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MR Falcon, A New EEG Analysis Technique for Beginners

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Abstract

Electroencephalogram (EEG) interpretation often becomes a difficult challenge. Due to the ability to record brain activity, EEG can be used as a tool in the diagnosis of epilepsy, as well as possible neurological emergencies, such as convulsive and non-convulsive status epilepticus, determination of brain function/extent of brain damage. coma, neurocritical state, care follow-up, intraoperative evaluation or post-subarachnoid hemorrhage, among others.

In Mexico, according to the latest records, there are around 1,000 certified neurologists (including neuropediatricians), for a population of 105 million inhabitants[1], which means that each one has to care for more than 100,000 people, and this amount is clearly insufficient for the attention. Of patients with neurological disorders, including the performance of procedures and the interpretation of ancillary diagnostic studies.

In this work, designed by a multidisciplinary team of specialists in various areas of neurosciences, we propose a method of EEG analysis, in a didactic, practical and structured way, using the novel MR FALCON step-by-step strategy aimed at neurologists in training. And non-neurologist physicians in contact with neurological patients. It is not intended to be an extensive review on EEG nor is it intended to replace the interpretation of expert physicians in neurophysiology and epileptology, but rather to be a new strategy that makes it possible to point out the fundamental aspects for EEG analysis, which help to quickly identify normal and abnormal patterns; making it easier for trainee neurologists and non-neurologists to make an early referral of patients to specialists in the field.

Keywords: Electroencephalography, Epilepsy, EEG, Status Epilepticus, Seizure, Training

Introduction

The electroencephalography (EEG) signal has a high complexity, and the process of extracting clinically relevant features is achieved by visual analysis of the recordings. The interobserver agreement in EEG interpretation is only moderate [2].

There have been several successful attempts in medicine to standardize the evaluation and reporting of complex clinical and/or electrographic patterns, for example, the Unified Parkinson's Disease Rating Scale and the scoring of the polysomnography recordings using the American Academy of Sleep Medicine (AASM) Manual for the Scoring of Sleep and Associated Events [3].

Previous computerized EEG reporting systems have been published Robert R. Young, Keith H. Chiappa, and their colleagues at Massachusetts General Hospital have in the 1980s used a locally developed software package for reporting EEG findings. Ronald Lesser and his colleagues at Johns Hopkins have been using a locally developed software package (“Reporter”) since 1998 for reporting EEG findings [3].

The SCORE working group, consisting of 25 clinical neurophysiologists/epileptologists from 15 European countries, elaborated a consensus proposal meant to reflect the needs and practice in different countries/centers. This consensus proposal was subsequently submitted to a pan-European review, organized by the European Chapter of the International Federation of Clinical Neurophysiology (IFCN). Developed a flowchart where 13 fundamental elements were integrated: 1. Personal Data of the patient. 2. Reference data. 3. Recording conditions. 4. Modulators/ procedures. 5. Backgrund Activity. 6. Sleepiness and drowsiness. 7 Interictal Findings, 8. Episodes. 9. Physiological patterns. 10. Patterns of uncertain significance. 11. EEG artifacts. 12. Polygraphic channels. 13. Diagnostic significance [2-3].

From these interpretation methods, software has been developed that facilitates the identification of the fundamental elements for the interpretation of the EEG [2].

Justification

Although there have been multiple attempts to standardize the interpretation of EEG by specialists, there are no strategies for trainee physicians and non-neurologists to perform a standardized and rapid analysis of the EEG. Because the EEG is a fundamental diagnostic, analysis, and prognostic tool in multiple branches of medicine, it is essential to have a tool that facilitates the analysis of EEGs and allows defining the non-neurophysiologist and non-epileptologist physicians when dealing with of a normal EEG, when of an abnormal one and when a specialist should be referred quickly.

Objective

Describe a strategy that, in the form of an acronym, allows neurologists in training or doctors who are not specialists in the field, to be able to analyze an EEG in a structured, fast and efficient way, being able to recognize normal, abnormal and probably pathological patterns, in order to be able to have a decision making in emergencies or to be able to make an early referral to specialists.

Methods

A group of specialists in neurosciences, made up of neurologists, neurophysiologists, neurosurgeons and internists, carried out an analysis of the subject in order to design together a strategy that would allow EEG analysis in a structured and simple way.

A summary of the bases was made to carry out the analysis of an EEG, allowing from this to generate an acronym that facilitates remembering the points to observe when analyzing an EEG, a table was designed that as a didactic material has the elements basics of the strategy and with images that allow to identify each one of the elements. Finally, an analysis of some electroencephalograms was carried out using the strategy.

We propose the following method for the systematic analysis of any EEG with and step by step approach: MR FALCON (Fig 1).

