) and focal impaired awareness (non-motor) seizures^{79, 82, 84}, fluctuating cognitive decline⁸⁶⁻⁸⁹ and transient epileptic amnesia.^{90, 91} In a (category III) LTVEM study evaluating 327 consecutive TLE patients,

subclinical seizures were detected in 8.3%, and 1% had only subclinical seizures recorded (all of which were detected within first 24 hours).⁹² Using post-ictal surveys during LTVEM, patients with convulsions associated with GGE were more self-aware of them than those with focal to bilateral tonic-clonic seizures.⁸¹

Patients with generalized epilepsies, severe epilepsy, and those with frequent seizures are good candidates for seizure quantification by LTVEM. Convulsions are readily identifiable,⁹³ however, absence seizures and bursts of generalized epileptiform activity may be subtle and subclinical unless response testing is performed. Also failure to recognize nocturnal seizures may occur in up to 86% of patients.⁹⁴ LTVEM can quantify seizure frequency and identify clinical phenomenology that could potentially allow medication changes to yield a more favorable response to treatment⁹⁵ and lead to improved patient outcomes.⁸⁴

Multiple lower-class studies were inconsistent and the confidence in evidence for utility of video-EEG monitoring to quantify seizures is low. All studies demonstrate patients under or overestimate their seizure frequency. Expert opinion for quantification using LTVEM is generally accepted when objective information is required for management.

Recommendation: The usefulness of LTVEM to quantify seizures in patients with epilepsy is weak.

3.4 Seizure Characterization for Surgical Management

Three prospective longitudinal cohort studies of patients with newly diagnosed epilepsy treated with ASM fail to show a decline in the drug-resistant epilepsies over 2 decades.⁹⁶ Despite new advances,⁹⁷ risks for morbidity and mortality exist for patients when seizures are uncontrolled.⁹⁸⁻¹⁰¹ Two category 1 randomized controlled clinical trials in adults, and one trial in children demonstrate effectiveness of epilepsy surgery against best medical practice following LTVEM.⁹⁸⁻¹⁰⁰ Position statements recommend epilepsy surgery be considered when patients are resistant to ASM.¹⁰¹ Epilepsy surgery is under-utilized,^{102, 103} with more than 10 million people worldwide who are potential surgical candidates.^{104, 105}

Multiple category III and IV studies stratify surgical candidacy based upon LTVEM results.^{47, 106} Scalp-based VEM and invasive EEG (iEEG) during LTVEM are standard neurophysiological techniques to characterize the seizure onset zone for surgery.^{11, 47} Few studies characterize seizure-onset denoted by EEG patterns relative to outcome.^{107, 108} A category III study involving 3057 seizures in 75 consecutive focal epilepsy patients after successful epilepsy surgery compared matched scalp and iEEG seizures from separate LTVEM sessions.¹⁰⁶ A multivariate analysis revealed, a localized scalp EEG at seizure onset (independent of location) predicted a favorable outcome after surgery,¹⁰⁶ while multilobar and widespread seizure onset predicted unfavorable surgical outcomes.^{106, 109} Other retrospective category III studies involving combined scalp and iEEG during VEM demonstrate moderate to favorable sensitivity and specificity for patterns predicting localization in patients with TLE.^{110, 111} In a prior report analyzing 61 patient with lesional focal epilepsies, 71 pairs of seizure-onset patterns matched between scalp and iEEG found some scalp seizure-onset patterns that were highly associated with a specific intracerebral pattern of the depth localized seizure-onset zone.¹⁰⁵ Single-center (category IV) studies suggest some focal extratemporal scalp patterns predict a seizure-free outcome.¹¹² In contrast, other reports found

dissimilar generators were capable of producing similar scalp-based ictal patterns.^{113, 114} A consortium funded by the European Union performed a systematic review and meta-analysis.¹¹⁵ Pooled estimates were calculated for sensitivity and specificity with respect to postsurgical seizure freedom. They found LTVEM had substantial heterogeneity across studies and were associated with moderate sensitivity and low specificity in identification of the epileptogenic zone. Higher sensitivity was seen in lesional TLE compared to lesional ETLE.¹¹⁵ As a result, guidelines for epilepsy surgery across Europe based upon the diagnostic accuracy of LTVEM were implemented.¹¹⁵ Due to lack of evidence for the utility of LTVEM in children, a modified Delphi process of pediatric epilepsy experts developed consensus-based guidelines for LTVEM in the pre-surgical evaluation of children in the United Kingdom (UK).²³

For patients with TLE there were two class 1 studies in adults and 1 class 1 study in children with indirect evidence of efficacy for surgical treatment compared to best medical therapy following LTVEM. There is high confidence in evidence that LTVEM should be used as part of the presurgical evaluation for TLE patients. For extra temporal epilepsies there is low confidence in evidence for LTVEM use to characterize seizure during presurgical evaluation.

Recommendation: LTVEM must be used in the presurgical evaluation in drug resistant TLE patients (strong recommendation). There is neither evidence for nor against LTVEM to characterize patients with drug-resistant extra temporal epilepsy in the presurgical evaluation (weak recommendation).

4. Yield of VEM

The overall diagnostic yield of LTVEM varies widely among studies ranging from 19% to 75% depending upon the definition of utility, methodology, and cohort of patients evaluated^{11, 13, 17, 35, 37, 50} but appears independent of the hospital setting.¹¹⁶ A systematic review found most of the literature on LTVEM focused on the noninvasive and invasive pre-surgical evaluation prior to epilepsy surgery.⁴⁷ A large, prospective study demonstrated that LTVEM was useful to clarify the clinical diagnosis in 56.3% of patients,¹¹⁷ and subsequent meta-analysis found the pre-admission diagnosis changed in 35.6% of patients following LTVEM prompting change in management.⁴⁷ Successful LTVEM sessions are significantly longer in the presurgical group than in the diagnostic groups.³⁵ No difference in diagnostic yield has been identified with respect to age,^{19, 118-120} patients with neurological impairment,¹²¹ or reason VEM was performed.³⁵ One retrospective study did not find a correlation between preadmission seizure frequency and yield for recording events during LTVEM.¹²² Furthermore, even patients who previously had ambulatory EEG,¹¹⁸ and those who had prior LTVEM, were found to have additive value in up to 77% of patients.³⁵ In a prospective comparative study (category II) of 129 patients with 10 month follow-up, after LTVEM, the diagnostic categories were changed from pre-admission in 41.1% of the patients, and 40.3% had revisions in management.¹²³

