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Extended Abstract

Electrical Activity of Brain during Neurogenic Pain

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Abstract

Keywords: Brain, electroencephalography, neurogenic pain, neurophysiology, neuroscience, pain.

Objective: Pain is a diverse phenomenon that leads to the excitation and activation of several regions of brain. The aim of this literature review is to determine the electrical activity of brain during neurogenic pain.

Methods: A literature review was conducted and literature search was performed using different search engines including Google scholar, JANE, PubMed, Cochrane and PEDro. Key words used were pain, neurogenic pain, neuropathic pain, brain waves, electroencephalography and brain electrical activity. Boolean terms were used to combine the terms during literature search. A total of twenty two studies were shortlisted and included in the study from 1991-2019.

Results: The findings of the literature showed alterations in the electrical activity of brain due to neurogenic pain, when analyzed using electro-encephalography (EEG) with over activation of brain's theta and beta waves, coupling between theta and beta frequency range, thalamo-cortical interplay and significant differences in theta frequency range.

Conclusion: It is suggested that neurogenic pain results in the alterations in the electrical activity of brain especially in terms of theta and beta waves on EEG.

Introduction

The actual or potential tissue damage leads to an unpleasant sensory and emotional experience known as Pain (1). Pain is a diverse phenomenon that leads to the excitation and activation of several regions of brain (2). A large network of neurons in the thalamic and cortical areas of the brain functions as the central processing unit of pain (1, 3). Several neuroimaging studies indicate that in addition to the associative cortical areas , several paralimbic structures are also playing a significant role in the overall experience of pain(2). Various parts of the brain fluctuating during the pain perception and thus called as the "pain matrix" include thalamus, somatosensory cortex (primary and secondary), medial and lateral prefrontal cortex, posterior and anterior insular cortex, basal ganglia, cerebellum, orbitofrontal cortex, premotor cortex and posterior parietal cortex(1, 2).

The dysfunction of peripheral and central nervous system gives rise to neurogenic pain (4). Neurogenic pain is perceived as discomfort without nociceptive stimulation from the periphery (1, 5). The terms such as neuropathic pain, central pain and deafferentation pain all are summed up into a broader term known as "*neurogenic pain*"(4). Up to 25% of the patients visiting pain clinics suffer from clinical syndromes representing this type of pain (4). Several concepts about the pathophysiology of neurogenic pain have been discussed in the literature (6-8). There is a dense and reciprocal linkage of certain neuronal structures or interconnection between thalamic and cortical areas of human brain (9). Furthermore, various studies have reported that the interruption in the normal functioning of Thalamo-cortical interaction is the source of neurogenic pain (8, 10, 11). The alteration or slight change in the signal transmission of Thalamo-cortical pathways gives rise to "Thalamocortical dysrhythmia" (12), observed in patients exhibiting the symptoms of neurogenic pain(11, 13). Moreover, it is also suggested that the reticular nucleus of Thalamus inhibits the central lateral and ventro-posterior nuclei, which leads to the imbalance between both the nuclei thus resulting in neurogenic pain(14). Modern imaging techniques provide the deeper insight to the location and function of these areas(15). Numerous studies indicate that the incidence of neurogenic pain increases over the age of 65, thus neurogenic pain is a major health concern in geriatric population (4).

Multiple levels of nervous system are involved in the extensive and complex process of pain transduction and perception (16). The cortical and subcortical distribution of neurogenic pain have been examined using electrophysiological and neuroimaging studies (7, 17). Brain's responses to pain have been identified in the literature through functional magnetic resonance imaging (fMRI), positron emission tomography (PET) and magnetencephalography (MEG) (11, 15, 18). Magnetoencephalography detects the physiological rhythm of the temporal region and serves as a clinical tool of neurophysiology (19) To determine the electrical activity of brain during neurogenic pain, various studies have been conducted using electroencephalography (EEG) and the frequency band power of alpha beta and theta waves during the process have been discussed (5, 11, 20). EEG contains continuous and wide frequency spectrum with lower and upper limit range (19). In contrast to fMRI, electroencephalogram has much defined temporal resolution as the electrical activity of brain is recorded directly from the scalp (21). However, it is hard to localize the source of electrical activity within the brain through EEG (21).

The aim of this literature review is to determine the electrical activity of brain during neurogenic pain.

