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Abnormalities in EEG as migraine marker: a mini review

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Abstract: The electroencephalogram (EEG) records the spontaneous electrical activity of the brain and is useful in diagnosing various brain conditions. It is commonly used in diagnosing epilepsy, Parkinson's disease, Alzheimer's disease, and multiple sclerosis. Recent research has also suggested that EEG can be used to detect migraine, although the findings in this area are still being investigated. The aim of this study is to review the use of EEG in detecting migraine in past and recent investigations. EEG has been used in migraine studies since the early 20th century, and subsequent studies have explored its use in understanding the pathophysiology of migraine and developing new treatments for the condition. Abnormal EEG patterns, including increased theta and delta activity and decreased alpha and beta activity, have been found in migraine patients during attacks. Studies have shown that EEG can be used to detect migraine and identify specific EEG biomarkers of the condition. Resting-state functional connectivity and altered connectivity in the anterior cingulate cortex have been linked to migraine chronification and may predict treatment outcomes in patients with chronic migraine. However, the specificity of EEG in diagnosing migraine is low, and more research is needed to determine its diagnostic utility.

Keywords: EEG, Abnormality, Migraine

1 Introduction

Electroencephalogram records spontaneous biological potential of the brain from the scalp, which is the spontaneous and rhythmic electrical activity of the brain cell group. EEG is expected to be useful in diagnosing brain conditions. EEG is commonly used in the diagnosis of

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epilepsy, which is a neurological disorder characterized by recurrent seizures. EEG can be used to detect abnormal electrical activity in the brain that is associated with seizures. The brain abnormal activities can be seen as spikes or sharp waves on the EEG recording. EEG can be used to detect changes in brain activity that are associated with Parkinson's disease, such as changes in the alpha and beta waves. Abnormal EEG patterns have been detected in Alzheimer's disease, including changes in the alpha and theta waves. EEG also can be used to detect changes in brain activity that are associated with multiple sclerosis, in which, abnormal beta frequency band is appeared in recording (Britton et al., 2016; Krumholz et al., 2007; Leocani et al., 2001; Tsolaki et al., 2014; Wang et al., 2020). Recently it has been shown that EEG can be used to detect migraine, however, the findings are still challenging in this area. The aim of this study was to review the application of EEG in detecting migraine over past and recent investigations.

2 Migraine

Migraine is a common problem worldwide with significant morbidity and economic impact affecting people of all ages, genders, and ethnicities. Migraine is a highly prevalent condition, affecting approximately 1 billion people worldwide. According to the World Health Organization (WHO), migraine is the second leading cause of disability worldwide, and it is estimated that 14.7% of the global population will experience migraine at some point in their lives. Migraine is very common, affecting one in five women, one in 16 men, and even one in 11 children. Approximately 28 million Americans have severe, disabling migraine headaches, and 17.6% of American women and 6% of American men had one migraine attack in the previous year (Woldeamanuel and Cowan, 2017). The WHO ranks migraine among the world's most disabling medical illnesses.

Migraine is characterized by recurrent attacks. Migraine is a common primary headache disabling neurological disorder characterized by multiple phases: premonitory, aura, headache, postdrome, and interictal. It is a paroxysmal disorder characterized by attacks of headache, nausea, vomiting, photophobia, and phonophobia. Genetic and environmental factors play a role in the development of migraine disease. Hormonal changes, specifically fluctuations and estrogen that can occur during menstrual periods, pregnancy and perimenopause can trigger a migraine attack. Other risk factors include certain medications, drinking alcohol, drinking too much caffeine, stress, sleep changes, weather changes, skipping meals or even certain foods like aged cheeses and processed foods. Migraine is a complex neurological disorder that involves a variety of pathophysiological mechanisms, including changes in cerebral blood flow, neuronal excitability, and neurotransmitter release. The trigeminovascular system and brainstem nuclei, hypothalamus, thalamus, brain cortex and other parts of the brain have been reported to be associated with migraine (Puledda et al., 2023; Kung et al., 2023; Martin et al., 2021; Friedman and De Ver Dye, 2009). Since the neural excitability changes may be followed by migraine attack, EEG has a potential to be used for predicting and diagnosis of migraine.

