Chapter

Basic Electroencephalogram and Its Common Clinical Applications in Children

Raafat Hammad Seroor Jadah

Abstract

Electroencephalography (EEG) is a non-invasive neurophysiological study that monitors electrical activity of the brain. EEG is an essential investigational tool to analyze and record electrical impulses of the brain and considered to be the gold standard electrophysiological test which can be used to help diagnose epilepsy. EEG can also be used to diagnose and evaluate other conditions such as sleep disorders, neurometabolic diseases with encephalopathy and neuropsychiatric disorders. It is also an essential ancillary test in other conditions such as brain death assessment. However, it is essential not to entirely rely on EEG for an absolute diagnosis of epilepsy as the main indication of EEG in general and in Pediatric age group in particular is to categorize different types of seizure and epilepsy syndromes for further evaluation and management.

Keywords: electroencephalography, epilepsy, neuropsychiatric, ancillary, electrophysiological, pediatric, encephalopathy

1. Introduction

EEG is a common, non-invasive and essential electrophysiological technique used to evaluate and study the brain function. EEG measures and investigates the cerebral electrical impulses by direct application of electrodes to the patient's scalp. EEG is considered the main neurophysiological study used in Pediatric population especially in children with epilepsy [1, 2] and remains the primary test used to study and assess other clinical conditions such as parasomnia and encephalopathy associated with neurometabolic disorders and post traumatic brain injury [3]. EEG study has been used in the evaluation and assessment of organic brain pathology in patients presented with psychiatric and behavioral disorders and has been also an essential tool to confirm absence of cerebral electrical activity in patients with brain death [4, 5]. Epilepsy diagnosis is primarily made based on the clinical history of the patient and hence it is necessary not to rely completely on the EEG study to confirm the diagnosis of epilepsy [6], however EEG is the major neurophysiological test used in the classification and evaluation of seizures and epilepsy syndrome in Pediatric patients [7].

1.1 History

In 1875, Richard Caton an English physician reported a spontaneous electrical variation from exposed cortical brain hemispheres of rabbits and monkeys [8]. Early in the twentieth century, specifically in 1912, Vladimir Vladimirovich Pravdich-Neminsky a Russian Physiologist reported the first electrical brain impulse and evoked response in animals (dog) [8]. However, in 1924 German Neurologist and Psychiatrist Hans Berger recorded the first human EEG in a graph paper which later named an electroencephalogram (EEG) device. Berger subsequently characterized different rhythmic nature and wave patterns of the brain activity based on the different physiological state of the subjects (**Figure 1**) [8]. The initial description of clinical encephalography was first reported by an American neurologist Frederic Andrews Gibbs in 1935 who initially documented the classical interictal spikes associated with epilepsy and first to demonstrate the typical 3 per second spike and wave discharges associated with absence epilepsy. He also described EEG pattern during impaired consciousness level (**Figure 2**) [8–10].

Figure 1.
Hans Berger, German neurologist and psychiatrist (1873–1941) [11].

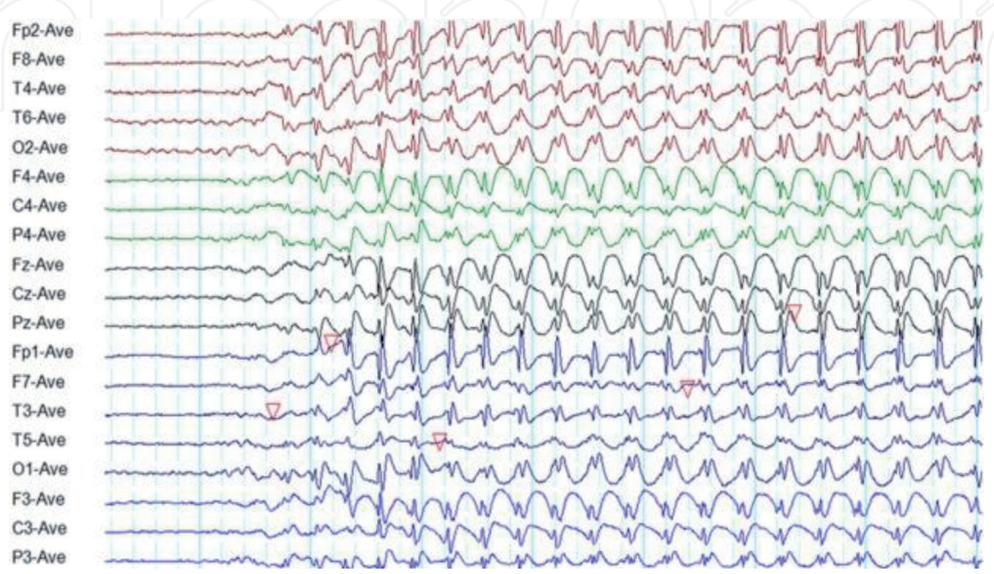

Figure 2.
The classical 3 per second spike and wave discharges was first described by Frederic Gibbs [10].

2. Analysis and understanding the complex brain network

The human brain consists of a complete and comprehensive network map of neuronal connections called human connectome. The normal maturation of these interconnected neurons associated with normal development of high cortical functions and motor skill consolidation. The failure of this network maturation can lead to some serious neurodevelopmental disabilities [12].

The connectivity of this complex brain network can be classified into three types: structural connectivity, functional connectivity and effective connectivity [13]. Structural connectivity can be further subdivided into two types. First the anatomical connections that links a bundle of neural elements and second is the interregional fibers linking cortical to subcortical gray matter areas [13].

Functional connectivity is obtained from time series analysis and reflects the statistical dependence within neural units. This time sense date can be defined by different methods which include EEG, Functional magnetic resonance imaging (fMRI) and magnetoencephalography (MEG) [13].

Effective connectivity (EC) defines the casual effects that one neural system exerts over another. EC cannot be assessed directly so several techniques have been used to study the EC. The Dynamic Casual Modeling (DCM) is the main method for evaluating EC by analyzing data from neuroimaging studies such as Functional Magnetic Resonance Imaging (fMRI) [14].

3. Preparing pediatric patients for EEG study

Performing electroencephalography (EEG) in children can be quite challenging as most of these children are not cooperative during this study due to the great fear and restlessness during the EEG procedure. It is vitally important to prepare a Pediatric patient for EEG study in order to have better interpretation of the EEG results. The application of psychological technique prior to the study and the availability of the parents during the procedure can be helpful to conduct the study smoothly and minimize the need for premedication drugs. However, the behavioral and psychological techniques are not always successful in a small proportion of children. Different premedication protocols have been proposed in order to alleviate the great distress and anxiety during the study. The ideal pharmacological agents for such procedure should have a minor impact on the EEG tracing with fast onset and few side effects. Benzodiazepine is the most common premedication agent used with Midazolam being the most popular drug to induce sedation for EEG study in children [15].

Chloralhydrate is another medication which has been used to induce sedation in the Pediatric population during different neurological studies including EEG. Chloralhydrate is a safe, cheap hypnotic non-opiate drug with no major side effects with the exception of vomiting in few cases. Chloralhydrate has been also shown to be effective and more time saving during EEG procedure [16].

