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ORIGINAL RESEARCH

Absolute Spectral Power (PSA) analysis of EEG waves in patients with Temporal lobe epileptic seizures

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ABSTRACT

Background: Many factors underlying basic epileptic conditions determine the characteristics of epileptic seizures and the therapeutic outcome. Visual obvious abnormalities in resting baseline EEG are cardinal but incompletely understood like feature of seizure onset zone in focal epilepsy and interictal epileptiform discharge. Present study is an attempt to diagnose that evidence of epileptic discharge in temporal lobe epilepsy (TLE), would persist during interictal period in absence of abnormalities in baseline EEG, which could increase the impact of automatic analysis of EEG waves for clinical relevance. **Material and Method:** Functional connectivity was estimated in the 20 channels of delta, theta, alpha, beta and gamma frequency bands of EEG by using 10-20 system, from 16 diagnosed focal epileptic seizure patients and 16 age and sex matched controls. During eye open session of EEG, observe the dynamics of the healthy brain, differ from the brain of dynamically focal epileptic patients during interictal period. Such differences can be observed by using absolute spectral power from BESS (Brain Electro Scan Software) of the Axxonet System and statistically measure by applied unpaired student t -test. **Results:** The high significance results found in slow frequency EEG theta wave and high frequency wave alpha and beta waves of EEG in power spectral analysis were observed that demonstrates the potential epileptic discharge occurring during interictal period without visible pathological activity for helping in the diagnosis and lateralization of TLE. **Conclusion:** This linear analysis helpful in extracting information from EEG signals in diagnosing specific neuronal correlates for TLE. Present findings concluded that epileptic discharges occur at different topographical regions of brain during interictal period and power spectral analysis plays a new insight in diagnosis of focal discharge. The detailed spectral analysis of EEG waves offers novel insight into focal epileptic patients when visually EEG findings were normal.

Key Words: Epileptic seizures, Linear analysis, Absolute Spectral power

INTRODUCTION

Epilepsy is one of the most common human brain disorders. It is often accompanied by disturbances in behavior, brain dysfunction, and cognitive impairment. According to the World Health Organization, 0.7% to 1% of the world's population suffer from epilepsy and this generally peaks in childhood and advanced age, meaning that a large proportion of patients have this chronic disease for most of their lives (Olesen J et al, 2006). Focal epilepsy originates in the medial or lateral aspect of temporal lobe of brain, mainly from mesial- basal temporal lobe including hippocampus, amygdale and Para hippocampal gyrus (Laufs H, 2012) Various parametric (Gath I,1992) and nonparametric (Jerger KK et al,2012) techniques have been applied to the analysis of epilepsy. When analysing EEG signals in the time domain, abnormal patterns such as spikes and sharp waves are detected; while in the frequency domain, features from the power spectrum are extracted (Willoughby JO et al, 2003). Jerger et al have also focussed on interictal spike patterns to predict and ultimately control seizure activity ((Jerger KK et al,2012). A systematic calculation of linear correlation allowed the possibility of extracting information on how the EEG signals across different regions are related. This together with known clinical history can aid in identifying the epileptic focus and provide further insight on seizure dynamics.

High-density scalp EEG revealed interictal network patterns concordant with cognitive deficits in TLE (Coito A et al, 2015) and significant connectivity differences in TLE compared to healthy controls in the absence of interictal spikes (Coito A et al, 2016).

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Machine learning algorithms have been used for automatic detection and localization of the epileptogenic zone in TLE using a multitude of imaging modalities. (Focke NK et al 2012;Kamiya K et al,2016)

This study is an attempt automatically diagnoses and lateralizes TLE based on EEG without visible pathological activity during interictal period.