3 EEG

Electroencephalography was introduced by Hans Berger of Jena, Germany, in 1929, primarily to study brain dysfunction in mental illnesses (Centorrino et al., 2002). Electroencephalogram (EEG) is a tool that enables clinicians to provide continuous brain monitoring and to guide treatment decisions-brain telemetry (Rubinos et al., 2020). EEG is a record of the oscillations of brain electric potentials recorded from perhaps 20 to 256 electrodes attached to the human. Most EEG signals originate in the brain's outer layer (the cerebral cortex), believed largely responsible for our individual thoughts, emotions and behavior. Cortical synaptic action generates electrical signals that change in the 10 to 100 millisecond range. EEG and MEG (magnetoencephalography) are the only widely available technologies with sufficient temporal resolution to follow these fast dynamic changes (Nunez and Srinivasan, 2007).

EEG is a non-invasive technique that records the electrical activity of the brain measuring the voltage fluctuations generated by the synchronized activity of millions of neurons in the brain (Niedermeyer and da Silva, 2005). The most commonly recognized EEG waves are: Delta Waves (0.5-4 Hz) which are typically associated with deep sleep and unconsciousness, Theta Waves (4-8 Hz) which are associated with drowsiness, daydreaming, and light sleep, Alpha Waves (8-13 Hz) which are present when a person is awake but relaxed, with eyes closed, Beta Waves (13-30 Hz) that are present when a person is alert and focused, and are associated with cognitive and motor activity, and Gamma Waves (30-100 Hz) that are the fastest type of brain waves and are associated with higher cognitive functions, such as perception, attention, and memory (Buzsaki, 2006).

EEG can detect the onset and spatio-temporal (location and time) evolution of seizures and the presence of status epilepticus. It is also used to help diagnose brain disorders and dysfunction. EEG is used to be a first-line method of diagnosis for tumors, stroke and other focal brain disorders, but this use has decreased with the advent of high-resolution anatomical imaging techniques such as magnetic resonance imaging (MRI) and computed tomography (CT) (Niedermeyer and da Silva, 2005). Despite limited spatial resolution, EEG continues to be a valuable tool for research and diagnosis.

4 Diagnostic value of EEG for detecting neurological disorders

EEG is a valuable diagnostic tool in epilepsy, providing evidence of a seizure disorder and helping to classify seizures and epilepsy syndromes. Recent research suggests that the EEG may also offer important information about the likelihood of seizure recurrence after a single unprovoked attack and following withdrawal from anti-epileptic medication. Continuous EEG video telemetry monitoring is used to diagnose non-epileptic pseudo-seizures and to locate the seizure focus for epilepsy surgery. Although still being investigated, newer tools such as EEG mapping and magneto-encephalogram show promise in defining the seizure focus in epilepsy

(Noachtar and Rémi, 2009; Ahmad et al., 2022).

EEG studies in individuals with ASD have revealed several abnormalities in brain wave patterns, including increased theta and delta activity, decreased alpha and beta activity, and increased coherence in certain brain regions (Coben and Myers, 2010). Some studies have suggested that EEG may have potential as a diagnostic tool for ASD (Sokhadze et al., 2009). Another study found that EEG could be used to differentiate between subtypes of ASD, with children with a higher level of language impairment showing more pronounced EEG abnormalities compared to those with milder language impairment (Khan et al., 2013).

Alzheimer's disease (AD) is the most common neurodegenerative disorder characterized by cognitive and intellectual deficits and behavior disturbance. The electroencephalogram (EEG) has been used as a tool for diagnosing AD for several decades. The hallmark of EEG abnormalities in AD patients is a shift of the power spectrum to lower frequencies and a decrease in coherence of fast rhythms (Jeong, 2004).

Electroencephalography (EEG) has, historically, played a focal role in the assessment of neural function in children with attention deficit hyperactivity disorder (ADHD). A moderately elevated prevalence of epileptiform EEG activity is described in children with ADHD without epilepsy compared with healthy children, during both wakefulness and sleep (Lenartowicz and Loo, 2014; Sand et al., 2013).