Pitfalls in VEM exist to compromise yield. Semiology alone may be vague or insufficient and post-ictal features over-interpreted and misdiagnosed as PNEA.^{11, 124, 125} There is a small risk that provocation by suggestion may lead to false positive results in patients with PNEA necessitating identification of the habitual event.¹²⁶ Results from category IV studies involving EEG over-interpretation in patients with PNEA misclassified as epileptic seizures^{43, 127} have been noted following LTVEM. During VEM, approximately 20% to 30% of patients with epileptic seizures and PNEA never have a seizure

during hospitalization for VEM^{41, 128, 129} leading to “inconclusive” results. In patients with epilepsy, VEM may not reveal IEDs in EEG and be devoid of a detectable scalp ictal rhythm during focal aware seizures^{130, 131} falsely leading to misdiagnosis as PNEA.¹³² Further, patients with PNEA can generate rhythmic movement artifacts that falsely mimics an electrographic seizure¹³³ or become obscured due to hyperkinetic epileptic seizures limiting identification of seizure onset in patients evaluated for epilepsy surgery.¹³⁴ Scalp ictal EEG may falsely localize and lateralize focal seizures,¹³⁵ especially those arising from mesial and posterior quadrant neocortices^{126, 136} potentially resolved when invasive EEG is performed.^{137, 138} One class II study provides low confidence in evidence that more than one-third of patients will experience a change in management after undergoing VEM.

Observation: LTVEM may result in a change in management in some patients (weak recommendation).

5. Technical standards

Minimal technical standards are essential to ensure high-quality recording, adequate storage, optimal review, and web-based remote exchange of information among providers at full-service epilepsy centers and in the community.^{125, 139} Evolving digital technology and computer sophistication of instrumentation has transformed the practice of LTVEM¹⁴⁰ leading to improved technical standards.¹⁴¹ International equipment guidelines for optimal methods of LTVEM including signal processing and electronic transfer, and larger storage capacity have facilitated widespread use in developed countries.^{14, 142, 143} However, high-level evidence-based standards evaluating equipment and instrumentation is unavailable with heterogeneity for current clinical practices for LTVEM.¹⁴⁴ We identified standard technical parameters for LTVEM using the modified Delphi method³² to reach an unprompted blind majority consensus of expert opinion (**Table 3**) by web-based survey questionnaire.

5.1 Electrode array and EEG recording

During LTVEM, EEG is telemetered over days through a cable or radio link in the hospital while behavior is documented by video. Computing power permits LTVEM to acquire and analyze a signal from the brain.¹⁴⁵ LTVEM and variations in sensory number and design allow signal detection from deep¹⁴⁶ and small regions of brain.¹⁴⁷ Interictal EEG abnormalities alone are insufficient to provide a definitive diagnosis.^{19, 63} A recent IFCN guideline evaluating the evidence for diagnosis and monitoring with EEG in people with epilepsy has been published separately.¹¹ Consensus was reached for LTVEM to use a greater number than the standard 21 electrodes used for standard EEG recording. Both the 10-20 and 10-10 international system of electrode placement were endorsed. We support recommendations for use of standard IFCN array of 25 electrodes (children and adults) during scalp-based LTVEM augmenting the basal temporal regions.²⁵ Dense EEG arrays during LTVEM and high sampling rates show even greater source localization.^{25, 148-150} This compares to a minimum of 16 channels for diagnostic LTVEM, and 32 for presurgical evaluation that has been recommended by the ACNS.^{14, 22} Routine use of basal temporal electrodes but not sphenoidal, nasopharyngeal, naso-ethmoidal electrodes is recommended. No consensus was reached regarding use of diagnostic electrode caps. Nor was consensus reached to recommend maximal allowable scalp electrode impedance though values less than 5 kΩ are routinely applied.^{25, 139} Consensus was reached for LTVEM to accommodate use of all forms of invasive electrodes.

Foramen ovale electrodes received negative consensus for use. Incorporating polygraphic recordings depend upon the focus of a specific clinical problem.¹⁵¹⁻¹⁵⁴ Oximetry, extra-oculogram, respiratory and tremor monitors with scalp recording are multimodal options during LTVEM. All raters recommended EKG recording was necessary to record during LTVEM.

LTVEM operating systems require hard drive memory capability to acquire at least 200 GB to allow for continuous monitoring up to one-week including software applications.¹⁵⁵ Solid-state multichannel amplifiers should be optically isolated and follow minimum technical standards of recording standard EEG.^{11, 139} Consensus was reached for analogue to digital converters today using 16-bit or higher, sample rates of more than 256 samples/second, and minimum filter settings between 0.5 Hz and 70 Hz. Following acquisition and digitization EEG signals should connect to a central computer capable of storing at least 24 hours of continuous VEM data.²² Network connectivity is required for media viewing and information transfer to archive data by technologists or junior physicians. There was consensus support to maintain the entire video and EEG files until LTVEM reporting was finalized. A recent retrospective 15-year study (category III) involving 1025 cases noted a trend of a rising population of patients with normal VEM results increasing from 4.1 to 24.1%.¹⁵⁶ Polygraphic recordings supplement LTVEM when abrupt motor signs occur.¹⁵⁷⁻¹⁵⁹ Noninvasive dense arrays approach may have similar localizing ability to invasive EEG (iEEG) in patients with focal seizures.^{160, 161} But there are technical challenges to recording dense array EEG during LTVEM, including limited data streaming and poor long-term tolerability of EEG head nets, so only low level evidence and expert consensus exists to support the use of dense array LTVEM in complex cases when patients are considered surgical candidates.^{160, 162, 163}