4. Technical aspects of electroencephalography

Electroencephalography EEG, since it's first introduction early in the 20th century, has been an essential and the most common neurophysiological device to monitor and study the electrical and functional activity of the brain [17]. EEG is a commonly used non-invasive tool to track and record the electrical field potentials captured by electrodes placed on the patient scalp. These electric field potentials

created by dipoles as a result of excitation of the epical dendritic postsynaptic potential at the cortical pyramidal cells [18, 19]. The measurement and assessment of the electric field potentials can be made by attaching conductive electrodes to the human scalp. At the present time the wet electrodes are the gold standard used for EEG study [19]. A conductive paste or gel need to be used during the application of wet electrodes to minimize electrode-skin impedance in order to achieve good conductivity of the electrical impulse. The typical value of skin impedance should be kept between 5 and 20 KΩ. This skin impedance should be continuously monitored during the EEG study to ensure proper and high-quality conductivity between the skin and the EEG electrode. Performing an EEG study is a time consuming process which require an expert EEG technician or neurophysiologist in order to obtain good quality EEG results for proper interpretation and reporting as the reading and analyzing EEG data is a hard task and must be interpreted by expert neurophysiologists. The location site and description of the scalp electrodes is well recognized by the international 10–20 system (**Figure 3**) [19, 20].

During the first EEG only 20–50% of patients with seizure disorder show interictal epileptiform discharges (IED) so the yield of the EEG study can be enhanced by many activation methods in order to capture the interictal epileptiform discharges which help confirming the diagnosis of epilepsy and seizure disorder [22]. The common activation procedure used in EEG laboratories includes Hyperventilation, intermittent photic stimulation (IPS), sleep and sleep deprived techniques. Hyperventilation (HV) is considered to be the first and oldest activation method used to trigger the interictal epileptiform discharges (IED) especially the one associated with absence epilepsy. HV is more effective in Pediatric population than in adult. A proper effective HV should be carried out for full 3 minutes with continuous recording and monitoring for one-minute post hyperventilation. HV is more efficient in diagnosing generalized seizures than focal epilepsy. The mechanism of HV to trigger interictal epileptiform discharges can be explained by hypocapnia induction which also manifest as background slowing or focal slowing in the EEG [22]. HV is a major provocation technique used to trigger the typical 3-Hz spike-and-wave discharge (SWD) which is characteristic for absence epilepsy as more than 90% of patients who have absence epilepsy show SWD during HV. The non-specific thalamic projection system (NSTPS) which is a part of the thalamocortical networks triggered by respiratory alkalosis and considered to be the major induction of SWD associated with absence epilepsy during the process of HV [23]. HV is an efficient and safe activation method for epilepsy and seizure disorder provocation however there are certain contraindication to perform HV during EEG study which includes patients with cardiopulmonary disease, sickle

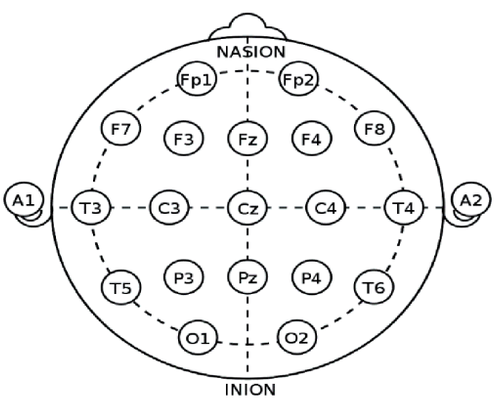

Figure 3.
The international 10-20 system [21].

cell anemia, Moy-Moya disease, subarachnoid and intracerebral bleeding and severe carotid stenosis [22].

A standard activation procedure used during the routine EEG study is the intermittent photic stimulation. This procedure done in a dimmed light room and application of different light frequencies between 1 and 30 Hz for 5 to 10 seconds during eye closure. The flashing light device should be kept 30 cm form the patient eyes. The response to intermittent photic stimulation (IPS) can be seen as an evoked potentials at frequencies less than 5 Hz seen posteriorly or drive response at the occipital regions or in the form of photoparoxysmal response (PPR) which was previously named photoconvulsive response. The most common types seizure disorder seen with IPS are absence epilepsy, myoclonic and tonic–clonic seizures [22].

Among the activation techniques used during routine EEG study is the sleep and sleep deprived approach which produce the maximum yield of interictal epileptiform discharges (IED) as compared to the hyperventilation and intermittent photic stimulation procedure. The young age patients tend to have better yield of IED with each activation technique than older patients [24].

5. Brain computer interface

A Brain Computer Interface (BCI) which also named as Brain –machine Interface (BMI) is a computer- build network system that allow direct communication between cerebral brain activity and external recordable machine without using human muscles or peripheral nervous system. BCI utilize and analyzes the brain signals to collect information and send them to output system. BCI network consists of five phases: Signal Acquisition, Signal Magnification, Feature Extraction, Categorization and Control Interface. BCI assesses and analyze brain activity through mainly electrophysiological and hemodynamic studies. The electrophysiological study consists mainly of EEG, electrocorticography and magnetoencephalography. The hemodynamic study measures glucose uptake by an active neurons and this can be evaluated by procedures like functional magnetic resonance and infrared spectroscopy. BCIs commonly used EEG to gain details from brain activity. The design of BCI is complex due to restricted resolution and data reliability detected by the brain [25, 26].

6. Different types of EEG study

The American Clinical Neurophysiology Society suggest at least 20 minutes' time duration for routine outpatient study. However, the International League against Epilepsy suggests a minimum 30 minute for routine EEG recording. Currently most routine EEG studies are done with an average time between 20 and 30 minutes. The abnormal epileptiform discharges found in 29–55% in patients with epilepsy on their first routine EEG study. Ambulatory prolonged EEG study is considered to be helpful diagnostic technique to capture interictal epileptiform discharges (IEDs) in epilepsy patients whom their first routine EEG studies reported normal. Prolonged ambulatory EEG study is considered to be superior to routine EEG in identifying IEDs specially during the natural sleep state. This procedure is also helpful to differentiate epileptic from non-epileptic psychogenic events. The duration of the ambulatory EEG study usually between 24 to 96 hours [27, 28].

Epilepsy Monitoring Unit (EMU) is an important and crucial part of the neurophysiological work up for the diagnosis and classification of epilepsy and evaluation of psychogenic non-epileptic seizures (PNES). EMU is also essential for patients

with intractable epilepsy resistant to antiepileptic medications and for evaluating candidates for possible epilepsy surgery [29].

EMU is strongly recommended for children with unclear history of paroxysmal episodes in order to differentiate between epileptic and non-epileptic events as this can be quite challenging in pediatric population. EMU is also important in evaluating different types of epilepsy syndromes in children. One of the vital advantages of the video-EEG telemetry is the monitoring and recording the ictal events especially in patients with partial epilepsy. EMU is a highly selective study should be done for carefully selected patients as this is an expensive and time consuming procedure [30]. The process of monitoring and recording video-EEG telemetry can range from 24 hours to 7 days. In some situation antiepileptic drugs need to be tapered in order to induce seizure activity for better evaluation of seizure semiology and localization of the epileptogenic zone [31].

