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Original article

Effect of intraoperative Magnesium sulphate on Electro-Encephalogram in patients undergoing lumbar fixation

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Abstract:

Aim:This study aimed to assess theElectro-Encephalogram changes after intraoperative Magnesium sulphate in patients undergoing lumbar fixation. **Methods**: This study was conducted at Beni-Suef University Hospital on 80 patients indicated for lumbar fixation. The selected patients were randomly assigned to one of the following two groups; the first group will received conventional general anesthesia only (40 participants) (control group), and the second group will received conventional general anesthesia with extra administration of intraoperative magnesium sulphate (40 participants) (Mg sulphate group). **Result**: The mean age of patients in Mg sulphate group was 46.11±11.89 years and most of them were males (67.5%) with average BMI 29.21±3.54.There was a significant difference between in postoperative period between Mg sulphate group and controlgroup without in the occipital (1,2) and temporal regions as regard absolute power of theta and alpha rhythms. **Conclusion**: This study concluded that there was a significant effect of Mg sulphate on the EEG in the form of increased absolute power of theta and alpha rhythms in the occipital (1,2) and temporal regions.

1. Introduction:

Magnesium sulphate has been studied as an effective adjuvant during anesthesia and postoperative analgesia after its usage perioperatively was demonstrated to reduce postoperative analgesic needs by Tramer and colleagues.[(1)]. Magnesium's analgesic impact has a mysterious mechanism, but we do know that it works by blocking NMDA receptors, which are involved in the development and maintenance of brain sensitization to nociceptive stimuli.[(2,3)].

Electroencephalogram (EEG) is a sensing tool used to assess and explore pain and brain dysfunction; it does so by monitoring electrical activity using electrodes implanted on the scalp, which subsequently record electrical impulses emanating from the brain. Different types of machine learning algorithms are used on computers to extract meaningful EEG characteristics from a variety of patient states and their corresponding EEG responses [(4)]

Visually examining EEG data, where the rhythms' amplitudes and frequencies reflect the patient's present state and circumstances, is used to identify brain-related disorders. Synaptic potentials created by activity of cortical neurons are crucial to the synchronization of the waves that make up EEG rhythms. They describe five types of brain waves, which fall into distinct high- and low-frequency groups. Alpha (), beta (), delta (), gamma (), and theta () are the names given to the corresponding frequency ranges and associated activities [(5)]

In a condition of calm, alert relaxation, the brain produces alpha waves. When eyes are closed eyes, the visual area produces no pattern, yet alpha rhythms are still there. They also show that the waves manifest in the brain's dorsal hemisphere, indicating that they originate in the occipital cortex. When the rhythm is formed when the patient is in an alert and active cognitive state, Beta waves are present. During periods of intense motor stimulation, rhythmic beta activity in the frontal cortex of the brain may be suppressed. [6]

Gamma waves and other high-frequency EEG signals originate in the frontal cortex and are generated during the simultaneous processing of several stimuli or states of intense focus and concentration. Although the delta waves are most prominent during sleep, they may also be seen during wakefulness. The thalamic region is linked to the theta rhythm, which manifests during sleep, sleepiness, and, when mixed with other frequencies, after preexisting stimulation [7].

Magnesium is a crucial mineral that plays a role in controlling energy production and membrane ion transport. Magnesium sulfate has been used to treat hypomagnesemia, preeclampsia, and polymorphic ventricular arrhythmia in addition to its anti-convulsive properties. Improvements in sedation and analgesia, reduced requirement for neuromuscular blocking medications, and protection against ischemic-reperfusion damage have all been associated to preoperative magnesium supplementation [8]

Recent results suggest that intraoperative magnesium may lessen postoperative agitation, further supporting magnesium's capacity to impact both pain relief and sedative level. Its effects on postoperative sedation and disorientation are, however, unclear[9]

The aim of this work was to evaluate the Electro-Encephalogram changes after intraoperative Magnesium sulphate in patients undergoing lumbar fixation.

2. Patients and methods:

This prospective randomized controlled trial was carried out on 80 patients indicated for lumbar fixation. The selected patients were randomly assigned to one of the following two groups; the first group will receive conventional general anaesthesia only (40 participants) (control group), and the second group will receive conventional general anaesthesia with extra administration of intraoperative magnesium sulphate (40 participants) (Mg sulphate group).Randomization was carried out using a closed opaque envelope technique. The patients were recruited from the Neurosurgery department, Beni-Suef University Hospital, in the period from Jan 2022 to Jul 2022.

