Journal of Clinical Neuroscience xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Journal of Clinical Neuroscience

journal homepage: www.elsevier.com/locate/jocn

Clinical commentary

Clinical factors associated with the yield of routine outpatient scalp electroencephalograms: A retrospective analysis from a tertiary hospital

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ARTICLE INFO

Article history:
Received 15 May 2017
Accepted 10 August 2017
Available online xxxx

Keywords:
Outpatient
Routine
EEG
Epilepsy
Seizure
Yield

ABSTRACT

The routine outpatient electroencephalogram (EEG) is most often used in the diagnosis and classification of epilepsy. The diagnostic yield of outpatient EEGs is low and the clinical factors contributing to the EEG outcome have not been well established. In this study, we sought to determine the yield and the factors predicting the EEG outcome. We retrospectively analyzed 1092 routine adult EEGs that were performed in a tertiary referral center over a period of 1 year. Patient demographics, sources of referral, and indications for EEG were recorded. The majority of the referrals were from neurologists (54.7%), followed by the emergency department (15.4%). The indications for requesting an EEG included patients with a provisional or established diagnosis of epilepsy (56.3%), first seizure (10.7%), and seizure mimickers (29.1%). The majority (66.7%) of the EEGs were normal, whereas 13.2% demonstrated epileptiform discharges. At the time of recording, epileptic seizures occurred in 0.6% of the cases. With logistic regression analysis, three factors were found to be significantly associated with an abnormal (epileptiform) EEG: no antiepileptic drug therapy, the age of the patient, and indication for EEG (pre-test provisional diagnosis). Patients who are not on antiepileptic drug therapy and with a diagnosis of epilepsy or seizures are more likely to have epileptiform abnormalities in EEGs. Our findings suggest that careful selection of patients is likely to improve the diagnostic yield and cost-effectiveness of routine outpatient EEG.

1. Introduction

Electroencephalography (EEG) is used in routine clinical practice for the diagnosis and classification of epilepsy. Routine outpatient EEGs are generally performed over a short period of time (20–30 min) and various activation procedures such as hyperventilation, photic stimulation, and sleep deprivation are used to increase the diagnostic yield. Electroencephalogram is a non-invasive test to demonstrate the abnormal cortical activity that underlies seizure disorders. Additionally, it can be used as a diagnostic tool in the evaluation of other neurological conditions such as psychogenic nonepileptic seizures (PNES), Creutzfeldt-Jakob disease, and encephalopathies. Prolonged inpatient video-EEG monitoring (VEM) provides valuable information on semiologic and electrographic correlation of seizures and can aid in the diagnosis of the underlying condition as well as the pre-surgical work-up in medically refractory epilepsy [1]. However, it remains an expensive investigation with limited availability. Therefore, being a relatively less expensive investigation, routine outpatient EEG still has a major role in clinical practice.

However, outpatient EEGs have a number of limitations. First, the spatial sampling can be inadequate with the standard EEG electrode placement, where small areas of the cortex and deeper structures such as mesial cortex may not be covered. Second, the relatively short duration of recording can reduce the probability of capturing epileptiform discharges. Third, antiepileptic drug (AED) withdrawal is not feasible as a method to increase the diagnostic yield. Finally, it is difficult to capture adequate periods of natural sleep during the outpatient EEG recordings. Studies indicate that epileptiform discharges are more likely to occur during non-rapid eye movement sleep [2,3].

There is limited data on the predictors of diagnostic yield in the routine outpatient EEG. The diagnostic yield can vary from 10% to 50% depending on cohort, clinical, and methodological factors [4–8]. A detailed understanding of predictors of the yield is likely to help us optimize the use of this common diagnostic test. Against this backdrop, we conducted the current study to investigate the

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http://dx.doi.org/10.1016/j.jocn.2017.08.014
0967-5868/

yield of routine outpatient EEG and clinical variables associated with epileptiform EEG abnormalities.

2. Methods

2.1. Data acquisition

We retrospectively collected data from all routine outpatient EEGs performed at Monash Medical Centre, Melbourne, Australia, over a period of 1 year from January 2011 to January 2012. Routine EEG was defined as a 30-min recording performed on an outpatient basis. Intermittent photic stimulation and hyperventilation were routinely performed as activation procedures unless there were contraindications or refusal by the patient. Sleep-deprived EEGs were recorded at the request of the referring clinician. The EEGs were recorded using a Compumedics digital EEG acquisition system (Compumedics Ltd, Melbourne, Australia) with scalp electrodes placed according to the international 10–20 system accompanied by synchronous video recordings. We excluded pediatric EEGs (age < 18 y) from the study.

We collated clinical and demographic data from the medical records and the test request forms. The clinical data included the source of referral, (general practitioner, neurologist, emergency physician, psychiatrist, and general physician), antiepileptic drug (AED) therapy, and the numbers of days since the last seizure. The indication for requesting the EEG was divided into the following categories: first seizure, epilepsy/seizures, PNES, syncope, dementias, transient global amnesia, and psychiatric presentations.