The Amplitude-Integrated EEG (aEEG) is another continuous electrophysiological modality used in both term and preterm newborns in the neonatal intensive care units (NICUs). Since it's first introduction late in 1980s. the aEEG considered to be the gold standard to monitor and assess neonatal brain background activity, diagnose and manage newborn seizure disorders and help in selecting newborns who might be benefit from cooling therapy. The aEEG also plays a major role in predicting the neurodevelopmental outcomes for term and preterm newborn babies. The application and recording of the aEEG is done by using two or four scalp electrodes applied to C3, P3, C4 and P4 positions of the newborn head according to the international 10–20 system. aEEG is a safe procedure which has a major limitation as it covers only small area of the head surface and hence focal epileptiform activity cannot be monitored during the aEEG recording [32–34].

EEG is considered to be the commonest procedure used for intraoperative neurophysiological and cerebral perfusion monitoring [35]. EEG is also considered to be the gold standard modality for evaluating patients for possible epilepsy surgery to localize and define different epileptogenic foci. EEG also plays an important role in understanding the nature and pathophysiology of epilepsy and presurgical evaluation of functional cortical mapping. However, routine EEG monitoring might not be always sufficient to evaluate certain types of epilepsy such as non-lesional temporal lobe epilepsy which necessitate the need of more interventional procedure such as the invasive electroencephalography (iEEG) [36, 37].

7. Basic EEG interpretation

A proper and detailed history taking is more reliable and important in diagnosing epilepsy and seizure disorders than EEG study. A solid and classical history of seizure even with the presence of normal EEG finding make the diagnosis of epilepsy is more likely as the sensitivity of single routine EEG study is only about 50% in diagnosing seizure disorders [38].

A single EEG study provides extensive data for interpretation. The main initial description of the EEG recording includes the amplitude, frequency and wave morphology. Hans Berger described two characteristic EEG wave frequencies during awake state: The alpha rhythm (8–12 Hz) which is more prominent in the arousable stage with eye closure and beta rhythm (13–30 Hz) commonly seen with mind focus state. In most people eye closure will result in frequency transfer from beta to alpha rhythms. Subsequent wave frequencies were identified the theta rhythm (4–7 Hz) and the delta rhythm (0.5–3 Hz) which are predominant during sleep in adults, and the gamma rhythm (> 30 Hz) which is associated with memory, information processing and cognitive skill (**Figure 4**) [39].

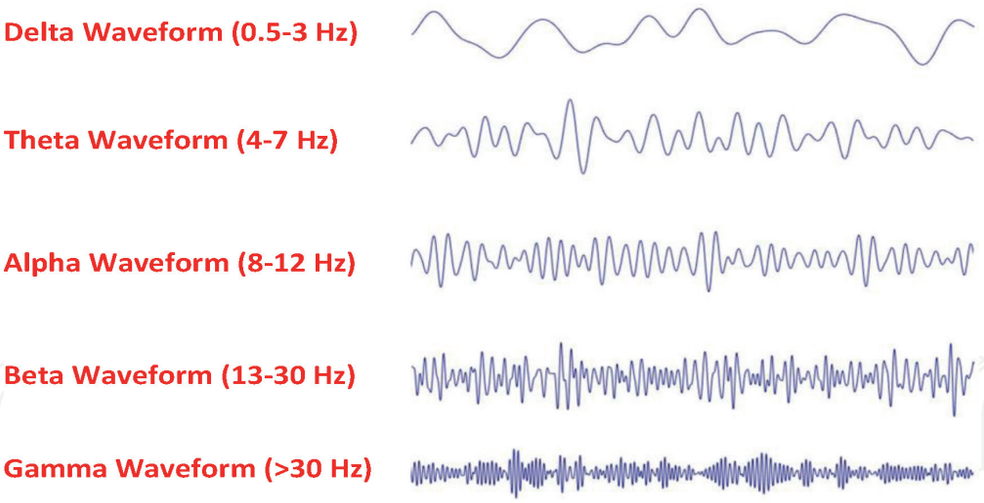

Figure 4.
Different EEG waveforms [39].

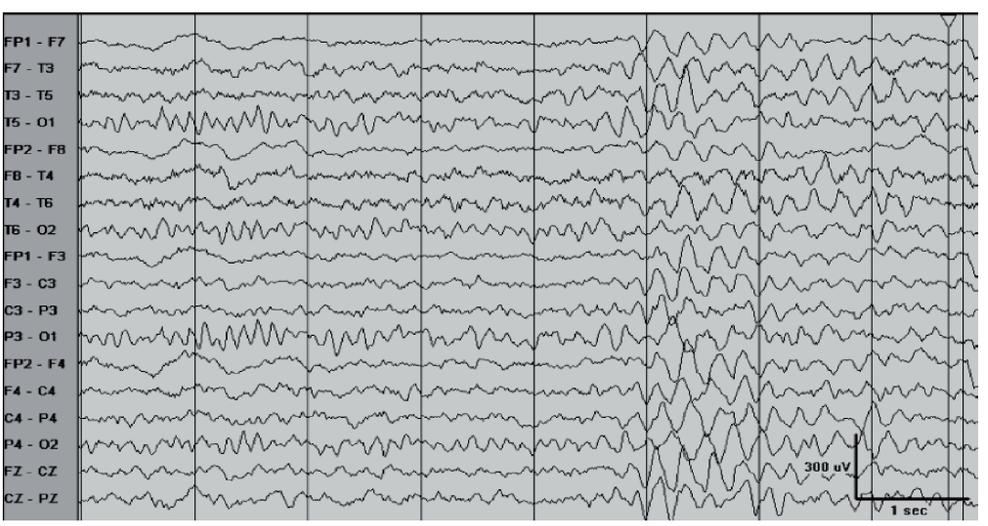

Figure 5.
Hypnagogic hypersynchrony. A normal EEG variant [42].

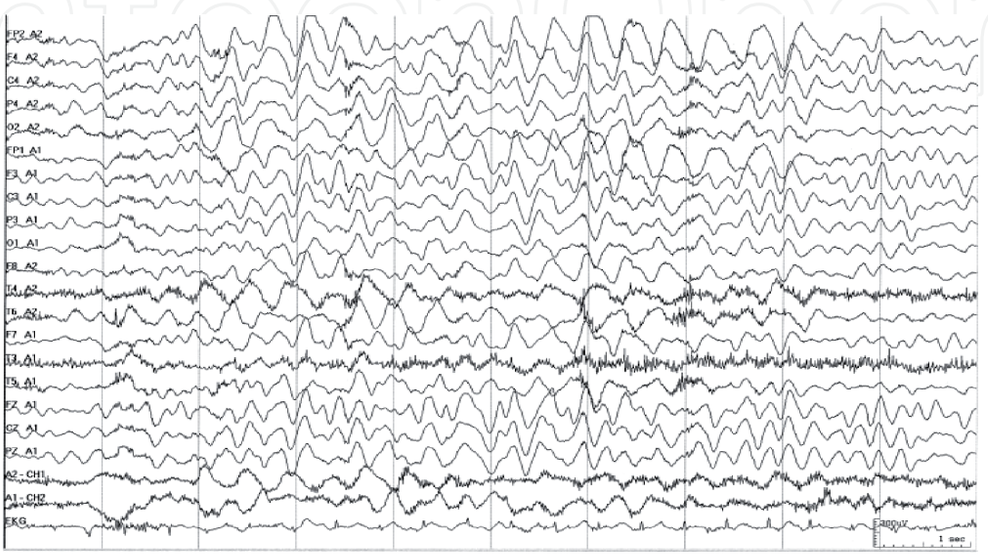

Figure 6.
High amplitude rhythmic slowing with hyperventilation [43].