MATERIAL AND METHOD

The present study was conducted to propose the biomedical importance in diagnostic field of complex partial epileptic patients. The study was approved by the Institutional Ethical Committee. The sample size required is 16 in each group (case and control) at 95% confidence and 80% power to verify the expected minimum difference of 0.66 [± 0.64] mean working memory task score of temporal lobe epileptic cases and age and sex matched healthy controls. Sample size of patients is obtained by OPD based random sampling technique. Temporal lobe epileptic (TLE) patients who are seizure free from last one year (interictal period) and are treated by AED (Anti-Epileptic Drugs) were included. The study included confirmed patients of temporal lobe epilepsy that undergo temporal lobe MR Protocol of the brain and Electroencephalography. Detailed clinical and family history of epilepsy and consent was taken. The present study is a hospital based, observational comparative case control study that included 16 patients of temporal lobe epilepsy (diagnosed on the basis of Magnetic Resonance (MR) Protocol and Electroencephalography findings) taken from the outdoor of Departments of Neurology and Medicine.

Inclusion Criteria adopted for the present: Age between 20 – 30 years, with epilepsy satisfying the guidelines lay down by the International League Epilepsy Society, during the interictal period of epilepsy. In the present study 12 out of 16 patients suffering from complex partial seizures, no significant changes were found in MRI.

Exclusion Criteria for the study was with known contraindications to Temporal Lobe MR Protocol epilepsy or any previously diagnosed non central nervous system disorders liable to cause seizures, syncope and hypoglycemic attacks, pseudo- seizures or drug induced seizures. Patients with malignanc previous craniotomy or cervical spine surgery or head injury.

EEG recording

In the present study, 21 channels scalp electroencephalography times series at tracing was acquired as further norms of International 10-20 system with biauricular reference (Jeger KK, 2006)

EEG was recorded from frontal (Fz/ Fp1/ Fp2, F3/ F4, F7/F8), temporal (T3/T4/T5, T6), central (C3/C4/ Cz), parietal (P3/P4/Pz) and occipital (O1/O2/Oz) regions of brain for detection of any epileptic discharge in brain during eye open session of EEG.

Data Acquisition: The following parameters were observed and evaluated: Absolute power of delta (0.2-3.9 Hz),theta(4.0-7.9Hz),alph(8.0-12.9Hz),beta 13.0-30.0 Hz) and gamma bands (30.1-80 Hz) of EEG wave‟s frequency was calculated. The EEG recordings were run for 5 minutes during interictal period in complex partial seizure patients and in healthy controls with the subjects at rest with eye open session. EEG data were offline re-referenced to common average reference and filtered between 0.5 to 30 Hz to remove possible high frequency noise.

Absolute Power: This is a frequency domain measure obtained after applying Fast Fourier Transform (Linear Transform) to time series EEG signals. The algorithm for above linear transformation is inbuilt in the BESS (Brain Electro Scan Software) of the Axxonet System in Neurophysiology Lab of Department of Physiology.

Statistical Analysis: The Microsoft excel 2010 was used for statistically analysis of recorded data. The unpaired t-test was used for the mean comparison of all parameters between patients and control subjects and considered two-sided p values < 0.05 to be significant

