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Quality of EEG recordings in neurology clinics in Iran

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ABSTRACT – *Aims*. The aim of this study was to investigate the pitfalls in performing EEG in neurology centres in Iran, in order to identify any mistakes and provide appropriate advice for the neurology community.
Methods. In this cross-sectional study, all patients who referred to the outpatient epilepsy clinic at Shiraz University of Medical Sciences, from April through to June 2018, were asked to provide any EEGs they had from other neurology centres. We reviewed the following information from their EEGs: number of channels, the design of the montages, and the setting of the filters.
Results. Eighty EEGs from different neurology centres were studied. With respect to the number of channels, 27 centres (34%) recorded 16 or more channels. With regards to the montage design, 34 centres (43%) had an appropriate design(s). With respect to high-frequency filter, three centres (4%) recorded their EEGs with 70-Hz high filter. With regards to the low-frequency filter, 43 centres (54%) recorded their EEGs with 1-Hz or lower filter. Just one centre performed EEGs in a standard fashion considering all variables.
Conclusion. In this study, we observed that most neurology centres in Iran did not record EEGs in a standard and acceptable fashion. Provision of a well-designed educational programme that ensures neurology residents are competent in the fundamentals of EEG recording and interpretation is of paramount significance.

Key words: design, EEG, filter, montage, quality

Electroencephalography (EEG) is the recording of electrical activity of the brain, and is a reliable test to assess cerebral function. It aids in diagnosis, classification, and management of patients with epilepsy. When combined with the history and neurological examination, EEG helps confirm the diagnosis of an epilepsy syndrome (Asadi-Pooya and Sperling, 2014). Although no single best method exists for recording EEGs, under all circumstances, some minimum standards are required for the standard clinical recording of EEGs in all age groups, except the very young (Sinha *et al*., 2016; Kane *et al*., 2017; Seeck *et al*., 2017; Tatum *et al*., 2018). Some of these minimum standards (Sinha *et al*., 2016; Acharya *et al*., 2016; Asadi-Kane *et al*., 2017; Pooya *et al*., 2017; Seeck *et al*., 2017; Tatum *et al*., 2018) include the following:

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– The minimum number of channels of simultaneous recording required to show the areas producing most normal and abnormal EEG patterns is deemed to be 16 (18 channels considering the extended standard array; *see below*).
– All 21 electrodes in the 10-20 system should be used. In addition, T9/T10 (10% inferior to T7/T8), F9/F10 (20% anterior to T9/10, or 10% inferior to F7/F8), and P9/P10 (10% inferior to P7/P8 or 20% posterior to T9/T10) should be added. If too few electrodes are used, the chance of interpretative errors increases.
– Montages should be logical. Orderly arrangements of channels that display EEG activity over the entire scalp, allow comparison of activity on both sides of the brain, and aid in localization of recorded activity to a specific brain region are necessary.
– The sensitivity for routine EEG recording should be set in the range of 5 to 10 μV/mm.
– For standard recordings, the low-frequency filter (or high-pass filter, which equals to [1/2 μ Time Constant]) should be no higher than 1 Hz, corresponding to a time constant of at least 0.16 seconds. The high-frequency filter should be no lower than 70 Hz. Low-frequency (high-pass) filter settings greater than 1 Hz may limit information about pathological delta activity when present, whereas high-frequency filter settings less than 70 Hz (including notch filter) can distort or attenuate interictal epileptiform discharges, to become unnoticeable.
– The notch filter (60-Hz or 50-Hz) can distort or attenuate spikes; it should be used only with other measures to reduce 60-Hz (or 50-Hz) interference fail.
– The baseline record should contain at least 20-30 minutes of technically satisfactory recording.
The Iranian neurology community is a prosperous, growing, and qualified society of more than 900 adult neurologists and 100 paediatric neurologists. However, subspecialized epilepsy and EEG training is rather new in Iran, established about 10 years ago (authors' personal experience). During these last 10 years, as the principal investigator of this study and one of the few epileptologists in the nation, the suboptimal quality of the EEGs performed by many centres has come to attention. The aim of this study was to investigate the pitfalls in performing EEGs in neurology centres in Iran, in order to identify any unrecognized mistakes associated with this procedure and provide appropriate advice based on the current standards for the neurology community, to improve quality of work.

Materials and methods

In this cross-sectional study, all patients who were referred to the outpatient epilepsy clinic at Shiraz University of Medical Sciences, which is the only epilepsy clinic in south Iran, from April 2018 until June 2018, were asked to provide any EEGs they had from other neurology centres. The outpatient epilepsy clinic at Shiraz University of Medical Sciences was established in 2008 and is one the first and few centres (less than 10 certified centres) in the country; this centre is a referral centre in Iran and serves patients from all over the country. This centre provides care for children and adults. We reviewed and identified the following information on all EEGs: the number of channels, the design of the montages, and the setting of high-frequency and low-frequency filters. We did not have access to some other important pieces of information, such as the duration of the recordings. We did not investigate the quality of EEG interpretations either. We used the guidelines provided by the International Federation of Clinical Neurophysiology (IFCN) as well as the American Clinical Neurophysiology Society (ACNS) as the current standards. This study was conducted with the approval by Shiraz University of Medical Sciences Review Board.