It is vitally important to ensure proper education and gain enough experience to read and interpret EEG recording in order to avoid misdiagnosis of epilepsy and to provide better care to the patient. It is also essential to appreciate the common benign variations of normal EEG study [40, 41].

A common normal patterns seen in EEG study which can be falsely interpreted as abnormal epileptiform discharges include multifocal sharp waves and spikes, generalized slowing with hyperventilation, hypnagogic hypersynchrony and most commonly is the background alteration at the temporal area (**Figures 5** and **6**) [38].

Over interpretation of normal EEG tracing is the main factor for misdiagnosis of epilepsy and seizure disorders. Improper neurophysiological training and inadequate experience is the major reason for over interpretation of normal EEG study. Conservative EEG interpretation and avoiding biased history are strongly recommended by all epileptologists [38].

8. Common clinical applications of EEG in children

Although the diagnosis of epilepsy is primarily made by clinical history, EEG remains an essential investigational tool to differentiate between epileptic and non-epileptic events, it's also important in the classification of different types of epilepsy and epilepsy syndromes [44–46]. Frequent classical epileptiform abnormalities seen in Pediatric population are hypsarrhythmia associated with infantile spasm, 3 Hz spike and wave discharges in absence epilepsy and burst suppression (**Figures 7** and **8**) [46].

According to the American Academy of Neurology and Child Neurology Society, EEG is recommended in children presented with their first attack of unprovoked seizure [49]. EEG is indicated in children with atypical febrile convulsion or prolonged febrile seizure and it is an essential investigational study in patients with newly diagnosed epilepsy and in classification of common childhood epilepsy syndromes such as centrotemporal spikes associated with benign rolandic epilepsy and Panayiotopoulos syndrome (idiopathic childhood epilepsy). EEG is also important in recording continuous spike-waves during slow-wave sleep (CSWS) in epileptic encephalopathies (**Figures 9** and **10**) [50].

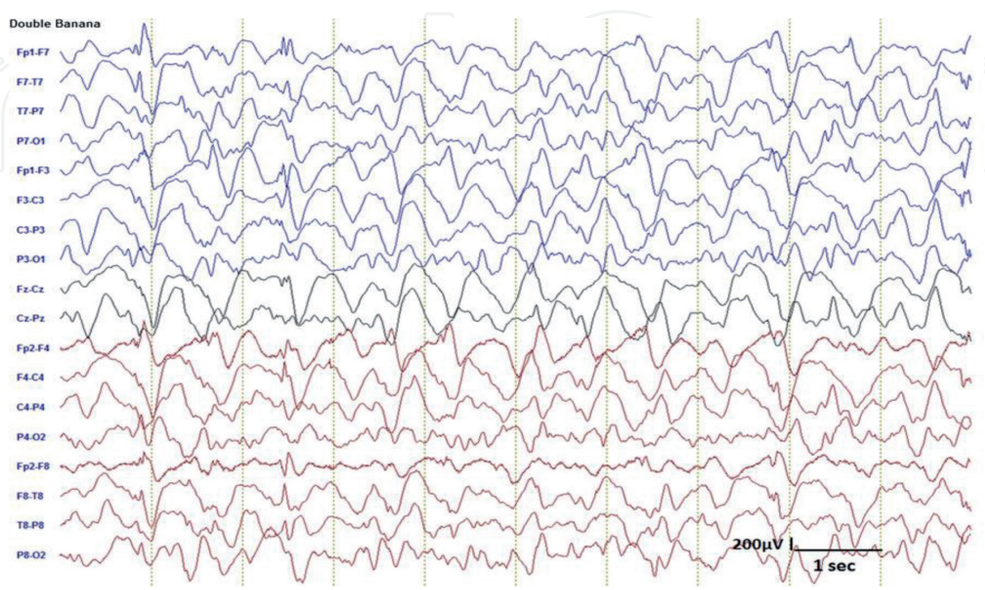

Figure 7.
EEG tracing showing bilateral, diffuse, high amplitude slow waves seen in hypsarrhythmia [47].

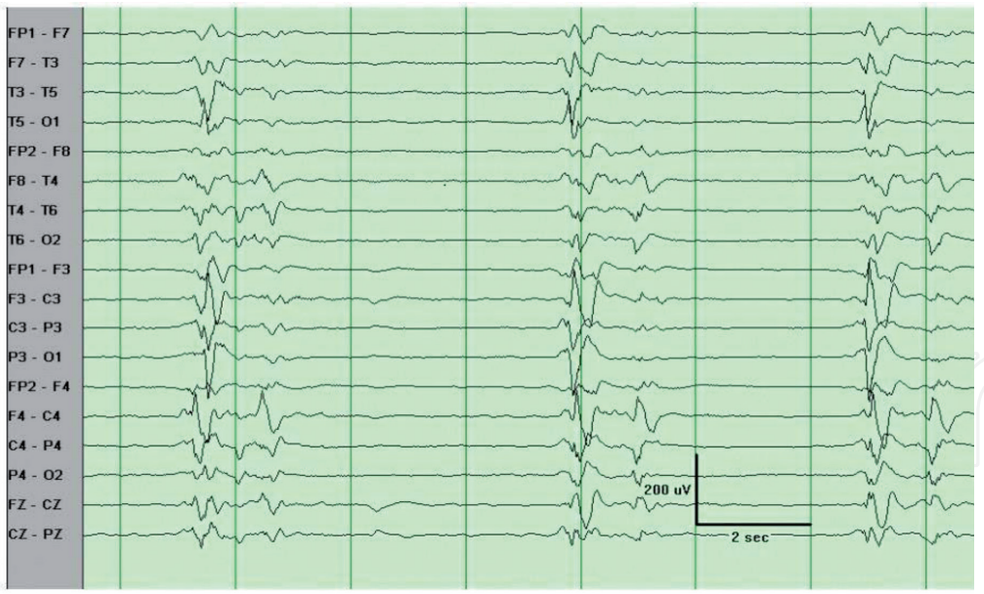

Figure 8.
EEG with burst suppression [48].

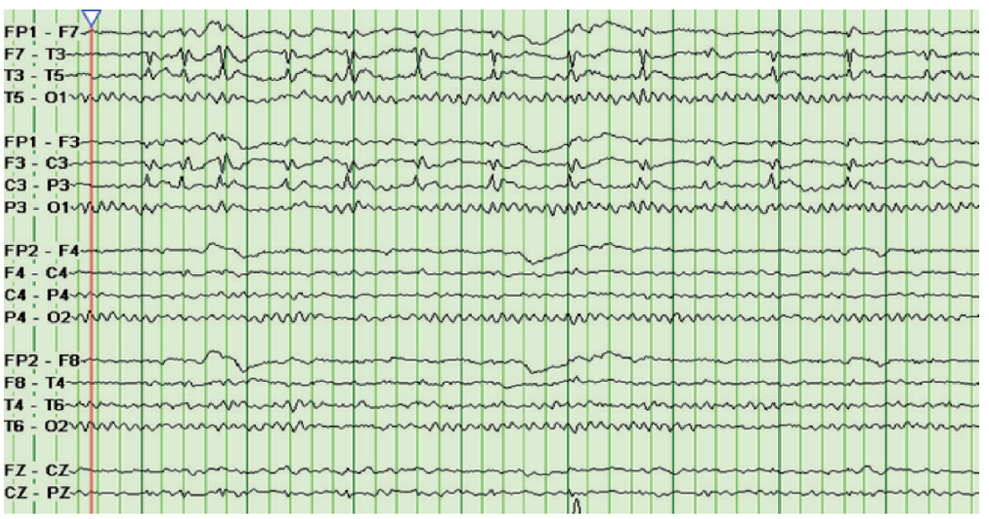

Figure 9.
EEG showing left centrotemporal epileptiform spike and wave discharges in patients with benign rolandic epilepsy [51].