EEG can also be used to diagnose sleep disorders such as sleep apnea and narcolepsy. EEG patterns during sleep can help identify the different stages of sleep and detect abnormalities such as sleep-disordered breathing (Niedermeyer and da Silva, 2005).

EEG can be used to diagnose encephalopathies, which are brain disorders that affect cognitive function. EEG can detect abnormalities in brain waves that are associated with encephalopathies such as hepatic encephalopathy and hypoxic-ischemic encephalopathy (Sirsi et al., 2023).

Electroencephalography has traditionally been considered a useful adjunct to the clinical evaluation of headache. Headache is a prevalent condition that can have various underlying causes. Primary headaches, which include migraine, tension-type headache, and cluster headache, are typically recurring and not caused by any organic disease. Secondary headaches, on the other hand, are less common and result from an underlying organic condition, such as sinusitis or subarachnoid hemorrhage. By considering the different types of headaches within each category (primary or secondary), conducting a comprehensive headache history, and performing a focused clinical examination, physicians can typically make an accurate diagnosis and determine whether additional laboratory testing or neuroimaging is necessary (Gomez-Pilar et al., 2022; Raucci et al., 2019).

5 Diagnostic value of EEG for detecting migraine

The use of electroencephalography (EEG) in migraine studies dates back to the early 20th century, when researchers noticed that some migraine patients showed abnormal EEG patterns during attacks (Nye and Thadani, 2015). Since then, numerous studies have explored the use of EEG in understanding the pathophysiology of migraine and in developing new treatments for the condition. One of the earliest EEG studies in migraine was conducted by Bjørk and colleagues in 2009. They found that some migraine patients showed an increase in slow-wave activity during attacks, which they attributed to a reduction in cerebral blood flow (Bjørk et al., 2009).

In a study the alpha rhythm of 18 patients with classical migraine (migraine with aura) was studied by EEG spectrum analysis for evidence of neural abnormalities during the asymptomatic period. Increased frequency dispersion and frequency asymmetries of the alpha rhythm were found (Nyrke et al., 1990). The most definitely abnormal EEGs with unilateral or bilateral delta activity have been recorded during attacks of hemiplegic migraine, and during attacks of migraine with disturbed consciousness (Sand, 1991). The findings also suggest some difference in the posterior background activity in the EEG in migraine patients as compared to the controls, but are not useful in differentiating migraine from non-migraine patients (Neufeld et al., 1991).

The correlations between clinical variables and EEG were studied, according to which, interictal EEGs from 33 migraineurs and 31 controls were compared. Absolute power, asymmetry and relative power were studied for delta, theta and alpha frequency bands in parieto-occipital, temporal and fronto-central areas. EEG variables were correlated to attack frequency, headache duration, attack duration, pain intensity, photo- and phonophobia. Compared with controls, migraineurs had increased relative theta power in all cortical regions and increased delta activity in the painful fronto-central region. In age-adjusted analyses, headache intensity correlated with increased delta activity (Bjørk et al., 2009).

Subsequent studies have confirmed the presence of abnormal EEG patterns in migraine patients during attacks, including increased theta and delta activity and decreased alpha activity (Bjørk et al., 2009). A study has shown that migraine is a common problem in children with abnormalities present in approximately 20% of the patients. It was revealed that migraine and abnormal EEG findings were significantly associated (Biglari et al., 2012). Although migraine can only be detected by expert medical doctors. However, studies have shown that the migraine analysis can be done also by using EEG. T5-T3 channel of EEG is generally used in the migraine detection by EEG. It is also very important to find out which EEG channels and brain lobes are more important to learn the characteristics of migraine (Akben et al., 2016). It has been shown that the resting-state EEG power density and effective connectivity differ between migraine phases and provide an insight into the complex neurophysiology of migraine. It was revealed that the entropy-based analytical methods identified enhancement or ''normalization'' of frontal electroencephalogram complexity during the preictal phase compared with the interictal phase. This classification model, using this complexity feature, may have the potential to provide a preictal alert to migraine patients (Cao et al., 2016). More recent EEG studies have focused on identifying specific EEG biomarkers of migraine. For example, one study found that migraine patients had reduced resting-state functional connectivity in the default mode network, a brain network involved in self-referential processing (Hunt et al., 2022). Another study found that migraine patients had altered EEG coherence patterns during visual stimulation, which could potentially serve as a biomarker for the condition (Chamanzar et al., 2021). It is generally believed that the abnormal rate of EEG in migraine patients is higher than that in normal people. It has been shown that the electroencephalogram of patients with migraine is more volatile, which is mainly manifested by the emergence of moderate and high amplitude theta waves, especially in the case of excessive respiration, and the specificity of diagnosis is low (Changmin, et al., 2020).