5.2 Video

Video recording is routine in LTVEM¹⁶⁴⁻¹⁶⁶ in concert with EEG in expanding numbers of EMUs.^{117, 167, 168} One camera is standard for LTVEM, however some centers use two cameras to provide complementary information from different viewing points. Prospective multi-rater studies (category II and III) have shown that compared with LTVEM, video alone may be useful when evaluating the clinical description of patients with observed seizures,^{125, 169} with similar sensitivity (category III) compared with EEG¹⁷⁰ in various patient populations.¹⁷¹ Implementing video recording added to EEG increases the diagnostic yield over EEG alone^{172, 173} detailing semiological classification.⁶⁶ However, no uniform nomenclature and consistent classification system differentiates patients with epilepsy from PNEA by video alone during LTVEM¹⁷⁴, although semiologies⁴² allow hierarchical clustering.^{175, 176} Based on video data alone, a prospective LTVEM study involving 5 epilepsy experts found 7/23 (30%) cases by all raters correctly classified epileptic seizures and PNEA.¹⁷⁷ A prospective study analyzing 120 seizures from 35 consecutive subjects detailing semiology found of 45 signs demonstrated on video, only 3 signs for epileptic seizures and 3 for PNEA were significantly useful in categorizing seizures, and no single clinical feature was sensitive and specific for either event.¹⁷⁸ Video recorded seizure phenomenology during VEM identifies patterns¹⁷⁹ that may localize or lateralize signs with relative specificity for their involvement.¹⁸⁰

Standard digital audio-video data is acquired with MPEG level 1 or 2 compression however, the synchronization between video and EEG has not been standardized.¹⁴ Split screen synchronized video

and dual screen review are reported to be useful to evaluate paroxysmal neurological events.¹⁸¹ Digital video (and audio) are typically encoded into MPEG, MPEG2, or MPEG4 formats differing in the degree of resolution and compression algorithms used, and synchronized with EEG by use of a time marker. 24-hour VEM requires up to 30 GB of memory and varies depending upon video resolution (usually 240 x 320 pixels vs 480 x 640 pixels), degree of coloration, number of frames/second, and machine data compression algorithm employed. Therefore, relevant clips involving event of interest are selected for storage of VEM data to limit memory use.

There were 4 class II studies (2 without EEG and 2 with EEG) that consistently showed benefit with the use of video. The confidence in the evidence of using video with EEG monitoring is moderate.

Recommendation: video should be combined with EEG during the use of LTVEM (strong recommendation).

5.3 Safety

The potential for dangerous consequences exist during LTVEM because patients' seizures are induced.⁸ Convulsions and seizure emergencies, falls, injury, and postictal psychosis among others are possible safety risks.^{33, 167} Standardized protocols are recommended for use to ensure patient safety.^{144, 182} Safety and quality data from 181,823 patients reporting on 34 different safety variables demonstrates a great deal of variation in reporting safety and quality measures in EMUs in a meta-analysis.⁴⁷ No validated protocols are universally available and utilized, and substantial variation in practice for essential aspects of LTVEM exist for performing optimal patient observation, tapering ASMs, and ASM rescue protocols.¹⁸³⁻¹⁸⁵ Therefore, great variation in quality and safety measures exists during LTVEM. A pooled proportion of adverse events occurred in 5-9% of patients in a meta-analysis.⁴⁷ Practice variability was present among 32 epilepsy centers in the UK reflecting differences in patient populations.¹⁶⁷

5.3.1 Clinical safety

Overall, LTVEM is an acceptably safe procedure with appropriate precautions.¹⁸⁶⁻¹⁸⁸ Safety issues are most frequently encountered for patients undergoing pre-surgical LTVEM.¹⁸⁹ Seizure provocation poses potential safety risks to patients represented by category III and IV studies.^{183, 190, 191} Even patients with PNEA are prone to adverse events, usually falls¹⁸³ often while in the bathroom.¹⁹² A large category III study of 976 patients found only 1.9% of patients fell (without injury) despite being freely mobile, a similar finding reported in other centers practicing restricted mobility.¹⁹³ One study (category III) compared falls in alert patients within the first 3 days of LTVEM (in the bathroom) and hospitalized patients with mental status changes who fell after 3 days (in their rooms).¹⁹⁴ Novel lift systems, patient education, frequent nursing rounds, use of bed alarms, and assistance when out of bed may limit fall risk.¹⁹² A category IV study reviewing records from an Epilepsy Foundation database identified 2/733 patients with aspiration following a GTC seizure, and shoulder dislocation in 8/806 during seizures accounting for an overall risk of <1%.¹⁹⁵ Such serious medical consequences associated with seizures such as malignant cardiac arrhythmias, bony fractures, and pneumonia rarely occur.^{187, 191} Prospective comparative studies (category III) show patients with PNEA have increases in heart rate and systolic

blood pressure during the ictal phase, potentially predisposing to complications when attacks are severe and prolonged.¹⁹⁶ Ictal asystole has been reported in 0.22–0.4% of patients undergoing LTVEM, and systematic review of 157 cases found females with early-onset epilepsy and preexisting heart conditions, and males with late-onset drug-resistant epilepsy and autonomic dysregulation were predisposed.¹⁹⁷ Sudden unexpected death in epilepsy during LTVEM has been rarely reported as retrospective series (category IV) but involving multiple centers throughout the world.^{198, 199}

Current practice recommendations reached consensus agreement to obtain informed consent before VEM. Requiring 24 hour a day observation of patients by nursing and professional staff over the monitoring duration was considered a minimum standard, including alarm systems and direct observation with video monitors.¹⁶⁷ A large, multicenter, category II study of epilepsy centers in the UK investigated staffing as a patient safety outcome recommending a nurse-to-patient ratio in an EMU should not exceed a ratio of 1:4.²⁰⁰ A category II prospective population-based observational study of patients implanted with invasive EEG electrodes found a risk of intracranial hemorrhage in a significant minority during LTVEM.²⁰¹ Nurse-to-patient ratios in an EMU was identified to promote safety but these studies provide low confidence in the evidence.

Recommendation: The safe, maximal patient to nurse ratio may be 1:4 (weak recommendation).

5.3.2 Electrical safety

Category IV clinical reports reflect essential safety features during LTVEM (**Table 4**).²²¹⁻²²⁵ Electrical safety rules and governance are unique to individual countries and established by the International Electrotechnical Commission. Electrical shocks usually result from chassis leakage current from LTVEM equipment electrically powered from the 120-volt (United States; 110 volts in Europe) power transformers. Electrical injury is possible when current passes through a patient from an electrical source or electrode contacts.^{202, 203} Any mains-powered electrical device may “leak” current and enter the patient through direct contact of a nearby metal object or indirectly by capacitive coupling inside an electrical device from nearby wiring. Safe current limits are set for both normal conditions and for single fault conditions (i.e., a disconnected earth ground). LTVEM safety guidelines exist for individual components of LTVEM equipment and are regularly checked for safe use according to hospital standards and biomedical engineering services.²⁰⁴ Proper grounding of the patient and the EEG recording equipment is critical for avoiding electrical shock risk.