OBSERVATION AND RESULTS

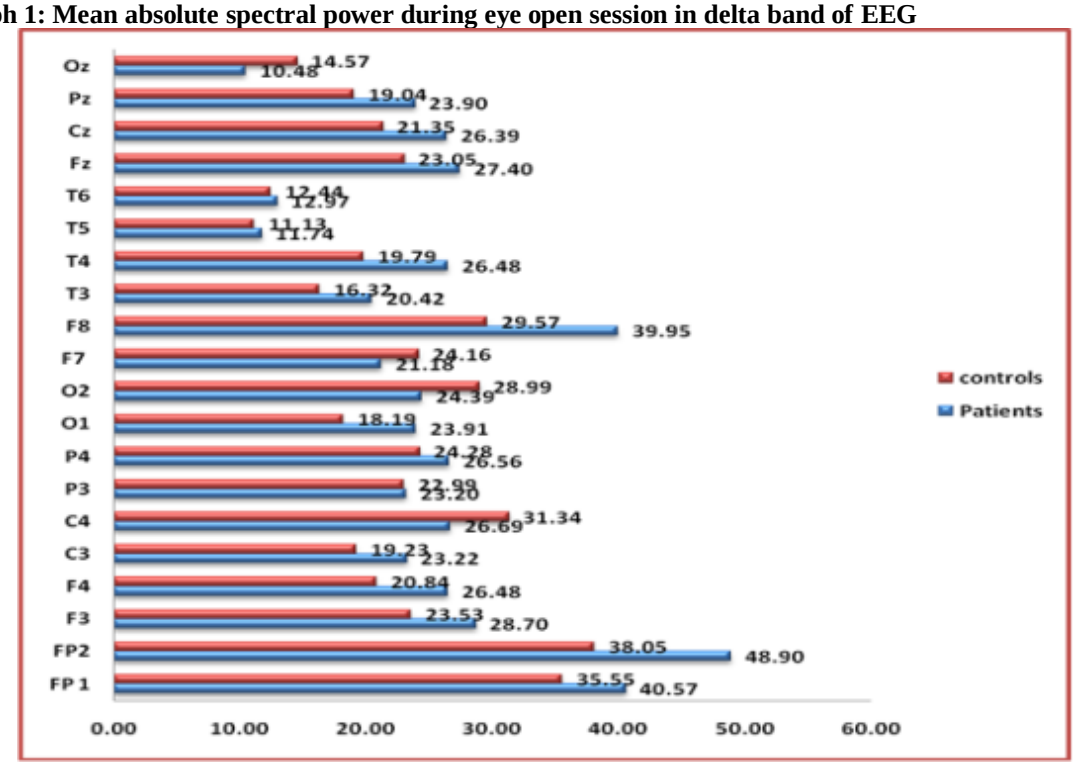
Table 1: Mean absolute spectral power during eye open session in EEG in delta band

Channels	Patients	Controls	p value
	Mean (SD)	Mean (SD)	
FP 1	40.566(11.2)	35.545(22.89)	0.437
FP2	48.89(19.02)	38.051(25.68)	0.185
F3	28.695(8.923)	23.531(10.896)	0.153
F4	26.480(11.29)	20.843(28.34)	0.466
C3	23.223(10.07)	19.22(8.61)	0.238
C4	26.685(9.96)	31.33(31.463)	0.579
P3	23.201(8.975)	22.98(15.415)	0.962
P4	26.56(8.99)	24.280(21.9)	0.703
O1	23.906(9.77)	18.186(8.16)	0.082
O2	24.387(10.92)	28.988(42.56)	0.678

DOI: 10.69605/ijlbpr_13.6.2024.56

F7	21.18(10.74)	24.155(11.587)	0.457
F8	39.9(11.9)	29.6(14.9)	**0.038***
T3	20.423(10.48)	16.316(8.99)	0.244
T4	26.5(9.07)	19.8(8.93)	**0.044***
T5	11.735(4.312)	11.12(4.24)	0.691
T6	12.9(4.91)	12.442(4.84)	0.761
Fz	27.40(7.65)	23.050(10.077)	0.179
Cz	26.39(10.43)	21.351(8.77)	0.149
Pz	23.90(8.69)	19.044(7.593	0.103
Oz	10.45(4.22)	14.568(12.455)	0.224

Graph 1: Mean absolute spectral power during eye open session in delta band of EEG



Absolute spectral power analysis results

Eye open session: During eye open session of EEG, the significant difference of mean absolute power was observed in F8 (p= 0.04) and T4 (p= 0.04) channels in delta band of EEG in patients of temporal lobe epilepsy when compare with that of healthy control population(**Table: 1, Graph 1**)

Table 2: Mean absolute spectral power during eye open session in EEG channels in theta band

Channels	Patients	Controls	p value
	Mean (SD)	Mean (SD)	
FP 1	15.460(4.131)	12.353(5.321)	0.075
FP2	17.3(5.14)	12.6(4.84)	**0.012***
F3	12.8(4.56)	9.71(2.9)	**0.030***
F4	10.81(5.715)	6.840(8.815)	0.141
C3	11.97(5.35)	9.226(3.57)	0.099
C4	13.293(5.25)	10.215(7.09)	0.173
P3	11.6(4.12)	8.69(2.87)	**0.026***
P4	14.1(3.86)	10.4(5.46)	**0.038***
O1	13.208(4.55)	8.971(2.51)	**0.003***
O2	12.581(5.55)	12.95(13.76)	0.920
F7	7.066(3.83)	8.84(2.28)	0.121
F8	14.53(4.134)	10.185(3.131)	**0.002***
T3	10.9(4.94)	7.63(2.5)	**0.025***
T4	13.21(4.24)	8.271(2.44)	**0.000***