All EEG reports were reviewed and the results were classified into the following categories: normal, epileptiform activity (focal), epileptiform activity (generalized), and non-epileptiform abnormality (such as slow activity). Normal variants were included in the normal EEG category. We also tabulated the clinical events (epileptic seizures and PNES) occurred during the EEG recording and captured on the video. Additionally, we collated information on factors potentially associated with the diagnostic yield. This included age, the time gap between the last clinical event/seizure and the EEG, use of AED therapy, indication for the EEG (pre-test diagnosis), sleep deprivation, source of referral, and activation procedures during the EEG recording (hyperventilation and intermittent photic stimulation).

2.2. Statistical analyses

We report frequencies and percentages for categorical variables and mean, standard deviation as well as the median for continuous variables. We defined the diagnostic yield as the number of positive EEGs divided by the total number of EEGs and expressed as a percentage with 95% confidence intervals (CI). We calculated the diagnostic yields for epileptiform abnormalities (both interictal and ictal), PNES, and non-epileptiform abnormalities (focal slowing, generalized slowing, and encephalopathic patterns) separately.

We first investigated the individual variables associated with epileptiform EEG outcome using univariate statistics. The presence or absence of epileptiform abnormalities (ictal and/or interictal) on EEG was the binary outcome. We selected age, use of AEDs (yes/no), source of EEG referral (neurologist, general practitioner, emergency physician, psychiatrist, other), pre-test diagnosis/indication for EEG (first seizure, epilepsy, other), sleep deprivation (yes/no), hyperventilation (yes/no), intermittent photic stimulation (yes/no), and the time gap (days) between the last seizure/clinical event and the EEG recording as our predictors. These variables were selected based on our clinical impression and previous research.

We then conducted multivariable analysis with logistic regression by fitting into the model those variables turned out to be statistically significant in the univariate analysis. We estimated the strength of associations with odds ratios and 95% CI. A p-value < 0.05 was considered to be statistically significant.

We performed the data analyses with IBM SPSS (version 21) statistical software package (IBM Corporation, New York, USA). This study was approved by the Human Research Ethics Committee of Monash Health.

3. Results

We analyzed a total of 1092 routine EEGs. The mean age of the cohort was 44.9 years (standard deviation = 20.9) with an age range of 18–97 years. There were 547 (50.1%) males and 545 females. The majority of the referrals were from neurologists (54.7%) followed by those from the emergency department (15.4%) and general practice (15.4%). In total, 770 patients (70.5%) were not on AEDs. The pre-test diagnoses made by the clinician requesting an EEG included epilepsy (56.3%), first seizure (10.7%) and seizure mimickers (PNES – 20.8%, syncope – 6.9%) (Table 1).

The majority of the EEGs (66.7%) were normal, while 7% showed focal epileptiform discharges, and 6.2% had generalized epileptiform discharges (Fig. 1). Accordingly, the yield of epileptiform abnormalities was 13.2% (95% CI: 11.31–15.32), whereas epileptic seizures and PNES revealed yields of 0.5% (95% CI: 0.19–1.06) and 1.5% (95% CI: 0.90–2.37) respectively. We found a higher yield for exclusively non-epileptiform abnormalities (20.1%; 95% CI: 17.79–22.53).

With univariate analysis, the following factors were significantly associated with a positive EEG outcome (i.e. epileptiform EEG): age ($p < 0.001$), use of AED ($p < 0.001$), indication for EEG (i.e., pre-test diagnosis; $p < 0.001$) and sleep deprivation ($p = 0.047$). The time lag between the last seizure and the EEG

Table 1
Characteristics of the cohort, sources of referral and indications for the EEG.

Variable	n (%)
Activation procedures	
Sleep deprived	131 (12%)
Photic stimulation	997 (91.3%)
Hyperventilation	867 (79.4%)
Demographic characteristics	
Average age	44.96
Number of males	547 (50.1%)
Number of females	545 (49.9%)
Clinical characteristics	
Median number of days since last seizure	27
Patients on antiepileptic drugs	770 (70.5%)
Patients not on antiepileptic drugs	322 (29.5%)
Sources of EEG referral	
Neurologist	597 (54.7%)
Emergency Physician	168 (15.4%)
General Medicine Physician	77 (7.1%)
General Practitioner	168 (15.4%)
Psychiatrist	32 (2.9%)
Neurosurgeon	8 (0.7%)
Other	42 (3.8%)
Indication for EEG	
First seizure	117 (10.7%)
Epilepsy/seizures	615 (56.3)
Psychogenic nonepileptic seizures	228 (28.1%)
Syncope	75 (6.9%)
Psychiatric presentation	27 (2.5%)
Transient global amnesia	15 (1.4%)
Cognitive change	15 (1.4%)

Please cite this article in press as: Monif M, Seneviratne U. Clinical factors associated with the yield of routine outpatient scalp electroencephalograms: A retrospective analysis from a tertiary hospital. J Clin Neurosci (2017), http://dx.doi.org/10.1016/j.jocn.2017.08.014