Microshock injury could occur to patients undergoing LTVEM with scalp electrodes if there is a low-resistance pathway into the body such as a pacemaker or saline-filled catheter which can provide a low resistance pathway to the heart.²⁰⁴ Currents of 5-10A can induce ventricular fibrillation²⁰² as a function of body habitus, current intensity, duration, and pathway.^{203, 205, 206} Ground loops are critical to avoid during LTVEM. Hazardous currents can be generated from ambient magnetic flux from powerline wiring in walls or ceiling in EEG leads that are too lengthy or widely separated.

There is no evidence for or against methods to ensure electrical safety in patients undergoing VEM. But principles that apply to electrical safety of all hospital devices apply to EEG equipment as well. Grounding safety rules should be followed to prevent patient injury.

5.4 Practice and Personnel

Despite the use of VEM as a gold standard for seizure diagnoses, limited appreciation of this technique is held by some general neurologists, psychiatrists, hospital administrators, and insurance carriers managing people with paroxysmal neurological disorders.¹⁶ The current practice of VEM has been outlined in a European multi-center web-based survey study.³³

5.4.1 Seizure Monitoring

Considerable variation in the practice and organization of EMUs was found in a web-based survey study involving 25 centers across 22 European countries, with subsequent recommendations to follow evidence-based LTVEM practices.³³ Delayed response to seizure alarms may occur due to high false-positive rates of detection.²⁰⁷ A retrospective multicenter study found average response time from caregivers was twice as fast as the response by EMU-based personnel.²⁰⁸ Staff uncovering patients during seizures to assist with evaluation of semiology found 40% of patients were fully or partially obscured for more than 30 seconds during the event compromising visualization.²⁰⁸ Implementing standardized protocol for managing and testing patients during seizures in the EMU can potentially increase the quality of the data recorded during LTVEM. A task force appointed by the ILAE Commission on European Affairs and the European Epilepsy Monitoring Unit Association prospectively studied (category II) testing paradigms during seizures in 152 consecutive patients (250 seizures) at 10 epilepsy centers with an interictal, ictal, and post-ictal testing paradigm successfully implemented in 93% of patients with seizures, limited only by seizures of short duration.²⁰⁹ A European survey showed 91% of EMUs performed ictal or postictal testing, however, there was no standardization of the procedure, and many EMUs lacked institutional guidelines for testing patients during seizure monitoring.¹⁴⁴ Retrospective comparative assessment of seizures in 33 adult or pediatric patients captured during LTVEM found behavioral testing during seizures was able to be performed in only 50% of patients whereas automated video-recorded behavioral tasks activated by computer-based seizure detection provided reliable behavioral assessment.²¹⁰ One category II study was unable to demonstrate superiority of a particular testing paradigm during VEM. Therefore, the confidence in evidence is low.

Recommendation: A written, standardized protocol may be used in each LTVEM unit for managing and testing patients during seizures (conditional recommendation).

5.4.2 Services

Guidelines for facilities, personnel and essential LTVEM services are established by experts in referral hospitals to comply with national and international standards.²¹¹ Partnerships between epilepsy specialists in full-service epilepsy centers performing LTVEM and referring clinicians should exist to form care networks to continue best practices and follow-up patient management.^{16, 212}

5.4.3 Staffing

Patients who undergo diagnostic LTVEM are subject to variable staffing models.^{116, 212, 213} Consensus was obtained for some elements involving staffing VEM units by skilled personnel (**Table 5**).

Specialized services such as functional brain mapping by electrical stimulation of invasive electrodes, electrocorticography, evoked potential recording, and investigative drug and device trials complement clinical care and require a high degree of expertise when considering resection or ablation of epileptogenic tissue.²¹² Individual qualifications and responsibilities have been outlined for a LTVEM laboratory.²² Implementing periictal nursing intervention was shown to shorten the duration of postictal generalized EEG suppression but oxygen administration did not in a retrospective (category III) study.²¹⁴ A national survey report in the UK recommended dedicating healthcare professionals in LTVEM units in charge of patient supervision should target one nurse for 4 patients or less as optimal¹⁶⁷ similar to an optimal ratio of technologists to patients monitored. Patient companions during LTVEM help document events, test awareness, ensure visualization of the patient on video, and alert staff at seizure onset. Immediate family members are often more helpful than non-family members.²¹⁵

Qualified EEG technologists and monitoring technicians are key members of the team during LTVEM to recognize events and interact with nursing staff and provide feedback during seizure monitoring. A survey study in the United States found 68.8% of participants provided continuous patient observation during LTVEM.¹⁹¹ A European survey study reported 80% of participants provided continuous observation with 10% only during daytime hours of operation and 10% performing observation intermittently in conjunction with automated seizure and spike detection algorithms.¹⁴⁴

5.4.4 Duration of Recording

Wide variability exists among epilepsy centers regarding the duration of VEM.²¹⁶ The duration of EMU admission for VEM depends upon the reason for admission.²¹⁷ One comparative trial (category III) in 226 patients found most patients undiagnosed following outpatient EEG received a definitive diagnosis in less than 1 day of VEM.²¹⁸ Other prospective studies (category III) required a second day of VEM²¹⁹ and others were nearly equal between 1-2 days.⁷⁶ In contrast, a retrospective (category IV) study of 439 LTVEM cases found 72 hours was able to record at least one seizure in 90% of patients with epilepsy (vs 48 hours for those with PNEA).¹²² One retrospective study (category IV) 5 days of LTVEM reported a 98% recovery rate for the targeted clinical event.⁷⁶