A recent study examined differences in resting state functional connectivity among the pain-related regions and revealed that beta connectivity was attenuated in migraine and that altered connectivity in the anterior cingulate cortex was linked to migraine chronification. These findings suggested that EEG may predict the treatment outcomes in patients with chronic migraine that those with lower pre-treatment occipital alpha power tend to show greater reduction in headache frequency (Pan et al., 2022).

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Conflict of interests

The authors declare no conflict of interest.

References

Ahmad, I., Wang, X., Zhu, M., Wang, C., Pi, Y., Khan, J. A., Khan, S., Samuel, O. W., Chen, S., & Li, G. (2022). EEG-based epileptic seizure detection via machine/deep learning approaches: A Systematic Review. *Computational Intelligence and Neuroscience, 2022*. https://doi.org/10.1155/2022/6486570

Akben, S. B., Tuncel, D., & Alkan, A. (2016). Classification of multi-channel EEG signals for migraine detection. *Biomed Res, 27*(3), 743-748.

Biglari, H. N., Rezayi, A., Biglari, H. N., Alizadeh, M., & Ahmadabadi, F. (2012). Relationship between migraine and abnormal EEG findings in children. *Iranian Journal of Child Neurology*, *6*(3), 21. PMID: 24665268

Bjørk, M. H., Stovner, L. J., Engstrøm, M., Stjern, M., Hagen, K., & Sand, T. (2009). Interictal quantitative EEG in migraine: a blinded controlled study. *The Journal of Headache and Pain, 10*, 331-339. https://doi.org/10.1007/s10194-009-0140-4

Britton, J. W., Frey, L. C., Hopp, J. L., Korb, P., Koubeissi, M. Z., Lievens, W. E., Pestana-Knight, E. M., & St Louis, E. K. (2016). Electroencephalography (EEG): An introductory text and atlas of normal and abnormal findings in adults, children, and infants. PMID: 27748095

Buzsaki, G. (2006). *Rhythms of the Brain*. Oxford university press.

Cao, Z., Lin, C. T., Chuang, C. H., Lai, K. L., Yang, A. C., Fuh, J. L., & Wang, S. J. (2016). Resting-state EEG power and coherence vary between migraine phases. *The Journal of Headache and Pain, 17*, 1-9. https://doi.org/10.1186/s10194-016-0697-7

Centorrino, F., Price, B. H., Tuttle, M., Bahk, W. M., Hennen, J., Albert, M. J., & Baldessarini, R. J. (2002). EEG abnormalities during treatment with typical and atypical antipsychotics. *American Journal of Psychiatry*, *159*(1), 109-115. https://doi.org/10.1176/appi.ajp.159.1.109

Chamanzar, A., Haigh, S. M., Grover, P., & Behrmann, M. (2021). Abnormalities in cortical pattern of coherence in migraine detected using ultra high-density EEG. *Brain Communications*, *3*(2), fcab061. https://doi.org/10.1093/braincomms/fcab061

Changmin, K., Chuna, Z., & Peiping, W. (2020). Application of EEG and Transcranial Doppler in Migraine Diagnosis. *Frontiers in Medical Science Research, 2*(1). doi: 10.25236/FMSR.2020.020105

Coben, R., & Myers, T. E. (2010). The relative efficacy of connectivity guided and symptom based EEG biofeedback for autistic disorders. *Applied Psychophysiology and Biofeedback*, *35*(1), 13-23. https://doi.org/10.1007/s10484-009-9102-5