The study included patients undergoing lumbar fixation of both genders with ASA I and ASA II and their age ranged between 20 – 70 years. Patients with sleep apnea syndrome, history of chronic pain interfering with sleep, history of neurodegenerative diseases, history of psychiatric diseases, illicit drug abuse, patients using hypnotic, anxiolytic, or antipsychotic drugs, pregnancy and patients with any illness known to affect sleep were all excluded from the study.

Anaesthesia technique:

All eligible patients had an electrocardiogram and standard hematological and biochemical tests conducted prior to surgery. The patient's preoperative vitals (Heart rate, noninvasive blood pressure, and oxygen saturation) were recorded after an 18-gauge intravenous cannula was placed and IV crystalloid fluids were administered upon arrival at the operation room.

Patients were randomly assigned into two groups, both groups received an injection of fentanyl 2µg/kg, propofol 1.5-2.5 mg/kg, and atracurium 0.5 mg/kg to induce anesthesia and relax the muscles. Lidocaine jelly 2% was applied to the oral cuffed tube used for laryngoscopy and endotracheal intubation. Mg sulphate group received extraloading dosage of Magnesium sulphate 30 mg/kg over 10 minutes, followed by a maintenance dose of 10 mg/kg/h Sevoflorane (1-2%) and an O_2 and air combination were used for anesthesia maintenance (70%: 30%). The end-tidal partial pressure of carbon dioxide was artificially maintained in both groups at 35-45 mmHg using controlled ventilation.

The trachea was extubated when the patient responded to commands at the conclusion of surgery, neuromuscular blockade was reversed with IV neostigmine 0.04 mg/kg, and atropine 0.02 mg/kg. All patients were then transported to the post-anesthesia care unit (PACU), where they received oxygen via face mask at a rate of 3–4 L/min and were monitored.

The patients' hemodynamics, including BP and HR, SPO_2, and end-tidal CO_2, as well as the depth and length of their anesthesia, were constantly tracked and recorded every 15 minutes.

Neurophysiological assessment.

Electroencephalography (EEG) and Quantitative electroencephalography (QEEG) were done for all included patients before, and between 24 hours and 48 hours after surgery. EEG and QEEG were carried out in the Neuro Diagnostic & Research Center (NDRC), Beni-Suef University Hospital, using Nihon Kohden EEG Japan machine combined with Neuroguide QEEG software. EEG recording was carried out for 20 minutes in a quiet room while the subject is relaxed with their eyes closed for 5 minutes and opened for 5 minutes to insure a high arousal level. The EEG scalp electrodes were applied according to the international 10-20 system using an ear lobe electrode as a reference. The absolute power of 5 electrodes (CZ, T3, T4, T5, T6,) were studied in the following frequency bands: delta (0.5-3Hz), theta (4-7 Hz) and also the absolute power of (O1, O2) were studied in delta theta and alpha (8-12 Hz) bands.

Statistical analysis

Statistical Package for the Social Sciences, Version 22 was used for data coding and entry (SPSS v 22). Mean and standard deviation were used to describe the data, while counts and percentages were used to describe the categorical variables. The means of two sets of quantitative data were compared using the Student t-test. When comparing the means of two sets of quantitative variables that are known to be related to one another, the paired sample t-test was utilized. The category data were compared using the Chi-square test. P-values more than 0.05 are not statistically significant, but P-values less than 0.05 are considered significant.

Ethical consideration:

This study was conducted according to the declaration of Helsinki, all data was anonymous, and the study protocol was approved by the research ethics committee of faculty of Beni-Suef University No.FMBSUREC/09012022/Abd-Elsadek.

3. Results:

Demographic data of patients under the study (table 1):

The demographic data of patients in the study are shown below in table (1). There were no statistically significant differences between both groups in either age (P-value = 0.167), sex (P-value =0.813) or BMI (P-Value = 0.220). The mean age in Mg sulphate group was 46.11±11.89 years while in the control group was 42.20±10.41 years. Males represented 67.5% of Mg sulphate group and 65% in control group while females represented 32.5% and 35% in both groups respectively. The BMI was 29.21±3.54 in Mg sulphate group and 28.15±3.34 in the control group. The artifact-free EEG was converted from the time to the frequency domain via a fast Fourier transform (FFT). Data were averaged across the set of segments to yield measures of absolute power and power ratio in each band; delta (1.5–3.5 Hz), theta (3.5–7.5 Hz) and alpha (7.5–12.5 Hz) within the left and right hemispheres for frontal, fronto-centro-parietal, temporal, and occipital electrodes. There was significant difference between postoperative patientswith Mg sulphate and controls without Mg sulphate in the occipital (1,2) and temporal regions as regard absolute power of theta and alpha rhythms (Table1).