Studies (category III and IV) in patients with PNEA confirmed by short-term VEM suggest LTVEM could be obviated when events are captured.^{129, 220} Facilities may be unavailable or inaccessible in remote regions and developing countries.²²¹ A recent prospective observational study in India (category III) correctly diagnosed about 80% of PNEA cases with short-term LTVEM.²²² However, shorter initial duration of LTVEM show higher risk for patient readmission in a large retrospective single center cohort comprised of 865 patients and 30-day encounters with a readmission rate of 7.0%.²²³ Overall, the optimal duration for LTVEM appears to be more than 3 days for patients with drug-resistant epilepsy and those with PNEA are typically diagnosed in less than 2 days.²²⁴ Retrospective studies show IEDs in the EEG appeared soon after sleep in more than 90% of patients with focal and generalized epilepsies.²²⁵ In a retrospective (category III) study of 596 admissions, nearly 40% of epilepsy patients had longer LTVEM durations compared to those with PNEA with the need to record additional seizures as the primary reason for extended stays.²¹⁷ For surgery, at least 3 seizures are generally representative in uncomplicated cases though higher number of seizures may be required when more than one epileptogenic zone is suspect. In bitemporal epilepsy patients implanted with a responsive

neurostimulator, the average time to record the first electrographic seizure from a contralateral focus was 41.6 days²²⁶ in a retrospective review (category III) evaluating the electrocorticogram. A large retrospective (category III) study of 1000 children (mean 7 years) monitored over 1.5 days ($r=1-10$) found longer sessions were associated with significantly higher rates of ILAE classification of epilepsies and lower rates of inconclusive session. Hence in adolescents LTVEM was recommended for 3 days or more when events are less than daily.²²⁷ Because the duration of LTVEM depends on the indication and on seizure frequency, the duration of LTVEM is variable and based upon the endpoint of recording.

Recommendation: The duration of LTVEM will vary relative to the indication for performance and number of seizures and events captured (conditional recommendation).

5.4.5 Activation

Activation protocols provide relative degrees of usefulness in patients with epilepsy.²²⁸ Two prospective multicenter studies (category II) support safety and efficacy of activation procedures during EEG.^{229, 230} In addition to hyperventilation and photic stimulation, sleep deprivation is recommended in guidelines to elicit abnormalities.^{139, 143, 231} In addition, exercise, stress, and dietary influences may precipitate seizures in some patients with epilepsy.^{232, 233} A random sample of 1000 standard EEGs in the UK validated the additive effect of activation to standard EEG in 11% of cases.²³⁴ In patients with epilepsy, standard EEG from category II and III studies demonstrate sleep as a potent form of activation to trigger seizures and IEDs.^{169, 235} Sleep-deprivation during LTVEM has diagnostic value in activating IEDs,^{236, 237} and an acceptable practice in the United States and Europe^{139, 238} to increase the yield^{239, 240} despite a lack of systematic analyses. The ACNS, ILAE, and NICE all recommend that HV is performed as part of a standard EEG.²⁴² Hyperventilation with breath counting and intermittent photic stimulation are useful in patients with GGE to clarify epilepsy syndromes.⁶² A prospective study (category I) of 52 seizures recorded over 247 days of LTVEM demonstrated the rate of activated seizures was nine times higher than the rate of control seizures and demonstrated value of instituting repeated hyperventilation as an activation technique combined with ASM withdrawal.²⁴¹ One category II study found usefulness of hyperventilation to activate 25% of patients with temporal lobe seizures during LTVEM.²⁴² Unique methods of activation during LTVEM may provoke seizures in some patients with reflex epilepsies using individualized stimuli including reading, writing, eating, performing arithmetic, and somatosensory stimulation.^{235, 243}

In the diagnosis of PNEA, there is marked methodological heterogeneity in activating techniques and low level of evidence in a systematic review including 11 prospective studies.²⁴⁴ Activation techniques expedited the goal of achieving event recording to diagnose patients with PNEA in a randomized controlled trial using simple suggestion techniques during LTVEM⁴¹, either alone^{229, 230} or in combination with photic stimulation¹²⁹ to provide evidence of suggestibility.²⁴⁵ Temple compression and tuning fork application were found in a retrospective (category IV) study to be most effective.²⁴⁶ However, controversy exists regarding ethical use of activation in PNEA.^{39, 247-249} Sensitivity range from of 77- 84%²⁵⁰⁻²⁵³ and specificity approaches 100%²⁵⁰ for diagnosis. In older comparative trials (category III and IV), using placebo (e.g., saline injection, application of color patches, alcohol patches or tuning fork

etc.) elicited PNEA in most patients.²⁵¹ Atypical events or epileptic seizures can occur in a minority resulting in an incorrect diagnosis.²⁵⁰ Provocation without placebo such as combined hyperventilation and photic stimulation may be favorable due to its comparable sensitivity to other placebos without perceived deception given its routine use in standard EEG,²⁵² non-inferiority,²⁵⁴ with the potential to shorten LTVEM and reduced costs by expediting the diagnosis for patients with infrequent events.²⁵⁵

There is moderate confidence in evidence that hyperventilation was successful in conjunction with ASM withdrawal as an activating procedure to provoke seizures in patients with GGE and low evidence in PNEA with expert-opinion suggesting patient-specific provocation methods may be performed in patients with reflex epilepsies.

Recommendation: patients with GGE should undergo hyperventilation in conjunction with ASM withdrawal as an effective activating procedure (strong recommendation).