Pediatric patients diagnosed with autistic spectrum disorder (ASD) with positive history of epilepsy and abnormal findings in the neurological examination, EEG study is indicated as a part of their screening tests. EEG is also recommended in monitoring antiepileptic medication in patients with confirmed diagnosis of epilepsy [50].

The background EEG monitoring has been also used in children with traumatic brain injury which is helpful in evaluating prognosis in these patients [50, 53]. EEG study with poor reactivity, prolonged discontinuity and burst suppression associated with poor prognosis, whereas EEG with good reactivity and normal sleep rhythm favor a good prognosis [53]. A prolonged EEG recording is also essential in children admitted to the PICU (Pediatric Intensive Care Unit) with suspected non-convulsive seizures (NCS). It has been also important in monitoring Pediatric patients underwent surgery for congenital cardiac anomalies as they are at risk to have seizure post-surgery [53].

Viral encephalitis is an inflammatory infectious neurological disease that affects the central nervous system (CNS) which triggers an immune response by the viral antigen causing damage to the brain parenchyma and associated with electrical disturbance of the brain activity [54]. Viral encephalitis is common in children with Herpes Simplex Virus (HSV) being the commonest agent for encephalitis in Pediatric population [54, 55]. EEG study is considered to be a part in the investigational work up in patients with viral encephalitis [56]. Patients with Herpes Simplex Encephalitis (HSE) found to have significant EEG changes in the early stage of the diagnosis. Unilateral Periodic Lateralized Epileptiform Discharges (PLED) is considered to be the most typical EEG finding which correlate with diagnosis of HSE [57] and found to have a good outcome as compared to bilateral periodic lateralized epileptiform discharges which associated with unfavorable prognosis (**Figure 11**) [58].

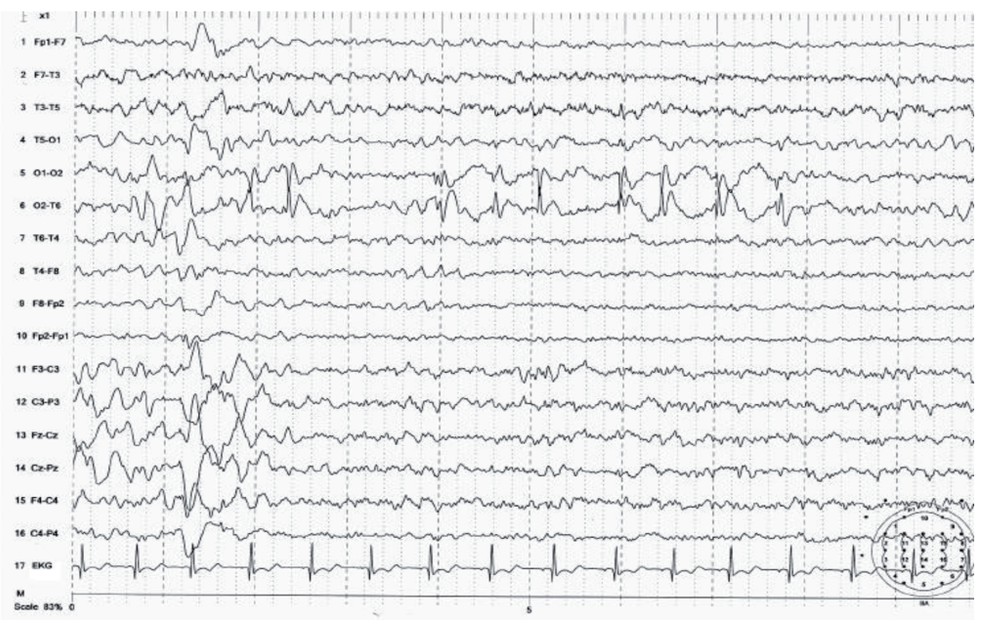

Figure 10.
Occipital spike and wave discharges seen in panayiotopoulos syndrome [52].

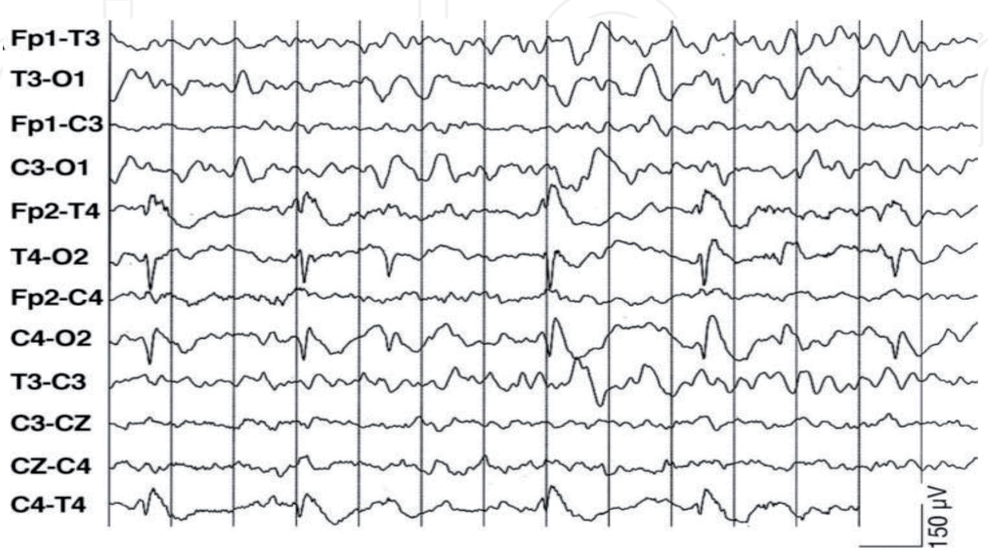

Figure 11.
Periodic lateralized epileptiform discharges (PLED) over the right central-temporal head regions seen in HSE [59].