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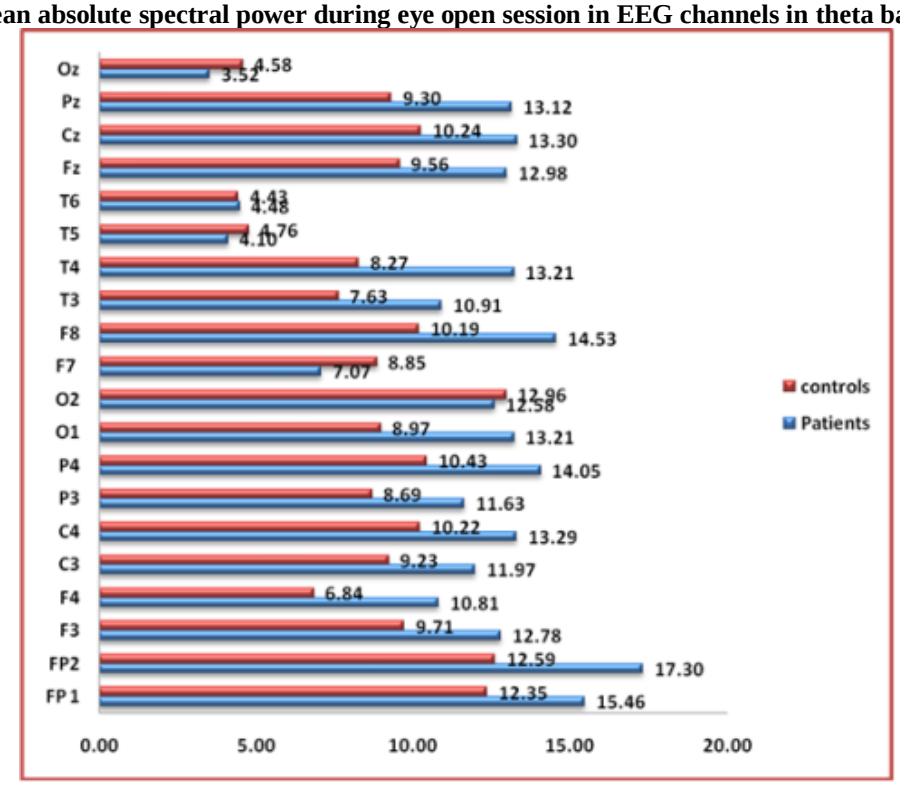
T5	4.10(1.64)	4.764(2.507)	0.386
T6	4.48(1.830)	4.432(1.971)	0.941
Fz	12.981(3.653)	9.56(2.098)	**0.003***
Cz	13.298(5.469)	10.241(3.493)	0.069
Pz	13.1(4.23)	9.3(2.96)	**0.006***
Oz	3.518(1.722)	4.584(2.516)	0.172

Graph 2: Mean absolute spectral power during eye open session in EEG channels in theta bands



Absolute spectral power analysis results

Eye open session: In theta band of EEG the significant difference was observed in FP2 (p= 0.01), F3 (p= 0.03), P3 (p= 0.03), P4 (p= 0.04),O1 (p= 0.003), F8 (p=0.002), T4 (p= 0.000), FZ (p= 0.003), T3 (p= 0.02) and PZ (p= 0.01) channels of EEG in patients of temporal lobe epilepsy when compare with that of healthy control population(**Table: 2, Graph 2**)

Table 3: Mean absolute spectral power of EEG channels during eye open session in alpha band