5.4.6 Drug reduction

ASM is routinely reduced during LTVEM to increase the likelihood of event capture. A judicious speed of ASM reduction should be balanced against ineffective or prolonged hospitalization for LTVEM.¹²² Current practices of ASM reduction are highly variable across epilepsy centers performing LTVEM. Rapid withdrawal may potentially obscure localizing information at seizure onset in the EEG during LTVEM in patients with drug-resistant epilepsy.^{33, 256} Introducing a scheduled taper of ASM according to a pre-prescribed protocol facilitates a standardized approach to safe seizure provocation.¹⁸² However, no standardized protocols for reduction of ASM during LTVEM exist²⁵⁷ and current practices are highly variable across centers.¹⁸⁴ Overly aggressive ASM taper may result in capturing non-habitual seizure semiology, obscure localizing information on ictal EEG, or produce seizure clustering and status epilepticus. Formal protocols focused on ASM taper were shown to have fewer seizure clusters during LTVEM.²⁵⁸ Various study methodologies and small sample sizes have limited reliable conclusions to recommend the optimal rate of ASM taper during VEM.²⁵⁹ In a comparative study (level II) ictal EEG localization did not change during ASM withdrawal during reduction of lamotrigine and carbamazepine during LTVEM performed during pre-surgical evaluation.²⁶⁰ Two prospective studies have provided high level evidence for the withdrawal of ASM during LTVEM.^{261, 262} One randomized controlled (category I) trial using open-label but blinded outcome assessed ASM reduction in 2 arms of 70 patients each, comparing fast taper by 30–50% (fast) and slow taper by 15-30%, in patients without a prior history of status epilepticus or frequent daily seizures and concluded fast taper of ASMs was safe and effective aside from an increase in 4-hour seizure clusters.²⁶¹ A second prospective study of 158 patients with no control arm (Category II) found rapid taper of ASM combined with sleep deprivation during LTVEM was safe and effective in adults relative to time of first seizure resulting in reduced time spent in the EMU.²⁶² This compares favorably with other retrospective, single-center, observational studies.²⁶³ In contrast, rapid ASM tapering within one day was associated with longer EMU admissions and greater seizure frequency during LTVEM.¹²² Rapid ASM taper in a category III study did not produce a significant adverse effect on the ECG or heart rate variability.²⁶⁴ Tapering carbamazepine was found to influence ictal semiology intensifying seizure frequency and severity compared to valproate in a category III study.²⁶⁵ In category IV studies involving barbiturates and benzodiazepines, taper triggered seizures in some people without epilepsy.²⁶⁶ Patients completely discontinued from ASM appear more likely to experience focal

to bilateral tonic-clonic seizures than those in whom ASM were partly discontinued.²⁶⁷ Slowly tapering ASM at home prior to inpatient LTVEM starting a week or more prior to admission has been reported to be safe in a retrospective observational cohort of 273 patients (category III) without complications.²⁶⁸

In patients without a prior history of status epilepticus or frequent daily seizures, ASM taper by 30–50% (fast) and slow taper by 15–30% was safe.

Recommendation: in patients without a history of status epilepticus or frequent daily seizures a taper of 30-50% daily should be considered (strong recommendation).

5.4.7 Automated Analyses

Automated analyses used to identify IEDs and electrographic seizures attempt to condense and reduce the large volume of data requiring physician review²⁶⁹ to facilitate time-efficient interpretation. Relying solely on automation alone is not recommended without EEG review by a qualified human interpreter to limit overestimating abnormality. Commercially available automated software is used to detect and validate epileptiform activity, classify, and quantify EEG abnormalities.²⁷⁰ However, while even better performance is likely to be encountered, human validation will be required. Software systems available for seizure detection have been tested in a prospective multi-center study²⁷¹ and retrospectively.²⁷¹⁻²⁷³ Algorithms for automated seizure detection during scalp LTVEM have a greater sensitivity than IED detection and may exceed 75.0% detection with low false positive rate²⁷⁴ to supplement patient and witness identified seizures. In a study of 159 patients with temporal lobe epilepsy, 794 focal seizures were analyzed with a sensitivity of 87.3% and 0.22 false detections per hour.²⁷⁵ However, this has not been confirmed in extratemporal seizures or generalized seizures of a short duration (e.g. epileptic spasms). In a recent study of the performance of the Persyst 14 seizure detection algorithm in prolonged EEGs from 120 patients, the performance of the system was comparable to three human experts and had a sensitivity of 78% and a false positive rate of 1 per day.²⁷³ Most commercially available systems will only identify a seizure if the ictal EEG changes have a minimum duration of at least 12 seconds. Automated analyses for seizure detection is estimated to save 1.3 hospital days per patient admission, based on the percentage of seizure detections captured solely by the computer.²⁷⁶

Recommendation: Automated algorithms for spike and seizure detection may provide complementary aid to expert assessment (weak recommendation).

5.4.8 Rescue Medication

The best seizure response occurs with preparation and when a protocol is in place for seizure urgencies and emergencies.¹⁶ Prolonged seizures, acute repetitive seizures, and rarely status epilepticus may result during VEM.²⁷⁷ Implementing safety strategies result in a clinically relevant reduction of adverse events.²⁷⁸ Fortunately, serious consequences and adverse events are rare when slow reduction of ASM is used with a benzodiazepine rescue protocol.²⁵⁹ In children and adults, class 1 evidence demonstrates both intravenous lorazepam and intravenous diazepam are efficacious as initial therapy in convulsive status epilepticus, though other ASM and routes of administration have proven similar efficacy.^{279, 280} A retrospective VEM study (category III) found duration differed with focal and

generalized seizures guiding the use of rescue medication.²⁸¹ No universal approach or standardized protocol exists for use of rescue medications during LTVEM in the EMU.²⁸² A useful protocol as part of the admission order set should contain personalized orders, treatment parameters, and when the physician is to be notified for prolonged or frequent seizures. The National Association of Epilepsy Centers recommends standing orders for both IV and non-IV emergency ASM to be used for seizures lasting more than 5 minutes.²⁸³ When to administer rescue ASM is center-specific and relative to seizure type and duration. A GTC seizure lasting 3 minutes or focal impaired awareness seizure lasting 5-10 minutes should prompt consideration of rescue ASM. More than one GTC seizure per 24 hours or more than 2 focal impaired awareness seizures in 12 hours also merits consideration.

5.5 Reporting

The VEM report has traditionally been a qualitative descriptions of waveform interpretation for VEM sessions using free text formats. The VEM report should include introductory demographic information regarding the patient and conditions of recording, a description of essential waveform characteristics, an assessment of normal or abnormal, and a clinical correlation in response to the clinical question posed prior to VEM.^{143, 196, 209} VEM interpretative reports, like standard EEG, are becoming increasingly automated.²⁰⁹ Providing graphic display of EEG samples²⁸ enhance reproducibility of interictal and ictal EEG portions of the VEM report to facilitate patient management and clinical research.²⁸⁴ Updated terminology^{59, 174} and newer classification systems¹⁰⁴ provide current framework of the report. Despite established American guidelines²⁸ and European consensus,²⁸⁵ significant variation in observing guidelines for standard EEG reporting exist.²⁸⁶ Moderate interobserver reliability plagues EEG interpretation which may be in part due to inconsistencies and lack of standardization for reporting style and terminology utilized.^{24, 285, 287} In 2017, the second International version of SCORE (Standardized computer-based organized reporting of EEG) initially published as a European consensus established a template for reporting and endorsed by the IFCN as a guideline based upon adaptation from IFCN, ILAE, and ACNS classification and glossary of terms to enhance the initial European version.²⁸⁵ The consequences of incomplete, inadequate, or false VEM reporting lies in the potential for initiating or continuing inappropriate treatment. Instituting electronic databases with a list of pre-established terms may result in higher inter-rater agreement of EEG features.^{285, 288, 289} Minimum standards are recommended when forming a LTVEM report. The final diagnosis should include the type of epileptic, nonepileptic, or unclassified event recorded. Seizure types should be specified according to ILAE terminology. For diagnostic reporting, both semiology and EEG recorded during seizure should follow a chronological order using standardized terminology (IFCN Glossary for EEG; ILAE Glossary for semiology). Patient information, conditions of recording, description of the recording and significant features, an impression (normal or abnormal), diagnostic significant and clinical correlation should be included. Detailing the electroclinical description of significant features during presurgical evaluation should specify lateralizing and localizing features for identification of the symptomatogenic zone at a minimum.