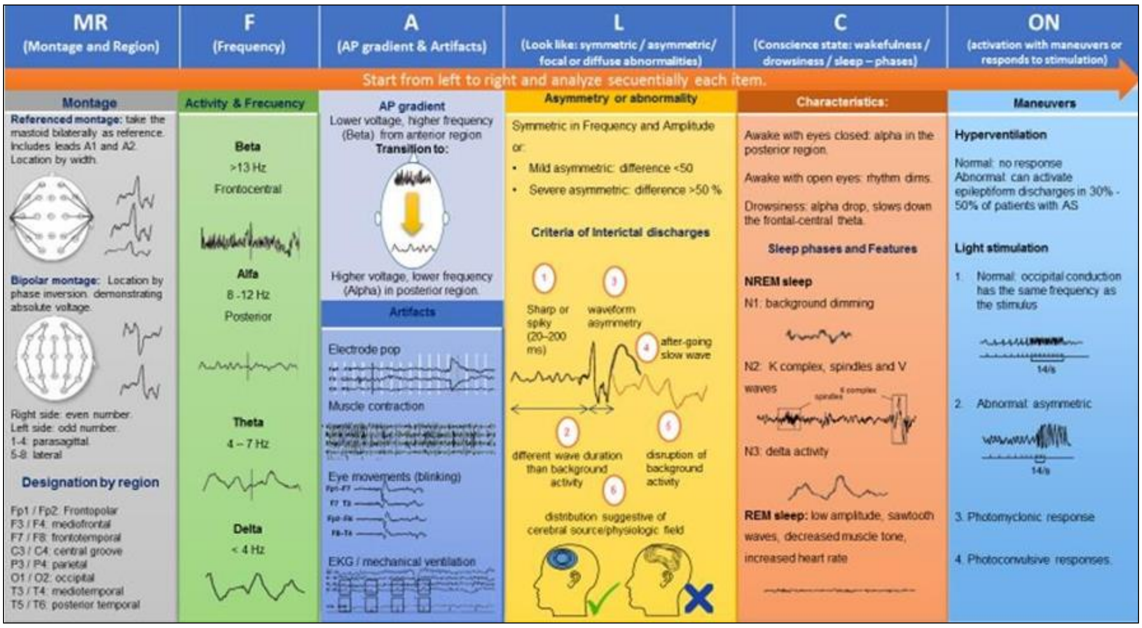

Fig 1: MR FALCON EEG analysis technique

MR FALCON is an acronym compound by:

- M. Montage: Bipolar, monopolar or referential.
- R. Region: F (frontal), parietal (P), temporal (T), occipital (O), numbers according the localization (Right side: even number / Left side: odd number)
- F. Frequency: Alpha (8-13 Hz). Beta (> 13 Hz), theta (4-<8 Hz), or delta (<4 Hz).
- A. Anteroposterior (AP) gradient and artifacts.
- L. Look like: if the EEG is symmetric or asymmetric, if there are focal or diffuse abnormalities, features of interictal discharges.
- C. Conscience state: wakefulness, drowsiness, and sleep – phases.
- ON. On state (activation) with maneuvers for stimulation.

MR FALCON can serve as a checklist to name and remember all the items to be evaluated behind each EEG, sequentially analyzing each one of the items, and involves the following points:

M. Montage

Electrical activity is recorded by means of electrodes, which are placed in mounts. An assembly is the set of pairs of electrodes that meet connected to each channel of signal amplification [2, 3]. It can be referred (monopolar), so called when taking the ear as a reference bilaterally, or bipolar, also called "double banana", named anteroposterior sense.

R. Region

According to the lobe they are in, they will be designated as

F (frontal), parietal (P), temporal (T), occipital (O). The electrodes that correspond to the right hemisphere are named with an even number; those that are designated with an odd number correspond to the left hemisphere. The electrodes placed in the parasagittal region are those from 1-4; those designated 5-8 correspond to a lateral position. The designations are made up of the electrical vector formed between 2 electrodes: Fp1 / Fp2: Frontopolar, F3 / F4: mid-front, F7 / F8: frontotemporal, C3 / C4: central groove, P3 / P4: parietal, O1 / O2: occipital, T3 / T4: mediotemporal, T5 / T6: posterior temporal[2].

F. Frequency

- Alpha frequency (8-13 Hz)

It is a background activity in vigil with eyes closed. It is present on the occipital region and has the characteristic of attenuating with the ocular opening, as well as can be blocked with sudden alertness or concentration. In up to 11% of the world population is considered absent (AD inheritance). Alpha frequency has a maturation phenomenon: 8 Hz in childhood, 9 to 12 Hz in adolescence [2, 3].

- Beta Frequency (> 13 Hz)

It is low voltage activity generally present on the frontal region. It has the characteristic of improving during drowsiness, as well as being more easily observed with the administration of benzodiazepines and barbiturates.

- Theta frequency (4-7 Hz)

Its presence may be a sign of mild cortical dysfunction in awake adults. However, it is considered normal in awake children or in adults in a state of drowsiness (use of alcohol, sedatives).
Frontocentral is found in young children (4 months-8 years) during sleepiness. On the other hand, in adolescents it has a previous predominance. In adults it is possible to find it in predominantly posterior regions of the head, with a diffuse distribution during drowsiness.

- Delta frequency (<4 Hz)

It is normal in children and during sleep. However, its finding in awake adults leads to moderate to severe cortical dysfunction (characteristic of encephalopathies).