Channels	Patients	Controls	p value
	Mean (SD)	Mean (SD)	
FP 1	8.53(2.73)	6.59(2.5)	**0.045***
FP2	9.72(3.26)	7.02(2.69)	**0.016***
F3	7.71(3.28)	5.69(2.23)	**0.050***
F4	6.514(3.655)	4.331(5.666)	0.205
C3	7.57(3.79)	5.725(2.885)	0.132
C4	8.123(3.599)	6.254(3.790)	0.163
P3	7.686(3.084)	6.263(3.729)	0.249
P4	9.284(2.81)	7.17(4.121)	0.101
O1	9.254(3.054)	7.179(3.11)	0.067
O2	8.916(3.784)	9.27(8.70)	0.880
F7	4.446(2.74)	5.049(1.72)	0.462
F8	8.855(2.835)	6.041(2.268)	**0.004***
T3	6.74(3.33)	4.48(1.37)	**0.017***
T4	8.35(2.95)	5.48(2.46)	**0.006***
T5	2.665(1.220)	3.550(2.828)	0.260
T6	2.90(1.358)	3.430(2.304)	0.437
Fz	7.68(2.57)	5.74(2.5)	**0.038***

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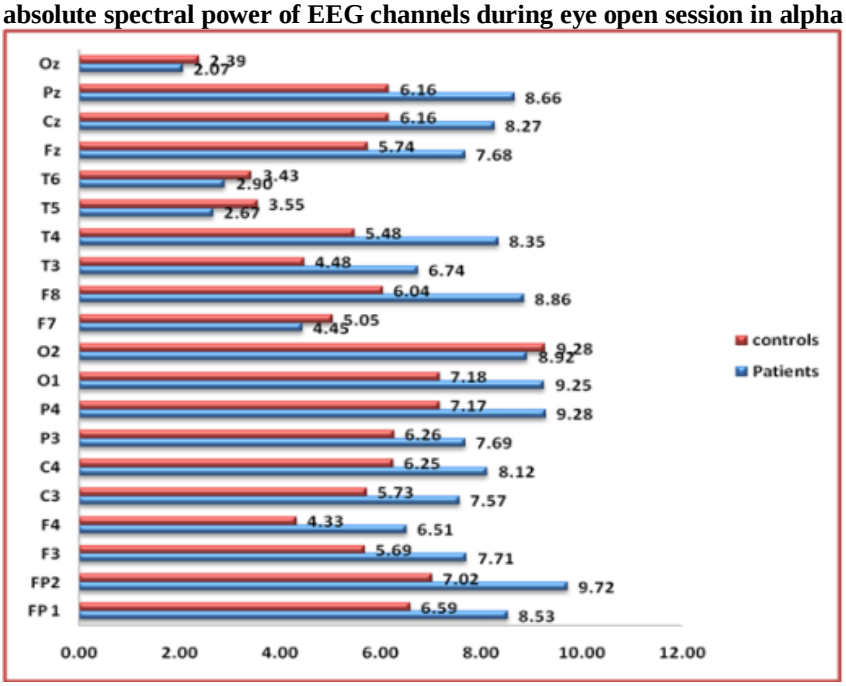
Cz	8.268(6.162)	6.162(2.894)	0.092
Pz	8.66(2.86)	6.16(3.09)	**0.024***
Oz	2.07191.175)	2.388(1.772)	0.555

Graph 3: Mean absolute spectral power of EEG channels during eye open session in alpha band



Absolute spectral power analysis results

Eye open session: The significant difference of mean absolute power was observed in FP1 (p= 0.04), FP2 (p= 0.02), F3 (p= 0.05), F8 (p= 0.004), T3 (p= 0.02), T4 (p= 0.006), FZ (p= 0.04) and PZ (p= 0.02) channels in alpha band of EEG in patients of temporal lobe epilepsy when compare with that of healthy control population (**Table: 3, Graph 3**)

Table 4: Mean absolute spectral power of EEG channels during eye open session in beta band of EEG