Friedman, D. I., & De Ver Dye, T. (2009). Migraine and the environment. *Headache: The Journal of Head and Face Pain, 49*(6), 941-952. https://doi.org/10.1111/j.1526-4610.2009.01443.x

Gomez-Pilar, J., Martínez-Cagigal, V., García-Azorín, D., Gómez, C., Guerrero, Á., & Hornero, R. (2022). Headache-related circuits and high frequencies evaluated by EEG, MRI, PET as potential biomarkers to differentiate chronic and episodic migraine: Evidence from a systematic review. *The Journal of Headache and Pain, 23*(1), 1-14. doi: 10.1186/s10194-022-01465-1

Hunt, C. A., Letzen, J. E., Krimmel, S. R., Burrowes, S. A., Haythornthwaite, J. A., Finan, P. H., Vetter, M., & Seminowicz, D. A. (2022). Is mindfulness associated with lower pain reactivity and connectivity of the default mode network? A replication and extension study in healthy and episodic migraine participants. *The Journal of Pain*, *23*(12), 2110-2120. https://doi.org/10.1016/j.jpain.2022.07.011

Jeong, J. (2004). EEG dynamics in patients with Alzheimer's disease. *Clinical Neurophysiology, 115*(7), 1490-1505. https://doi.org/10.1016/j.clinph.2004.01.001

Khan, S., Gramfort, A., Shetty, N. R., Kitzbichler, M. G., Ganesan, S., Moran, J. M., Lee, S. M., Gabrieli, J. D., Tager-Flusberg, H. B., Joseph, R. M., Herbert, M. R., Hämäläinen, M. S., &

Kenet, T. (2013). Local and long-range functional connectivity is reduced in concert in autism spectrum disorders. *Proceedings of the National Academy of Sciences, 110*(8), 3107-3112. https://doi.org/10.1073/pnas.1214533110

Krumholz, A., Wiebe, S., Gronseth, G., Shinnar, S., Levisohn, P., Ting, T., Hopp, J., Shafer, P., Morris, H., Seiden, L., Barkley, G., & French, J. (2007). Practice Parameter: Evaluating an apparent unprovoked first seizure in adults (an evidence-based review):[RETIRED]: Report of the Quality Standards Subcommittee of the American Academy of Neurology and the American Epilepsy Society. *Neurology*, *69*(21), 1996-2007. doi: 10.1212/01.wnl.0000285084.93652.43

Kung, D., Rodriguez, G., & Evans, R. (2023). Chronic Migraine: Diagnosis and Management. *Neurologic Clinics*, 41(1), 141-159. https://doi.org/10.1016/j.ncl.2022.05.005

Lenartowicz, A., & Loo, S. K. (2014). Use of EEG to diagnose ADHD. *Current psychiatry reports*, *16*, 1-11. https://doi.org/10.1007/s11920-014-0498-0

Leocani, L., Colombo, B., Magnani, G., Martinelli-Boneschi, F., Cursi, M., Rossi, P., Martinelli, V., & Comi, G. (2001). Fatigue in multiple sclerosis is associated with abnormal cortical activation to voluntary movement—EEG evidence. *Neuroimage*, *13*(6), 1186-1192. https://doi.org/10.1006/nimg.2001.0759

Martin, V. T., Feoktistov, A., & Solomon, G. D. (2021). A rational approach to migraine diagnosis and management in primary care. *Annals of Medicine*, *53*(1), 1969-1980. https://doi.org/10.1080/07853890.2021.1995626

Neufeld, M. Y., Treves, T. A., & Korczyn, A. D. (1991). EEG and topographic frequency analysis in common and classic migraine. Headache: *The Journal of Head and Face Pain, 31*(4), 232-236. https://doi.org/10.1111/j.1526-4610.1991.hed3104232.x

Niedermeyer, E., & da Silva, F. L. (2005). *Electroencephalography: Basic Principles, Clinical Applications, and Related Fields*. Lippincott Williams & Wilkins.