Methodology:

An online literature search was performed using different search engines and data bases including Google scholar, JANE and PubMed, Chochrane and PEDro. Key words used were brain, brain waves, electroencephalography, neurophysiology, neuroscience, neurogenic pain, neuropathic pain and pain. To combine the key words, Boolean terms were used. A total of twenty two studies were identified and shortlisted from the literature and cited in the manuscript from the year 1991-2019.

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Results and Discussion:

A study conducted by Micheals et al. on patients with chronic neurogenic pain reported EEG over activation in numerous structures of pain matrix. On the basis of EEG data and functional low resolution electromagnetic tomography (LORETA), the over activation of high theta and low beta frequency ranges were observed. The enhanced theta and beta activity was also observed in the resting EEG recording in the patients with neurogenic pain, which supports the thalamo cortical interplay mechanism. Multiple areas of pain matrix including, anterior cingulate cortex (ACC), insulate cortex IC, inferior posterior parietal cortices, prefrontal and primary secondary and supplementary cortices were reported to have localized theta and beta over activations (5).

The study conducted by Sarthein et al. recorded electrical brain activity in chronic neurogenic pain patients. EEG readings were taken under two different conditions, resting with eyes open and resting with eyes closed. However, the focus was on the eyes closed session as this state was less susceptible to motion artifacts. EEG of healthy controls was taken as a reference. A significant difference was observed in the EEG frequency spectrum between patients and healthy controls. The results showed boosted coupling between theta (4-9Hz) and beta (12-25Hz) frequencies in patients with chronic neurogenic pain compared to healthy controls. However, theta EEG frequency was significantly reduced post thalamic surgery in patient group (10).

Another study conducted in 2003 recorded local field potentials (LFP) as well as EEG to observe the electrical activity of brain in patients with different neurological disorders. Results showed enhanced EEG power in the range of theta waves, and also the phase coupling between theta and beta waves in patients with neurogenic pain, epilepsy and movement disorders. There was also significant theta coherence between LFP and EEG with up to 70% strength. (9).
Study conducted by Drewes et al. observed that pain in choric pancreatitis has a neurogenic origin. Electrical activity of brain was recorded and compared between eight patients and twelve healthy controls using 64 EEG scalp electrodes. The patient group was electrically stimulated up to pain threshold via nasal endoscope. When the results of the EEG were compared between the control and patients' group, the latter group showed peak activity in the theta band. Furthermore, differences between both the groups were observed in the range of delta band as well but insignificant differences in the other frequency bands. The peak values and significant differences in the theta band showed neurogenic origin of the pain in the patients suffering chronic pancreatitis (22).

Results of another study conducted by Linas et al. indicated thalamocortical dysrhythmia when magnetoencephalography (MEG) was performed in patients suffering with neurogenic pain (trigeminal neuralgia and upper limb phantom pain), Parkinson's disease and tinnitus. Spontaneous brain activity was recorded using 148 channels MEG system. Results showed boosted low frequency theta rhythmicity in the patients group compared to controls (11).

Study conducted by boord et al. observed the electrical activity of brain among patients suffering from neuropathic pain following spinal cord injuries. EEG was recorded in the control group (able bodied individuals) and patient group (paraplegics with neuropathic pain) in the state of eyes open and eyes closed. Statistically significant slowing of EEG and reduced EEG spectral activity was observed in the EEG of the patients suffering from neuropathic pain compared to the healthy controls (20).

Results of the study conducted by Daniel et al. on neurogenic patients revealed that the recordings in the medial thalamus (before therapeutic medial Thalamotomy) had slow calcium spikes. Furthermore, the patients presented no response to somatosensory stimulus as shown by microelectrodes recordings. However, after medial Thalamotomy was done, 67% of the patients were without somatosensory deficits with 50-200% pain relief. There was also a spatial overlap between bursting activities and the extreme efficiency of therapeutic lesions in the central lateral nucleus suggests that this structure plays in a key role in the pathway of neurogenic pain. Thus it was suggested that the over inhibition of central lateral and ventroposterior nuclei by thalamic reticular nucleus leads to the imbalance of both the nuclei, resulting in neurogenic pain (14)

Conclusion:

This review has suggested that the neurogenic pain results in the alterations in the electrical activity of brain as detected by EEG. Furthermore, the literature clearly shows that over activation of brain's theta and beta waves, coupling between theta and beta frequency range, Thalamocortical interplay and significant differences in theta frequency range among patients and controls are some of the common features in the electrical activity of brain of the patients exhibiting neurogenic pain.

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