A. Anteroposterior (AP) gradient and artifacts

At this point, we must verify that the electrical activity is organized in a sense, what we call, an anteroposterior gradient: lower voltage, higher frequency (Beta) in the anterior region, with transition to higher voltage, lower frequency (Alpha) in the posterior region. In the posterior region the alpha sinusoidal rhythm predominates, which is observed at the occipital level, with more detail during wakefulness and with the eyes closed, with increased amplitude in the left hemisphere [3]. Some slight head movements produce artifacts, like waveforms that are seenover the posterior head regions [4]. Water condensation within the tubing connected to the ventilator may produce artifacts that simulate intermittent polysharp-waves [4, 5]. Yoo *et al*. reported one patient with irregular bursts of sharp activity time-locked to a gurgling sound independent of the ventilator rate due to movement of fluids within the upper respiratory tracts and/or the tube [6].
Movements of the head/body synchronous to cardiac activity (pulsatile force on the aortic arch) generates pulse artifact, also mainly seen on the posterior electrodes in contact with the bed in the supine position and the ECG helps identify this artifact[6]. There are also many environmental/electric artifacts in ICU, such as 50/60-Hz notch interferences.

L. Look like (asymmetric or abnormal features)

Asymmetry at frequency, at amplitude, or both may be synonymous with alteration; however, there are some abnormalities or interictal epileptiform discharges (IEDs). The presence of at least 4 of 6 operational criteria proposed by International Federation of Clinical Neurophysiology defines a sharp transient as epileptiform[8] (see Table 1).
There are some abnormal patterns which occur in particular situations:
A. Burst suppression: Periodic bursts of abnormal activity separated by periods of electrocerebral silence. If we find this pattern, it is the result of severe brain injury, for example, after cardiopulmonary arrest. EEG patterns in anoxic-ischemic encephalopathies are well known, from generalized periodic discharges to burst-suppression and silence [6] but prognostication in some patients may prove challenging [7]. Respiratory encephalopathies are more often the consequence of hypercapnia than hypoxemia [9].
B. LPDs (lateralized periodic discharges): an acute epileptic focus in a focal or lateralized pattern. The presence of this pattern is frequent in focal lesions, such as temporary lesions in herpes simplex encephalitis or lesions of vascular etiology [10].
C. Periodic acute waves: typical of Creutzfeldt-Jakob disease. A typical path is considered to be one consisting of periodic acute wave complexes, widely distributed over both hemispheres. EEG is thus helpful in identifying patterns of periodic discharges, subclinical seizures, non-convulsive status epilepticus, focal slowing (e.g., with strokes), and delayed recovery from anesthesia (sleep patterns) [4, 11].

C. Conscience state (wakefulness / drowsiness / sleep - phases)

a. Awake with eyes closed: alpha rhythm over the posterior region of the head (P3-O1 and P4-O2) in an awake patient with eyes closed.
b. Awake with open eyes: The rhythm dims.
c. Drowsiness: Alpha occipital rhythm block, slows down the frontal-central theta. Vertex waves (bilateral synchronous acute waves with maximum intensity in central channels) are identified.
d. Sleep Phase N1 and N2: Normal sleep EEG with V waves (these waves are maximal over the vertex region and resemble the letter "V") and K spindles (10–14 Hz sinusoidal activity).
e. Sleep Phase 3: 20 - 50% delta, fewer sleep spindles (K) and fewer vertex waves; presents > 50% delta activity, not K-spindles.
f. REM (rapid eye movements) sleep: low amplitude, sawtooth waves, decreased muscle tone, increased heart rate.

ON. On state (activation) with maneuvers or responds to stimulation

Procedure and response:

- Verbal or physical stimulation: Eye opening, call by name, surprise response, nociceptive stimuli
- Hyperventilation: normal: No response. Abnormal: may activate epileptiform discharges in 30% -50% of patients with absence crisis.

- Light stimulation: normal: Occipital driving has the same frequency as the stimulus. Abnormal: asymmetric suggests an occipital injury. There is photomyoclonic response in drug abstinence. Juvenile myoclonic epilepsy is the most common type of generalized epilepsy associated with photoconvulsive response.
- Sleep deprivation: Increases the possibility of interictal discharges in patients with normal EEG. Ideally, we should simultaneously identify some interictal epileptiform discharge elements [5], such as spike (70 milliseconds, potentials seem higher than spikes), spike and wave (spike followed by slow wave), multiple spike and wave (quick paroxistic activity) [8].

Conclusions

It is highly relevant that a physician who is not a neurophysiologist or a non-epileptologist can analyze an EEG in a structured and efficient manner. Since in underdeveloped countries or in rural areas, there are few specialists who can interpret these studies and the dissemination of this knowledge would help other doctors to detect problems such as epilepsy, status epilepticus or brain death and allow a quick and efficient referral to the doctor specialist [9, 10]. The MR FALCON method could be a promising strategy for EEG analysis for beginners in these countries.

Disclosure of Conflicts of interest

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