Results

Eighty EEGs from different adult (69) and paediatric (11) neurology centres were studied.
With respect to the number of channels recorded during the EEGs, 27 centres (34%) recorded 16 or more channels and 53 centres (66%) recorded fewer numbers of channels; 24 centres (30%) recorded just eight channels and one centre recorded six channels. With regards to the montage design, 34 centres (43%) used an appropriate bipolar or reference montage design(s) (irrespective of the number of channels), while other centres (46 centres; 57%) used inappropriate designs, such as illogical arrangements (*e.g.* bipolar montages with right and left-side channels in all possible arrangements), not covering the entire scalp, with reference to an inappropriate electrode (*e.g.* referencing the temporal electrodes to the ipsilateral ears). With respect to high-frequency filter, just three centres (4%) recorded their EEGs with 70-Hz filter and the rest (96%) used lower high-frequency filter settings. Twenty-eight centres (35%) used high-frequency filters of 15 Hz or lower; consequently, filtering any and all potential epileptiform spikes. With regards to the low-frequency filters, 43 centres (54%) recorded their EEGs with 1-Hz or lower filters and 37 centres (46%) used higher low-frequency filter settings. Six centres (8%) used low-frequency filter setting at 5 Hz, essentially filtering any and all potential delta activity. Just two centres (2.5%) performed EEGs in a standard fashion with the minimum requirements, as

described in the introduction. Just one centre used the extended standard array, including the inferior temporal chain.

Discussion

In this study of a large sample of EEGs performed by various neurology centres in Iran, we observed that most centres did not record EEGs in a standard and acceptable fashion.

A low-frequency filter setting higher than 1 Hz (46% of the EEGs in our study) attenuates slow-wave activity; therefore, important information may be lost when pathological delta activity is present. Similarly, a setting lower than 70 Hz for the high-frequency filter (96% of the EEGs in our study) may distort or attenuate epileptiform spikes and other pathological sharp abnormalities into unrecognizable waveforms and can also cause muscle artefact to resemble pathological spikes (Sinha *et al*., 2016; Tatum *et al*., 2018). A great diversity of montages exists among various EEG laboratories, but many of these montages fail to display the brain activity adequately (Sinha *et al*., 2016); this was clearly observed in our study. For a guideline on standard montages to be used in clinical EEG recordings, refer to Seeck *et al*. (2017).

EEG recording with lost or inaccurate or uninterpretable information is poor medical practice (Sinha *et al*., 2016) and should be avoided. We should emphasize that, however, the use of low-frequency or high-frequency filters with appropriate annotation on the recording can clarify certain types of patterns on the EEG recordings. These filter controls, hence, should be applied selectively and cautiously (Sinha *et al*., 2016).

One reason for this disastrous situation of the quality of EEG recordings in Iran, based on our personal experience of the interactions with other neurologists, is that many neurologists do not have enough knowledge of the basic fundamentals of EEG. When companies introduce and sell their EEG equipment to physicians, they design the montages and set the filters to show that their EEG system records a perfect and artefact-free EEG! Educating neurology residents to improve their knowledge of fundamentals of EEG may improve and rectify this significant pitfall. A competent electroencephalographer should be able to design appropriate EEG montages and should have the knowledge to adjust the EEG settings in different circumstances in order to provide the best possible interpretation of the EEG findings.

Another important issue that we could not address in this study is the art of EEG interpretation. It is clearly very difficult, if not impossible, to interpret an EEG appropriately and correctly if the recording does not meet the minimum standard technical requirements. A systematic approach is essential for the interpretation of a well-performed EEG, and when combined with good clinical judgment, this will improve diagnostic accuracy and improve therapeutic outcomes (Asadi-Pooya and Sperling, 2014). The over-interpretation of EEGs is a common clinical practice and is an important contributor to the misdiagnosis and mismanagement of patients (Benbadis and Tatum, 2003; Benbadis and Lin, 2008; Asadi-Pooya *et al*., 2013). Unfortunately, even after formal training, many neurology residents do not achieve competency to interpret EEG patterns appropriately (Dericioglu and Ozdemir, 2018).

We should remember that the EEG is only an ancillary tool, and its usefulness depends largely upon the skill and knowledge of the person who performs and interprets it. Providing a well-designed educational programme that ensures neurology residents are competent in the fundamentals of EEG recording and interpretation is of paramount significance. Like all other diagnostic tests, even a well-performed EEG has limitations and cannot replace careful history-taking and good clinical judgment. However, in knowledgeable and skilled hands, EEG may provide important and valuable information for many patients with paroxysmal events, and enhances our understanding of their conditions (Pillai and Sperling, 2006). □

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TEST YOURSELF

(1) Which setting is not appropriate to record an EEG?
A. The sensitivity for routine EEG recording should be set in the range of 5 to 10 μV/mm.
B. The low-frequency filter (or high-pass filter) should be no higher than 1 Hz.
C. The high-frequency filter (or low-pass filter) should be no lower than 35 Hz.
D. The notch filter should be used only with other measures to reduce 60-Hz (or 50-Hz) interference fail.

(2) What is the minimum acceptable duration for a routine EEG recording in the office?
A. 10 minutes
B. 5 minutes
C. 20 minutes
D. 60 minutes

(3) Low-frequency filter settings greater than 1 Hz may limit information during which of the following conditions?
A. When pathologic delta activity is present
B. When an interictal focal sharp wave is present
C. When spike-waves are present
D. When polyspikes are present

Note: Reading the manuscript provides an answer to all questions. Correct answers may be accessed on the website, www.epilepticdisorders.com, under the section "The EpiCentre".