Noachtar, S., & Rémi, J. (2009). The role of EEG in epilepsy: a critical review. Epilepsy & Behavior, 15(1), 22-33. https://doi.org/10.1016/j.yebeh.2009.02.035

Nunez, P. L., & Srinivasan, R. (2007). Electroencephalogram. *Scholarpedia*, *2*(2), 1348. doi: 10.4249/scholarpedia.1348

Nye, B. L., & Thadani, V. M. (2015). Migraine and epilepsy: review of the literature. *Headache: The Journal of Head and Face Pain*, *55*(3), 359-380. https://doi.org/10.1111/head.12536

Nyrke, T., Kangasniemi, P., & Lang, H. (1990). Alpha rhythm in classical migraine (migraine with aura): abnormalities in the headache-free interval. *Cephalalgia, 10*(4), 177-181. https://doi.org/10.1046/j.1468-2982.1990.1004177.x

Pan, L. L. H., Hsiao, F. J., Chen, W. T., & Wang, S. J. (2022). Resting State Electrophysiological Cortical Activity: A Brain Signature Candidate for Patients with Migraine. *Current Pain and Headache Reports, 26*(4), 289-297. https://doi.org/10.1007/s11916-022-01030-0

Puledda, F., Silva, E. M., Suwanlaong, K., & Goadsby, P. J. (2023). Migraine: from pathophysiology to treatment. *Journal of Neurology*, 1-13. https://doi.org/10.1007/s00415-023-11706-1

Raucci, U., Della Vecchia, N., Ossella, C., Paolino, M. C., Villa, M. P., Reale, A., & Parisi, P. (2019). Management of childhood headache in the emergency department. review of the literature. *Frontiers in Neurology, 10*, 886. https://doi.org/10.3389/fneur.2019.00886

Rubinos, C., Alkhachroum, A., Der-Nigoghossian, C., & Claassen, J. (2020, December). Electroencephalogram monitoring in critical care. In *Seminars in Neurology* (Vol. 40, No. 06, pp. 675-680). Thieme Medical Publishers, Inc.. https://doi.org/10.1055/s-0040-1719073

Sand, T. (1991). EEG in migraine: a review of the literature. *Functional Neurology, 6*(1), 7-22. PMID: 2055554

Sand, T., Breivik, N., & Herigstad, A. (2013). EEG-utredning ved AD/HD. *Tidsskrift for Den norske legeforening*, *133*, 312-316. https://doi.org/10.4045/tidsskr.12.0224

Sirsi, D., Lowden, A., Dolce, A., Machie, M., Thomas, J., & Joshi, C. (2023). EEG and clinical characteristics of neonatal parechovirus encephalitis. *Epilepsy Research*, 107143. https://doi.org/10.1016/j.eplepsyres.2023.107143

Sokhadze, E. M., El-Baz, A., Baruth, J., Mathai, G., Sears, L., & Casanova, M. F. (2009). Effects of low frequency repetitive transcranial magnetic stimulation (rTMS) on gamma frequency oscillations and event-related potentials during processing of illusory figures in autism. *Journal of Autism and Developmental Disorders*, *39*, 619-634. https://doi.org/10.1007/s10803-008-0662-7

Tsolaki, A., Kazis, D., Kompatsiaris, I., Kosmidou, V., & Tsolaki, M. (2014). Electroencephalogram and Alzheimer's disease: clinical and research approaches. *International Journal of Alzheimer's Disease*, *2014*. https://doi.org/10.1155/2014/349249

Wang, Q., Meng, L., Pang, J., Zhu, X., & Ming, D. (2020). Characterization of EEG data revealing relationships with cognitive and motor symptoms in Parkinson's disease: a systematic review. *Frontiers in Aging Neuroscience*, *12*, 587396. https://doi.org/10.3389/fnagi.2020.587396

Woldeamanuel, Y. W., & Cowan, R. P. (2017). Migraine affects 1 in 10 people worldwide featuring recent rise: a systematic review and meta-analysis of community-based studies involving 6 million participants. *Journal of the Neurological Sciences*, *372*, 307-315. https://doi.org/10.1016/j.jns.2016.11.071