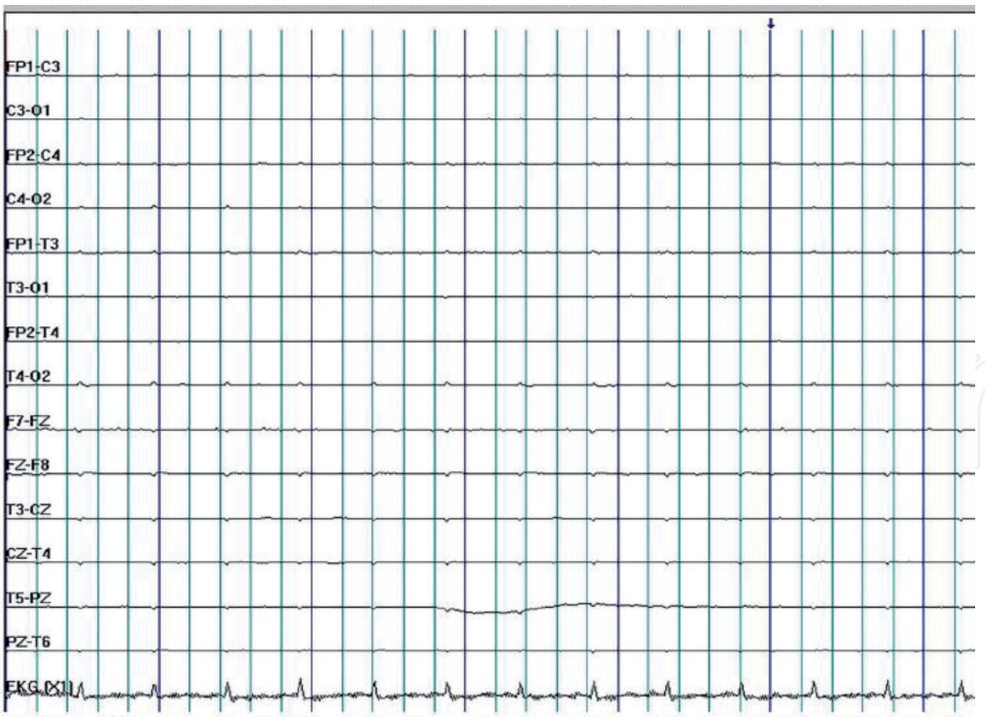

Figure 12.
Isoelectric EEG. No cerebral brain activity with sensitivity over 2 μV/mm [62].

EEG study can be also used as an ancillary test to support the diagnosis of brain death. Although positive diagnosis of brain death can be made by two separate settings of clinical examination, The American Neurological Association strongly suggest the use of EEG study to confirm the diagnosis of brain death. Hypothermia and hypotension should be avoided when applying EEG for brain death assessment [60]. Isoelectric encephalogram is confirmed when 30 minutes of EEG recording reveals complete absence of cerebral activity with sensitivity over 2 μV/mm in the absence of electrolyte disturbance and sedative medications (**Figure 12**) [61].

9. Conclusion

EEG is considered to be save non-invasive procedure since its first application early in the 20th century. This procedure is done by trained EEG technicians and it should be interpreted by Neurologist or expert Neurophysiologists in order to obtain a high quality report to reach a proper diagnosis and provide optimal management to the patient.

Performing EEG study in children can be a difficult task because of the great fear and anxiety in this age group patients, so its vitally important to properly prepare these patients to minimize EEG artifacts for better interpretation of the EEG report.

EEG is an essential neurophysiological study especially in Pediatric patients to differentiate epileptic form and non-epileptic events as the differential diagnosis for paroxysmal episodes in children is wide and varies according to certain age group.

Although the diagnosis of brain death is primarily made on clinical basis, EEG remains an important ancillary test for diagnostic confirmation of brain death.

Conflict of interest

The author declares no conflict of interest.

Funding

None.

Abbreviations

EEG	electroencephalography
fMRI	functional magnetic resonance imaging
MEG	magnetoencephalography
IED	interictal epileptiform discharges
IPS	intermittent photic stimulation
BCI	brain computer interface
EMU	epilepsy monitoring unit
aEEG	amplitude-integrated EEG
ASD	autistic Spectrum disorder

Author details

Raafat Hammad Seroor Jadah
Department of Paediatric, Bahrain Defence Force Hospital, Royal Medical Services, Kingdom of Bahrain

*Address all correspondence to: nader212@hotmail.com

References

[1] Gregory A Light, Lisa E Williams, Falk Minow, Joyce Sprock, Anthony Rissling, Richard Sharp, Neal R Swerdlow, David L Braff. Electroencephalography (EEG) and event-related potentials (ERPs) with human particpants. Curr protoc Nuerosci.2010 Jul; Chapter 6: unit6.25.1-24. DOI: 10.1002/0471142301.ns0625s52.

[2] Mohammed M S Jan Assessment of the utility of Paediatric electroencephalography. Seizure.2002 Mar; 11(2):99-103. DOI: 10.1053/seiz.2002.0621.

[3] C D Binnie, P F Prior Electroencephalography J Neurol Neurosurg Psychiatry. 1994 Nov; 57(11): 1308-19.DOI: 10.1136/jnnp.57.11.1308.

[4] S S O'Sullivan, G M Mullins, E M Cassidy, B McNamara The role of the standard EEG in clinical psychiatry. Hum psychopharmacol. 2006 Jun; 21(4): 265-71. DOI: 10.1002/hup.767.

[5] Daniel Kroeger, Bogdan Florea, Florin Amzica. Human brain activity patterns beyond the isoelectric line of extreme deep coma. PLoS One. 2013 sep 18; 8(9): e75257.13 pages (1-13).

[6] Ushtar Amin, Selim R Benbadis. The Role of EEG in the Erroneous Diagnosis of Epilepsy. J Clin Neurophysiol. 2019 Jul; 36(4): 294-297. DOI: 10.1097/WNP.0000000000000572.

[7] M Sundaram, R M Sadler, G B Young, N Pillay. EEG in epilepsy: Current perspectives. Can J Neurol Sci. 1999 Nov; 26(4): 255-62. DOI: 10.1017/s0317167100000342.

[8] Mahmoud Al-Kadi, Mamun Bin Ibne Reaz, Mohd Alauddin Mohd Ali. Evolution of Electroencephalogram Signal Analysis Techniques During Anesthesia Sensors (Basel). 2013 May; 13 (5): 6605-6635. DOI: 10.3390/s130506605

[9] Prasad Vannemreddy, James L Stone, Konstantin V slavin. Frederic Gibbs and his contributions to epilepsy surgery and electroencephalography. Neurosurgery.2012 Mar; 70 (3): 774-82. DOI: 10.1227/NEU.0b013e3182351699.

[10] Hal Blumenfeld. Consciousness and epilepsy: why are patients with absence seizures absent? Prog Brain Res. 2005; 150:271-286 DOI: 10.1016/S0079-6123(05) 50020-7

[11] James L Stone, John R HughesEarly history of electroencephalography and Establishment of the American Clinical Neurophysiology Society. J Clin Neurophysiol. 2013 Feb; 30(1): 28-44 DOI: 10.1097/WNP.0b013e31827edb 2d.

[12] Stuart Oldham, Alex Fornito. The development of brain network hubs Dev Cogn Neurosci. 2019 Apr; Volume 36:100607 Number of pages 60 (1-60) DOI : 10.1016/j. dcn. 2018.12.005.

[13] Olaf Sporns. Structure and function of complex brain networks Dialogues Clin Neurosci. 2013 sep; 15(3): 247-262. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3811098

[14] Peter Zeidman, Amirhossein Jafarian, Nadege Corbin, Mohmed L. Seghier, Adeel Razi, Cathy J. Price, Karl J. Friston. A guide to group effective connectivity analysis, part 1: first level analysis with DCM for fMRI. Neuroimage. 2019 oct 15; 200: 174-190 DOI: 10.1016/j.neuroimage.2019.06.031.