Channels	Patients	Controls	p value
	Mean (SD)	Mean (SD)	
FP 1	6.59(4.11)	11.5(3.18)	**0.005***
FP2	13.8(11.7)	8.5(5.5)	**0.003***
F3	10.9(9.89)	6.35(2.03)	**0.002***
F4	9.103(5.087)	9.341(6.298)	0.061
C3	9.82(4.83)	5.86(1.95)	**0.005***
C4	10.178(4.741)	7.458(5.853)	0.159
P3	9(4.17)	6.03(3.37)	**0.034***
P4	10.7(4.02)	7.02(5.02)	**0.028***
O1	10.5(4.2)	5.95(1.78)	**0.000***
O2	9.964(4.69)	8.65(10.70)	0.658
F7	6.596(3.891)	6.27(2.233)	0.773
F8	12.6(4.68)	7.41(2.64)	**0.001***
T3	9.49(4.71)	5.41(1.8)	**0.003***
T4	11.3(4.37)	6.43(1.82)	**0.000***
T5	3.863(1.327)	3.306(1.271)	0.235
T6	4.253(1.378)	3.350(1.28)	0.065
Fz	10.4(3.89)	6.08(1.77)	**0.000***
Cz	10.7(5.11)	6.19(1.93)	**0.003***
Pz	9.91(3.82)	5.7(1.65)	**0.000***
Oz	3.46(1.611)	3.471(2.582)	0.991

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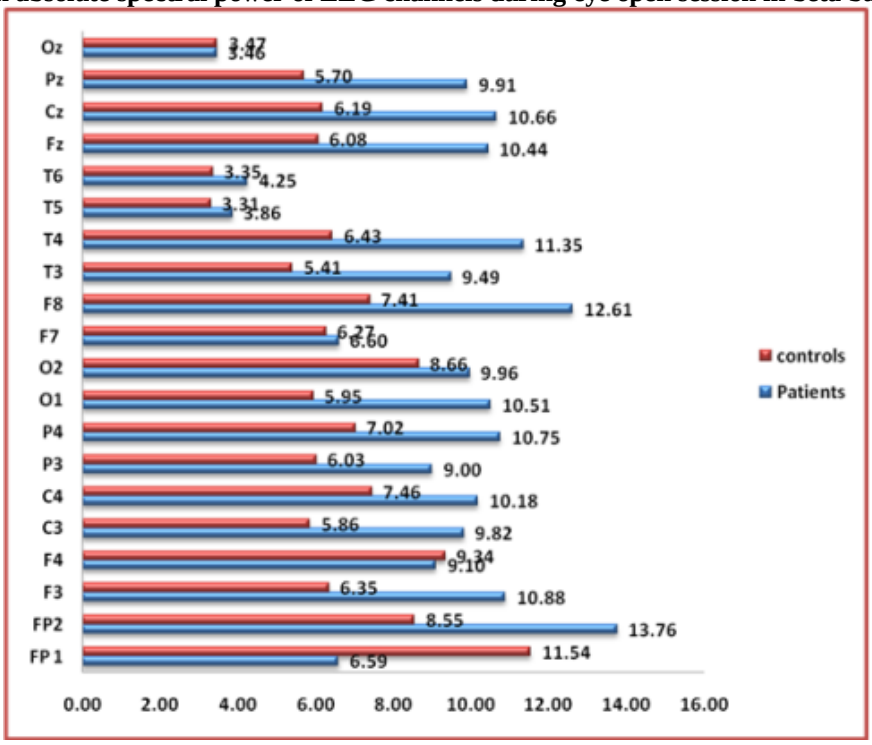
Graph 4: Mean absolute spectral power of EEG channels during eye open session in beta band of EEG



Absolute spectral power analysis results

Eye open session: In beta band of EEG the significant difference mean absolute spectral power was observed in FP1 (p= 0.005), FP2(p=0.003),F3 (p= 0.002), C3 (p= 0.005), P3 (p= 0.034), P4 (p= 0.028), O1 (p= 0.0004), F8 (p= 0.0005), T3 (p= 0.003), T4 (p= 0.0003), FZ (p= 0.0003), CZ (p= 0.003), PZ (p= 0.0003) channels of EEG in patients of temporal lobe epilepsy when compare with that of healthy control population(**Table:4, Graph 4**).