6. Conclusions

Significant gaps in evidence exist due to substantial heterogeneity, narrow spectrum conclusions, and limited high-level evidence across published national and international studies on

selected features of LTVEM. This clinical practice guideline provides a comprehensive synthesis of the standards for LTVEM in people with epilepsy and provides recommendations using GRADE to implement standardize approaches to selected aspects of its use (**Table 6**). This does not preclude the numerous reports, national and international guidelines, and position statements from providing guidance to perform LTVEM. Experience gained from selective aspects of VEM provides important insight into conducting comprehensive high-level studies in areas with limited information and points the way for further clinical research development.

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Figure Legends

Figure: PRISMA diagram of the systematic literature search and breakdown of peer-reviewed journals selected for evaluation.

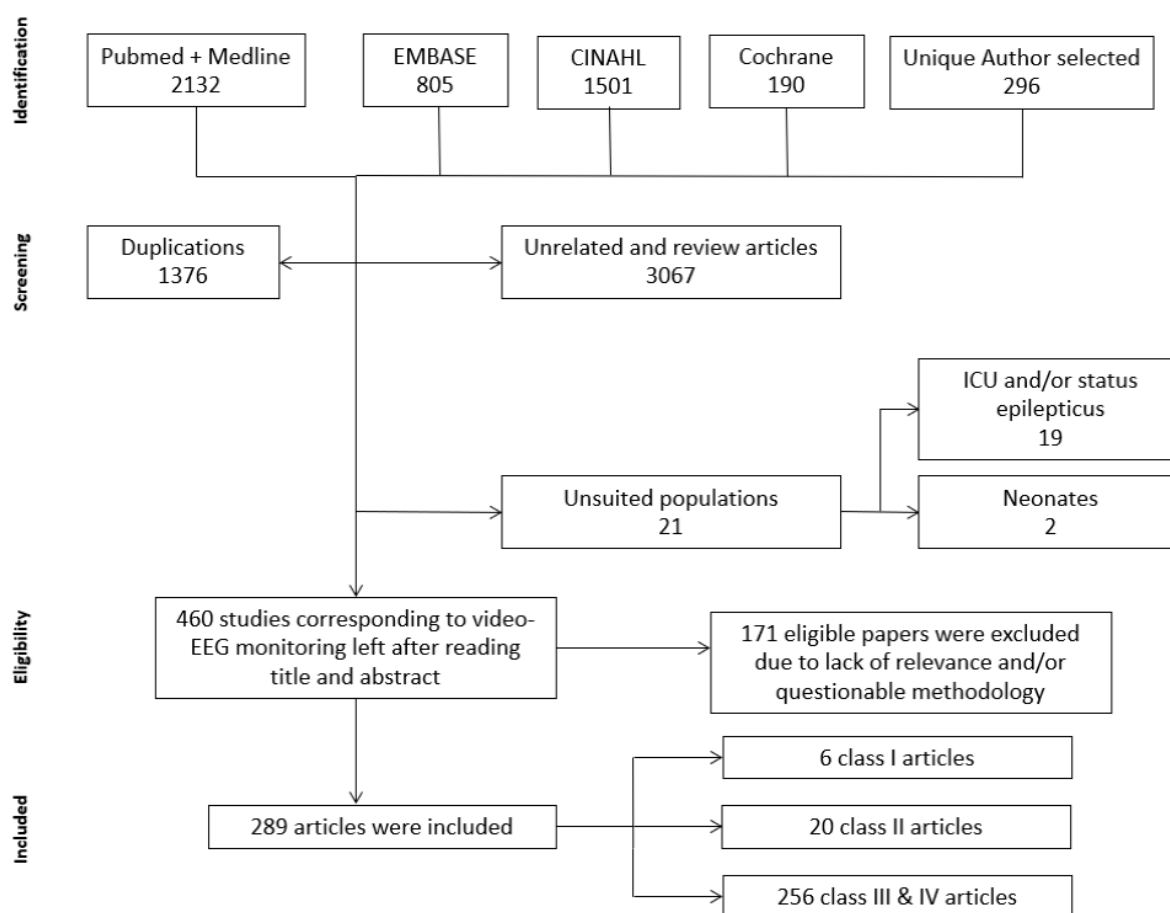


Table Legends

Table 1: Category 1 and 2 manuscripts addressing selected components of the minimal standards for LTVEM.

