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Review

The role of outpatient ambulatory electroencephalography in the diagnosis and management of adults with epilepsy or nonepileptic attack disorder: A systematic literature review

Andrew Lawley [a], Shaun Evans [b], Francesco Manfredonia [a], Andrea E. Cavanna [b,c,d,e,*]

[a] Department of Neurology, Royal Wolverhampton NHS Trust, Wolverhampton, UK
[b] School of Medicine, University of Birmingham, Birmingham, UK
[c] Department of Neuropsychiatry, Birmingham and Solihull Mental Health NHS Foundation Trust, Birmingham, UK
[d] Sobell Department of Motor Neuroscience and Movement Disorders, Institute of Neurology and UCL, London, UK
[e] School of Life and Health Sciences, Aston Brain Centre, Aston University, Birmingham, UK

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ABSTRACT

Electroencephalography (EEG) is an established diagnostic tool with important implications for the clinical management of patients with epilepsy or nonepileptic attack disorder. Different types of long-term EEG recording strategies have been developed over the last decades, including the widespread use of ambulatory electroencephalography (AEEG), which holds great potential in terms of both clinical usefulness and cost-effectiveness. In this paper, we present the results of a systematic review of the scientific literature on the use of AEEG in the diagnosis of epilepsy and nonepileptic attacks in adult patients. Taken together, our findings confirmed that AEEG is a useful diagnostic tool in patients with equivocal findings on routine EEG studies and influences management decisions in the majority of studies. There is evidence that AEEG is also more likely to capture events than sleep-deprived EEG; however, there are currently insufficient data available to compare the diagnostic utility of modern AEEG technology with inpatient video-telemetry. Further research on the combined use of AEEG and home-video recording is, therefore, warranted.
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1. Introduction

Electroencephalography (EEG) is an established diagnostic tool for the investigation of patients who present with clinical events raising the diagnostic suspicion of epileptic seizures [1]. However, it has consistently been shown that a standard 20-minute EEG recording may be reported as normal in 45–66% of patients with epilepsy [2–6]. Repeated EEG recordings may improve the diagnostic yield [2,4], especially if performed following sleep deprivation [7], but still fail to detect a diagnostically-relevant abnormality in a significant proportion of patients. Over recent decades, the use of prolonged EEG recording has increased in response to this diagnostic difficulty, with the development of inpatient video-telemetry (IVT) and outpatient ambulatory electroencephalography (AEEG) [8,9].

Although demonstrated to have a high diagnostic yield [10] and to alter the diagnosis in 58% of patients in one study [11], IVT is expensive, often inconvenient to patients, and not widely available. Ambulatory EEG was first developed in the early 1970s using 4-channel analog cassette recording [12] and has evolved to 32-channel digital recording capable of up to 96 h of data capture, although 48-hour recording has been suggested to be sufficient in 95% of cases [13]. Studies performed in the 1980s explored the utility of ambulatory 4-channel recording, with variable improvements in the diagnostic yield over routine studies reported [14,15]. This perhaps reflects the lack of spatial resolution and difficulty distinguishing muscle and movement artifacts, with reliability unsurprisingly improved by the addition of extra channels [16]. Details of earlier work utilizing smaller numbers of channels are beyond the scope of this paper but discussed elsewhere in reviews of this subject [16,17].

Ambulatory EEG has the advantages of being less expensive, more widely available, and less restrictive to patients than IVT. It also allows patients to be examined in their natural environment, with exposure to natural triggers. Potential disadvantages include increased artifact contamination from an uncontrolled environment and patient movement, inability to safely taper antiepileptic medication, and inability for epilepsy clinicians to witness seizure semiology. The latter disadvantage is particularly important when considering the International League Against Epilepsy recommendation that video-EEG is the gold standard in the diagnosis of nonepileptic attacks [18]. Video-EEG is recommended where diagnosis has not been reached by clinical assessment and standard EEG and may have additional benefits such as seizure quantification, assessment of relationship to stimuli, and behavioral consequences [19]. Over the last few years, home-video facilities have increasingly been used to allow capturing of clinical events with synchronized video-recording alongside AEEG [20]. The issue of diagnosis of "epilepsy versus nonepilepsy" is a very different scenario from the classification of epilepsy

* Corresponding author at: Department of Neuropsychiatry, The Barberry National Centre for Mental Health, 25 Vincent Drive, Birmingham B15 2FG, UK. Tel.: +44 121 3012280.
E-mail address: a.e.cavanna@bham.ac.uk (A.E. Cavanna).

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type, which is in turn different from the localization of epilepsy for surgical purposes. The use of AEEG may certainly contribute to these three levels of diagnosis, but its contribution and accuracy are not likely to be the same at all three levels.

The role of AEEG in the investigation of epilepsy and nonepileptic attacks is not fully defined, and it is recognized that its use varies across services, often influenced by the availability or the attitudes of clinicians. It has been suggested that this can result in its underutilization [21]. In this paper, we present the results of a systematic review of the scientific literature on the use of AEEG in the diagnosis and clinical management of adult patients with epilepsy or nonepileptic attack disorder.