Explanation:Dominance of the occipital alpha power seems to be driven by a decrease in cortical and an increase in thalamic activity.The anatomical regions which displayed the most marked and reversible theta and alpha waves phenomena were occipital and the thalamus.

Table (1): Pre and post-operative neurophysiological assessment in both Mg sulphate and control groups

Quantitative EEG parameters		Preoperative assessment [mean (SD)]	Postoperative assessment [mean (SD)]	P-value	P- value between groups
Theta Abs Frontal7	Mg sulphate Group	5.86(2.89)	7.66(5.00)	0.159	0.272
	Control group	5.79 (2.81)	5.94 (2.71)	0.844	
Theta Abs Frontal 8	Mg sulphate Group	7.27 (4.27)	8.42 (4.63)	0.347	0.253
	Control Group	6.63 (1.87)	7.05 (2.54)	0.421	
Theta Abs Temporal3	Mg sulphate Group	4.58 (2.71)	7.22 (5.95)	0.036*	0.135
	Control Group	4.53 (2.27)	4.45 (2.32)	0.886	
Theta Abs Temporal4	Mg sulphate Group	4.74 (2.32)	9.90 (14.11)	0.112	0.123
	Control Group	4.21 (1.46)	5.27 (3.28)	0.111	
Theta Abs O1	Mg sulphate Group	5.31 (3.17)	10.61(14.60)	0.091	0.392
	Control Group	5.57 (2.27)	6.99 (7.63)	0.425	
Theta Abs O2	Mg sulphate Group	6.32 (3.97)	13.97(18.26)	0.063	0.071
	Control Group	5.83 (2.48)	6.31 (3.35)	0.491	
Theta Abs frontal (Fz)	Mg sulphate Group	6.22 (4.48)	7.25 (4.83)	0.457	0.936
	Control Group	7.05 (6.79)	6.68 (6.08)	0.584	
Theta Abs central (Cz),	Mg sulphate Group	2.83(1.45)	3.15(1.55)	0.447	0.412
	Control Group	3.05 (3.00)	2.21 (1.13)	0.248	
Theta Abs parietal (Pz)	Mg sulphate Group	3.01(2.00)	4.87(6.02)	0.137	0.324
	Control Group	3.37(2.84)	2.81 (1.73)	0.438	
Alpha Abs Frontal 7	Mg sulphate Group	4.77(3.24)	6.40(5.53)	0.164	0.098
	Control Group	4.23(3.32)	3.77 (1.60)	0.468	
Alpha Abs Frontal8	Mg sulphate Group	5.14(3.07)	7.28(6.44)	0.090	0.140
	Control Group	4.76(2.73)	4.62 (2.16)	0.823	

Alpha Abs Temporal3	Mg sulphate Group	4.64 (3.36)	7.49 (8.82)	0.116	0.242
	Control Group	5.10(6.86)	3.66 (2.24)	0.341	
Alpha Abs Temporal4	Mg sulphate Group	4.93(3.50)	11.56(16.48)	0.080	0.047
	Control Group	4.10 (3.21)	4.38 (2.72)	0.718	
AlphaAbs occipital (O1)	Mg sulphate Group	7.60(7.52)	16.29(20.12)	0.048*	0.407
	Control Group	9.36 (10.94)	9.32 (11.14)	0.991	
Alpha Abs occipital (O2)	Mg sulphate Group	9.11 (7.34)	22.39(25.99)	0.030*	0.063
	Control Group	9.56 (13.51)	8.15 (7.78)	0.637	
Alpha Abs frontal (Fz)	Mg sulphate Group	3.95(3.54)	6.51 (6.17)	0.059	0.054
	Control Group	3.52 (2.52)	3.14 (1.95)	0.574	
Alpha Abs central (Cz),	Mg sulphate Group	2.34(1.89)	3.00 (2.39)	0.125	0.085
	Control Group	2.08(1.44)	1.60 (1.22)	0.217	
Alpha Abs parietal (Pz)	Mg sulphate Grou	3.59(3.12)	6.00(6.81)	0.132	0.406
	Control Group	4.03(5.07)	3.61 (5.10)	0.789	