Table 1										
Author and Year	Class	Aspect of VEM	No. of Patients (MvsF)	Age Range (mean)	Prospective/Retrospective	Control	Randomization	Comparison Arm	Single/Multicenter	Type of Seizures
Dvivedi et al., 2017	1	Diagnosis	116 (57 vs 59)	0.8-17 (9.0;10.0)	Prospective	YES	YES	YES	Single	Focal and Generalized
Engel et al., 2012	1	Diagnosis	23	Not specified (34.3)	Prospective	YES	YES	YES	Multicenter	Focal (TLE)
Wiebe et al., 2001	1	Diagnosis	80 (40 vs 40)	Not specified (34.4;35.5)	Prospective	YES	YES	NO	Single	Focal (TLE)
Jonas et al., 2011	1	Hyperventilation	80 (39vs41)	7-77 years (32)	Prospective	NO	NO	YES	Single	Focal and Generalized
Kumar et al., 2018	1	Withdrawal of AED	140 (88 vs 52)	2-80 years (20.3)	Prospective	YES	YES	NO	Single	Focal and Generalized
Lancman et al., 1994	1	Activation	93	6-53 years (26.7)	Prospective	YES	NO	YES	Single	PNEA
Koutroumanidis et al., 2008	2	Classification	33 (15v18)	7-44 (20) ; 13-56 (24.3)	Prospective	NO	NO	NO	Single	Generalized
Kandler et al., 2013	2	Safety	Not specified	Not specified	Prospective	NO	NO	NO	Multicenter	Focal and Generalized
Hedegard et al., 2014	2	ICM Complications	Not specified	2-58 years (26)	Prospective	NO	NO	YES	Single	Not specified
De Marchi et al., 2017	2	Safety and efficacy	113 (35v78)	10 to 70 years (24.9)	Prospective	NO	NO	NO	Single	Generalized
Craciun L et al., 2017	2	Safety	976 (428vs528)	1- 80 years (24.57)	Prospective	NO	NO	NO	Single	Not specified
Guaranha et al., 2009	2	Activation	76 (35 vs 41)	12-53 years (24.3)	Prospective	NO	NO	NO	Single	Generalized
McGonigal et al., 2002	2	Yield of VEM	30 (8vs22)	Over 16 years	Prospective	YES	YES	NO	Single	PNEA
Walczak et al., 1994	2	Utility and reliability	68	Not specified	Prospective	NO	NO	YES	Single	PNEA
Chen et al., 2011	2	Induction	51 (42 vs 9)	No range(12.56; 11.26; 17.78)	Prospective	NO	NO	YES	Single	PNEA
Rizvi et al., 2014	2	Safety	158 (83 vs 75)	Not specified (37.2)	Prospective	NO	NO	NO	Single	Focal and Generalized
Furbass et al., 2015	2	Automatic Detection	205	Not specified	Prospective	NO	NO	YES	Multicenter	Not specified
Salinsky et al., 1997	2	Automatic Detection	72	11-56 years (32.4)	Prospective	NO	NO	NO	Single	Not specified
Benbadis et al., 2001	2	Classification	78	Not specified	Prospective	NO	NO	YES	Multicenter	Focal and Generalized
Lee et al., 2009	2	Diagnosis and Management	129 (72 vs 57)	7-89 years (38.3)	Prospective	NO	NO	YES	Single	Epileptic and PNEA
Goyal et al., 2014	2	Induction	190 (73 vs 117)	No range(21.38; 21.08)	Prospective	YES	NO	YES	Single	Epileptic and PNEA
Baheti et al., 2011	2	Utility and reliability	148	No range(51.3)	Prospective	NO	NO	NO	Single	Epileptic and PNEA
Kane et al., 2014	2	Hyperventilation	3170	0.25-97 (33.1)	Prospective	NO	NO	YES	Multicenter	Epileptic and PNEA
Yogarajah et al., 2009	2	Duration	612	No range (36)	Retrospective	NO	NO	YES	Single	Epileptic and PNEA
Jedrzejczak et al., 1999	2	Diagnosis	1083	Not specified	Retrospective	YES	NO	YES	Single	Epileptic and PNEA
Alving et al., 2009	2	Diagnosis and Duration	234	0.6-80(30)	Retrospective	NO	NO	YES	Single	Epileptic and PNEA

Table 2: PICO questions ascertaining population, intervention, comparator cohorts, and outcome questions addressing indications, technical requirements, and performance in practice of LTVEM.

Table 2	
Population	Children and adults with seizures with intensive need for diagnosis, classification/quantification, or to characterize refractory seizures for surgery
Intervention	Video-EEG monitoring lasting for more than 24 hours
Comparator	Historical diagnosis and site of surgery
Outcome	Event cessation in non-epileptic attacks, seizure reduction or seizure freedom, usefulness

Table 3: Summary of Technical Parameters Reached in Majority Using Modified Delphi Method.

Table 3	
VEM Technical Feature	Majority Response
Disc electrodes applied individually for diagnostic scalp based VEM	Yes
Intracranial monitoring electrodes (all types but foramen ovale)	Yes
Basal temporal additional electrodes	Yes
Nasopharyngeal or sphenoidal additional electrodes	No
10-10 system application	Yes
Source localization software recommended (surgical VEM)	Yes
Minimal number of electrodes for VEM	>21
Use of EKG	Yes
Use of oximetry, extra-oculogram, polygraphy	Optional

Table 4: Electrical safety guidelines for VEM equipment. Adapted from Burgess RC. Electrical Safety. Chapter 5. In: Handbook of Clinical Neurology, K.H. Levin and P. Chauvel, Editors. Vol. 160 (3rd series) Clinical Neurophysiology: Basis and Technical Aspects. 2019:67-81.).

Table 4	
VEM	Recommendations
Power source	• Use approved three-pronged plugs, receptacles, and power cords for electrical devices. • Patients should be connected in each EMU room to a single cluster of power receptacles. • Banks of electrical receptacles should be located together near the head of the bed.
Patient room	• Move dual-wired devices away from patients and avoid metal contact with the bed. • Educate EMU and nursing staff to avoid connections between the patient and ground. • Do not touch metal objects and the patient at the same time to avoid electrical connection.
Grounding	• Do not connect the patient to earth ground. • Only use equipment with an isoground connection to the patient. • Periodically test electrical equipment for current leakage (cable current should be <10 mA).
Electrical equipment	• Turn equipment on before patient connection/disconnect before turning equipment off. • Do not use extension cords. • Employ battery-operated equipment where possible.
Patient	• Recording electrodes should not be connected to building ground, only through isoground.
Stimulation	• The cardiac area should not be within the stimulating field. • For electrical stimulation studies, do not exceed intensity or duration recommendations. • The stimulus delivery subsystem should be entirely isolated from the building ground.
Equipment testing	• Equipment should be checked for compliance with hospital safety standards and biomedical services. • A sticker should be placed to attest equipment safety (and date). • Testing at regular intervals by biomedical engineering should determine electrical safety and include visual inspection of power cords, plugs and grounds, wiring, and room wall receptacles. • Measurements of ground pin contact tension should not be > 10 oz, chassis leakage current should normally be < 100mA, and leakage current from each terminal should be < 20mA.

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