[15] Mahmoud Reza Ashrafi, Hossein Mohebbi, Mahmoud Mohammadi, Elham Azizi, Gholam Reza Zamani, Alireza Tavasoli, Reza Shervin Bady, Firozeh Hosseini. Clonidine versus

Chloral Hydrate for Recording sleep EEG in children Iran J Child Neurol.2020 Winter; 14 (1): 85-92 Retrieved from https://pubmed.ncbi.nlm.nih.gov/32021632.

[16] Razieh Fallah , Sharam Jalili, Motahhareh Golestan, Sedighah Akavan Karbasi, Mohammad-Hosein Jarahzadeh. Efficacy of Chloral Hydrate and Promethazine for Sedation during Electroencephalography in Childern; a Randomised Clinical Trial. Iran J pediatr.2013 Feb ;23(1) Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3574988

[17] Hector Rieiro, Carolina Diaz-Piedra, Jose Miguel Morales, Andres Catena, Samuel Romero, Joaquin Roca-Gonzalez, Luis J Fuentes, Leandro L Di Stasi. Validation of Electroencephalographic Recordings Obtained with a Consumer-Grade, Single Dry Electrode, Low-Cost Device: A Comperative Study. Sensors (Basel).2019 Jun 23; 19(12): 2808 18 pages (1-18) DOI: 10.3390/s19122808.

[18] Alexander J Casson Wearable EEG and beyond. Biomed Eng Lett. 2019 Jan 4; 9(1): 53-71.DOI: 10.1007/s13534-018-00093-6.

[19] M.A. Lopez –Gordo, D. Sanchez-Morillo, F.Pelayo Valle. Dry EEG Electrodes Sensors (Basel). 2014 Jul; 14(7): 12847-12870. DOI:10.3390/s140712847.

[20] Mark O'Sullivan, Andriy Temko, Andrea Bocchino, Conor O'Mahony, Geraldine Boylan, Emanuel Popovici. Analysis of a Lost-Cost EEG Monitoring System and Dry Electrodes toward Clinical use in the Neonatal ICU. Sensors (Basel) .2019 Jun; 19(11): 2637 16 pages (1-16). DOI: 10.3390/s19112637.

[21] C Kabdebon, F Leroy, H Simmonet, M Perrot, J Dubois, G Dehaene-Lambertz. Anatomical Correlations of the International 10-20 sensor placement system in infants. Neuroimage.2014 Oct 1; 99:342-56. DOI: 10.1016/j.neuroimage.2014.05.046.

[22] Oscar E Mendez, Richard P Brenner. Increasing the yield of EEG. Clin Neurophysiol. 2006 Aug; 23(4): 282-93. DOI: 10.1097/01.wnp.0000228514.40227.12.

[23] Kathryn A. Salvati, Mark P. Beenhakker. Out of thin air: Hyperventilation-triggered seizures. Brain Res. 2019 Jan 15; 1703:41-52. DOI: 10.1016/j.brainres.2017.12.037

[24] Elisa Baldin, W A Hauser, Jeffrey R Buehhalter, Dale C Hesdorffer, Ruth Ottman. Utility of EEG Activation Procedures in Epilepsy: A Population-Based Study. J Clin Neurophysiol.2017 Nov; 34 (6): 512-519. DOI: 10.1097/WNP.0000000000000371.

[25] Jerry J. Shih, Dean J. Krusienski, Jonathan R.Wolpaw.Brain-Computer Interfaces in Medicine. Mayo Clin Proc. 2012 Mar; 87(3):268-279. DOI: 10.1016/j.mayocp.2011.12.008

[26] Luis Fernando Nicolas-Alonso, Jaime Gomez-Gil. Brain – Computer Interfaces, a Review. DOI: 10.3390/s120201211

[27] David B. Burkholder, Jeffrey W. Britton, Vijayalakshmi Rajasekaran, Rachel R. Fabris, Perumpillichira J. Cherian, Kristen M. Kelly-Williams, Elson L. So, Katherine C. Nickels, Lily C. Wong-Kisiel, Terrence D. Lagerlund. Gregory D. Cascino, Gregory A. Worrell, Elaine C. Wirrell. Routine Vs extended outpatient EEG for the detection of interictal epileptiform discharges. Neurology. 2016 Apr 19; 86(16): 1524-1530. DOI: 10.1212/WNL.0000000000002592.

[28] Udaya Seneviratne, Wendyl Jude D'Souza. Ambulatory EEG. Handb Clin Neurol. 2019; 160: 161-170. DOI: 10.1016/B978-0-444-64032-1.00010-2.

[29] Brian D Moseley, Sandra Dewar, Zulfi Haneef, Dawn Eliashiv, John M Stern. Reasons for prolonged length of stay in the epilepsy monitoring unit. Epilepsy Res. 2016 Nov; 127:175-178. DOI: 10.1016/j.eplepsyres.2016.08.030.

[30] O Bennett- Back, S Uliel-Siboni, U Kramer. The yield of video- EEG telemetry evaluation for non-surgical candidate children. Eur J Paediatr Neurol. 2016 Nov; 20(6): 848-854. DOI: 10.1016/j.ejpn.2016.05.017.

[31] Jayanti Mani Video electroencephalogram telemetry in temporal lobe epilepsy Ann Indian Acad Neurol. 2014 Mar; 17 (Suppl 1): S45-S49. DOI: 10.4103/0972-2327.128653.

[32] Hannah C. Glass, Courtney J. Wusthoff, Renee A. Shellhaas. Amplitude Integrated EEG: The Child Neurologist's Perspective J Child Neurol. 2013 Oct; 28(10): 1342-1350. DOI: 10.1177/0883073813488663

[33] Nora Bruns, Susanne Blumenthal, Irmgard Meyer, Susanne Klose-Verschuur, Ursula Felderhoff-Muser, Hanna Muller. Application of an Amplitude –Inegrated EEG Monitor (Cerebral Function Monitor) to Neonates J Vis Exp.2017 Sept 6; (127): 55985 9 Pages (1-9). DOI: 10.3791/55985

[34] Maliheh Kadivar, Elahe Movahedi Moghadem, Reza Shervin Badv, Raziye Sangsari, Maryam Saeedy. A Comparison of Conventional Electroencephalography with Amplitude Integrated EEG in Detection of Neonatal Seizures. Med Devices (Auckl) . 2019 Dec 10; 12: 489-496. DOI: 10.2147/MDER.S214662.

[35] Michael R Isley, Harvey L Edmonds Jr, Mark Stecker. Guidelines for intraoperative neuromonitoring using raw (analog for digital waveforms) and quantitative electroencephalography: a position statement by the American Society of Neurophysiological Monitoring.J Clin Monit Comput. 2009 Dec; 23(6): 369-90. DOI: 10.1007/s10877-009-9191-y.

[36] Aashit K. Shah, Sandeep Mittal. Invasive electroencephalography monitoring: Indications and presurgical planning. An Indian Acad Neurol. 2014 Mar; 17(Suppl 1): S89-S94 DOI: 10.4103/0972-2327.128668.

[37] Edward H. Bertram Electrophysiology in epilepsy surgery: Roles and limitations. Ann Indian Acad Neurol. 2014 Mar; 17 (Suppl 1): S40-S44 DOI: 10.4103/0972-2327.128649.