Abs: Absolute values *P-value is significant

4. Discussion:

It was recently found that greater delta and theta power in the EEG corresponds with increasing delirium severity after surgery, confirming what has been known for decades from electrophysiological studies: that the EEG slows and rises in amplitude in delirium. These cortical dynamics changed with plasma cytokines and were linked to decreased connection, suggesting an inflammatory mechanism for delirium [(10)]

The EEG displays the integrated postsynaptic potential of the brain's cortex. Therefore, delta power fluctuates throughout sleep and anesthesia in direct correlation with the amount of grey matter present. However, new evidence suggests that weaker EEG power corresponds with neurodegenerative indicators in the brain's structure, blood, and cerebrospinal fluid [(11)]

This study was conducted at Beni-Suef University Hospital to evaluate the effect of intraoperative administration of Magnesium sulphate on Electro-Encephalogramin patients undergoing lumber fixation. The mean age of patients in Mg sulphate group was 46.11±11.89 years and most of them were males (67.5%) with average BMI 29.21±3.54. There was no statistically significant difference between both groups in either age, sex or BMI.

The main findings of this study werea significant difference between postoperative patient with Mg sulphate and control grop in the occipital (1,2) and temporal regions as regard absolute power of theta and alpha rhythms.Dominance of the occipital alpha power seems to be driven by a decrease in cortical and an increase in thalamic activity. The anatomical regions which displayed the most marked and reversible theta and alpha waves phenomena were occipital and the thalamus.

This agreed with the findings of a cohort study on postoperative delirium conducted by Tanabe and colleagues. They found that higher levels of EEG delta and theta activity correspond with more severe postoperative delirium [12]

The role of the Thalamus in cognition is vastly underappreciated. The thalamus and its connections to the cortex are essential for a wide variety of cognitive processes [13]

Researchers Moran et al. showed that theta oscillations in the local field potential of neuronal ensembles are important mediators of human working memory by looking at the peak frequency in the theta and alpha bands. The ability to store and manipulate information temporarily in a place called working memory (WM) is seen as a crucial cognitive resource for the efficient pursuit of immediate tasks [14]

The amount of mental effort necessary to pay attention to and comprehend an auditory message has been described in several papers as being reflected in increases in theta and alpha power [15, 16, 17].

Recent theoretical work in cognitive neuroscience implies that increases in alpha-power represent functional regulation of unattended inputs or task-irrelevant brain areas, while frontal-midline theta dynamics have been frequently linked to working memory and cognitive control processes [18]

Patients without delirium showed spectral peaks centered primarily in the theta (6-8 Hz) and alpha (8-10 Hz) frequency bands when their eyes were closed during a state of wakefulness, as determined by an evaluation of the electroencephalogram's spectral features and its relationship to the severity of postoperative delirium conducted by Guay et al. [19].

Sleep EEG oscillations have been linked to thalamic activity, according to a number of lines of evidence. They are first and foremost rhythmically regulated by thalamic activity. In addition, the reticular thalamus, which is thought to primarily govern the activity of thalamocortical cells, plays a vital role in the development of sleep spindles across the whole thalamocortical system. Some research points to the thalamus as a possible regulator of alpha and theta waves [20].

Since magnesium influences the limbic-hypothalamic-pituitary-adrenocortical axis, Eby and colleagues concluded that magnesium plays a substantial role in the recovery from severe depression by examining the sleep-electroencephalogram (EEG), which revealed the participation of the axis [21]

Additionally, Mg^{2+} deficiencies cause sleep abnormalities characterized by increased alertness as identified by EEG, as shown in research by Held et al. on the impact of oral Mg on sleep EEG in people [22]

Despite the lack of understanding of its mechanism, magnesium has been found to reduce postoperative delirium and sleeplessness. Magnesium sulfate acts as a non-competitive NMDA receptor antagonist and reduces pain by preventing calcium ions from entering cells. Magnesium sulfate administered intravenously reduces brain lactate concentrations and reduces electroencephalographic (EEG) changes caused by cerebral ischemia. Delirium may have been lessened by magnesium's ability to protect the brain from the potentially fatal effects of hypotension and other factors for a considerable length of time [23].

5. Conclusion:

This study concluded that there was a significant effect of Mg sulphate on the EEG in the form of increased absolute power of theta and alpha rhythms in the occipital (1,2) and temporal regions.

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