2. Methodology

A systematic review of the literature was undertaken according to the methodological standards outlined in the PRISMA statement [22]. The following selection criteria were developed to determine inclusion of original studies in the present review: 1) focus on the impact of AEEG on diagnosis, syndromic classification, management decisions, or clinical outcomes; 2) comparative investigation with routine EEG, EEG with activation techniques, or IVT (either in the same cohort of patients or in a control group); 3) outpatient settings; 4) adult patients, defined for the purposes of this study as patients over 18 years of age or mixed age groups (differentiated where possible); and 5) minimum of 16 EEG recording channels to reflect the use of currently available technology.

MEDLINE (1966 to May 2015), Embase (1974 to May 2015), and PubMed databases were independently searched by two researchers using the search terms 'ambulatory EEG', 'portable EEG', 'prolonged EEG', 'video-EEG', 'video-telemetry', and 'long-term EEG', as well as their derivations, as keywords or text words. Reference lists from identified articles were manually screened. For practical purposes, only English language papers were included.

All relevant studies were independently screened using a protocol adapted from guidance in the Cochrane handbook of systematic reviews

Table 1
Description of ambulatory electroencephalography studies included in the literature review.

Study	Aim(s)	Population	*n*	Ambulatory EEG	Duration	Comparator	Diagnostic yield (%)	Frequency (%) of captured events (epileptic)	Other key findings
Brunnhuber et al. [24]	To describe the development and implementation of video-EEG telemetry in the patient's home	N/A	5	Xltex Connex video-EEG system, continuous recording	3 days (average)	IVT (in a test–retest design)	80.0	80.0 (80.0)	All patients preferred AEEG to IVT.
Chang et al. [25]	To determine whether AEEG provides reliable localization to guide surgical resection in TLE	Age range: 22 to 43 years; 1 male	7 AEEG 14 IVT	16 channels, continuous recording	5 to 21 days	IVT (in a separate control group)	N/A	100.0 (100.0)	Surgical outcome similar in both groups
Dash et al. [21]	To determine usefulness of AEEG, reasons for failure and patient satisfaction	Age range: 13 to 60 years (mean: 36.6 years); 45 males	101	32-channel Xltec EEG system, continuous recording	24 to 72 h	Previously undergone routine EEG in most patients (93%)	71.3	40.6 (9.9)	High levels of patient satisfaction
Faulkner et al. [26]	To characterize usefulness of AEEG in investigating paroxysmal events	Age range: 12 to 79 years (mean: 39 years); 132 males	324	32-channel ProFusion EEG system, continuous recording	72 to 96 h	Previously undergone routine EEG in most patients (data not available)	67.6	51.5 (15.7)	87% of events captured in first 72 h; no significant difference between latency of epileptic events and latency of nonepileptic events
Koepp et al. [27]	To determine feasibility and the prognostic value of AEEG in predicting outcome following AED withdrawal in patients with learning difficulties	Age range: 22 to 85 years (median: 65 years); 12 males	18 (3 dropouts)	16-channel Oxford Instruments system, continuous recording	19 to 24.5 h	Previously undergone 20-minute EEG with photic stimulation and hyperventilation	N/A	0.0 (0.0)	Detection of IEDs predicted seizure recurrence following medication withdrawal in all cases.
Liporace et al. [28]	To determine whether sleep-deprived EEG or AEEG is diagnostically more useful in patients with a normal routine EEG	N/A	46	16-channel computer-assisted DigiTrace system, noncontinuous recording	24 h	Previously undergone sleep-deprived EEG with photic stimulation and hyperventilation	32.6	15.2 (15.2)	Management affected in 15.2% (all cases in which seizures were detected)
Morris et al. [29]	To assess the clinical usefulness of AEEG	Age range: 6 months to 69 years	344	16-channel computer-assisted DigiTrace system, noncontinuous recording	32 h (average)	Previously undergone routine EEG (normal in 191 patients)	67.5	74.4 (N/A)	The 67.5% of recordings rated as useful consisted of 25.1% showing EEG abnormalities and 42.4% showing no changes from background EEG during clinical events.
Morris et al. [30]	To assess the clinical usefulness of AEEG via survey of referring clinicians	Age range: 6 months to 69 years	145 (24 surveys not returned)	16-channel computer-assisted DigiTrace system, noncontinuous recording	32 h (average)	Previously undergone routine EEG	N/A	N/A	80.2% of patients benefitted from undergoing AEEG, with seizure freedom/reduction in 84% of the follow-up sample.
Zarkou et al. [31]	To determine the diagnostic yield of repeat EMU admission versus AEEG in patients with a previous nondiagnostic EMU stay	N/A	19 AEEG 13 IVT	N/A	N/A	IVT	5.3	N/A (N/A)	Repeat EMU admission more likely to secure diagnosis than AEEG

Abbreviations. AEEG = ambulatory electroencephalography; IVT = inpatient video-telemetry; TLE = temporal lobe epilepsy; AED = antiepileptic drug; IED = interictal epileptiform discharge; EMU = epilepsy monitoring unit; N/A = not available (information not reported in the study).

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