[38] Selim R. Benbadis, Kaiwen Lin. Errors in EEG interpreation and misdiagnosis of epilepsy. Which EEG patterns are overread? Eur Neurol. 2008;59 (5): 267-71 DOI: 10.1159/000115641.

[39] Yi Sun, Changwei Wei, Victoria Cui, Meihong Xiu, Anshi Wu. Electroencephalography: Clinical applications during the perioperative period. Front Med (Lausanne). 2020 June; Volume 7, article 251 10 pages (1-10). DOI: 10.3389/fmed.2020.00251.

[40] William O Tatum. Normal "suspicious" EEG Neurology. 2013 Jan 1; 80 (1 Suppl 1): S4-11.DOI: 10. 1212/WNL.0b013e31827974df.

[41] Jose Mari-Acevedo, Kirsten Yelvington, William O Tatum. Normal EEG Variants. Handb Clin Neurol.2019; 160:143-160. DOI: 10.1016/B978-0-444-64032-1.00009-6.

[42] E M Mizrahi. Avoiding the pitfalls of EEG interpretation in childhood epilepsy. Epilepsia. 1996; 37 Suppl 1: S41-51. DOI: 10.1111/j.1528-1157.1996.tb06021.x

[43] Leanna M Lum, Mary B Connolly, Kevin Farrell, Peter K H Wong. Hyperventilation- induced high-amplitude rhythmic slowing

with altered awareness: a video-EEG comparison with absence seizures. Epilepsia.2002 Nov; 43(11): 1372-8. DOI: 10.1046/j.1528-1157.2002.35101.x

[44] Arif Khan, Aravindhan Baheerathan. Electrocephalogram after first unprovoked seizure in children: Routine, unnecessary or case specific. J Pediatr Nuerosci.2013 Jan- Apr; 8(1): 1-4 DOI: 10.4103/1817-1745.111412.

[45] B Kollar, Z Carnicka, P Siarnik, L Krizova, S Sutovsky, P Traubner, K Klobucnikova. The importance of interictal electroencephalography in paroxysmal states. Bratisl Lek Listy. 2014; 115 (3): 168-70. DOI: 10.4149/bll_2014_168.

[46] K S Rana. Rational use of EEG in childhood epilepsy Indian J Pediatr. 2000 Jan; 67 (1 Suppl): S22-31. Retrieved from https://pubmed.ncbi.nlm.nih.gov/11129891

[47] Natia Japaridze, Muthuraman Muthuraman, Friederike Moeller, Rainer Boor, Abdul Rauf Anwar, Gunther Deuschl, Urlich Stephani, Jan Raethjen, Michael Siniatchkin. Neuronal Network in west Syndrome as revealed by source analysis and renormalized partial directed coherence. Brain Topogr.2013 Jan; 26 (1): 157-70. DOI: 10.1007/s10548-012-0245-y.

[48] Stephen A Thompson, Stephen Hantus. Highly Epileptiform Bursts Are Associated with Seizure Recurrence. J Clin Neurophysiol.2016 Feb; 33(1): 66-71. DOI: 10.1097/WNP.0000000000000232.

[49] A B Chelse, Kent Kelley, Joseph R Hageman, Sookyong Koh. Initial evaluation and management of a first seizure in children. Pediatr Ann. 2013 Dec; 42(12): 244-8. DOI: 10.3928/00904481-20131122-08.

[50] Kaminska A, Cheliout-Heraut F, Eisermann M, Touzery de Villepin A, Lamblin MD. EEG in children, in the laboratory or at the patient's bedside. Neurophysiol Clin. 2015 Mar;**45**(1):65-74. DOI: 10.1016/j.neucli.2014.11.008

[51] P Dryzalowski, S Jozwiak, M Franckiewicz, J Strzelecka. Benign epilepsy with centrotemporal spikes-current concepts of diagnosis and treatment. Neurol Neurochir pol.2018 Nov-Dec; 52(6): 677-689. DOI: 10.1016/j.pjnns.2018.08.010.

[52] R Caraballo, R Cersosimo, C Medina, N Fejerman. Panayiotopoulos-type benign childhood occipital epilepsy: a prospective study. Neurology. 2000 Oct 24; 55(8):1096-1100. DOI: 10.1212/wnl.55.8.1096.

[53] Nicholas S. Abend, Kevin E. Chopamn, William B. Gallentine, Joshua Goldstein, Ann E. Hyslop, Tobias Loddenkemper, Kendall B Nash, James J. Riviello Jr, Cecil D. Hahn. Electroencephalographic Monitoring in the Paediatric Intensive Care Unit. Curr Neurol Neurosci Rep. 2013 Mar; 13(3): 330 10 Pages (1-10). DOI: 10.1007/s11910-012-0330-3.

[54] Yupeng Wu, Meihua Chen, Yu Cui, Xiying He, Jingzhong Niu, Yanbo Zhang, Li Zhou. Viral encephalitis in quantitative EEG. J Integr Nuerosci.2018;17(3-4): 493-501. DOI: 10.3233/JIN-180084.

[55] Kevin Messacar, Marc Fischer, Samuel R Dominguez, Kenneth L Tyler, Mark J Abzug. Encephalitis in US children Infect Dis Clin North Am.2018 Mar; 32(1): 145-162. DOI: 10.1016/j.idc.2017.10.007.

[56] Michael J. Bradshaw, Arun Venkatesan. Herpes Simplex Virus-1 Encephalitis in Adults: Pathophysiology, Diagnosis and Management. Neurotherapeutics.2016 Jul;13(3):493-508. DOI: 10.1007/s13311-016-0433-7.

[57] C W Lai, M E Gragasin. Electroencephalography in herpes

simplex encephalitis. J Clin Neurophysiol. 1988 Jan; 5(1): 87-103. DOI: 10.1097/00004691-198801000-00003.

[58] Young-Soo Kim, Keun-Hwa Jung, Soon-Tae Iee, Bong Su Kang, Jung Sook Yeom, Jangsup Moon, Jung –Won Shin, Sang Kun Lee, Kon Chu. Prognostic value of initial standard EEG and MRI in patients with Herpes Simplex Encephalitis. J. Clin Neurol.2016 Apr; 12(2): 224-229. DOI: 10.3988/jcn.2016.12.2.224.

[59] Alberto M Cappellari, Giacomo Tardini, Alberto R Bona, Massimo Belli, Fabio Triulzi, Emilio F Fossali. Teaching NeuroImages: Infantile herpes simplex encephalitis. Neurology. 2014 Aug 12: 83(7): e85-6. DOI: 10.1212/WNL.0000000000000695.

[60] Natalie Henderson, Mark J McDonald. Ancillary studies in evaluating Paediatric brain death. J Pediatr Intensive Care. 2017 Dec; 6(4): 234-239. DOI: 10.1055/s-0037-1604015.

[61] W Szurhaj, M-D Lamblin, A Kaminska, H Sediri. EEG guidelines in the diagnosis of brain death. Neurophysiol Clin. 2015 Mar; 45(1): 97-104. DOI: 10.1016/j.neucli.2014.11.005.

[62] Matthew A Koenig, Peter W Kaplan. Brain Death. Handb Clin Neurol .2019; 161: 89-102. DOI: 10.1016/B978-0-444-64142-7.00042-4.