Table 5: Mean absolute spectral power of EEG channels during eye open session in gamma band

Channels	Patients	Controls	p value
	Mean (SD)	Mean (SD)	
FP 1	9.429(3.99)	7.280(4.025)	0.140
FP2	12.6(6.46)	8.42(4.81)	**0.045***
F3	8.475(4.970)	5.788(2.59)	0.065
F4	7.60(4.732)	5.47(6.927)	0.317
C3	7.31(4.93)	5.040(2.210)	0.103
C4	7.985(4.985)	7.553(7.315)	0.846
P3	7.195(4.640)	5.854(4.473)	0.412
P4	8.801(4.116)	6.374(6.358)	0.210
O1	7.53(4.77)	4.83(2.15)	**0.048***
O2	7.478(5.021)	7.602(10.961)	0.968
F7	5.985(4.221)	5.871(2.859)	0.929
F8	11.3(5.38)	7.06(3.29)	**0.011***
T3	7.12(4.86)	4.37(2.27)	**0.049***
T4	8.61(4.83)	5.07(2.45)	**0.014***
T5	3.374(1.712)	2.98(1.032)	0.447
T6	3.611(1.78)	3.182(1.152)	0.425
Fz	7.95(4.34)	5.45(2.19)	**0.048***
Cz	7.931(5.053)	5.32(2.269)	0.069
Pz	7.34(4.5)	4.85(1.96)	0.052
Oz	3.19(1.885)	3.99(3.153)	0.386

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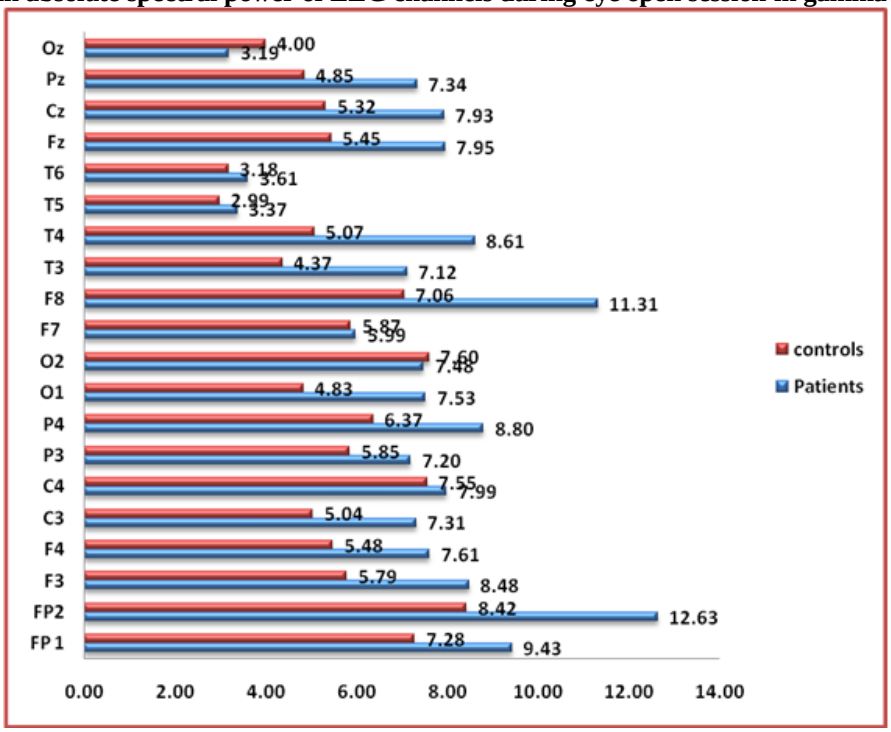
Graph 5: Mean absolute spectral power of EEG channels during eye open session in gamma band



Absolute spectral power analysis results

Eye open session: The significant difference mean absolute spectral power of gamma band of EEG was significant observed in FP2 (p= 0.05), O1 (p= 0.05), F8 (p= 0.01), T3 (p=0.05), T4 (p= 0.01) and FZ (p= 0.05) channels of EEG in patients of temporal lobe epilepsy when compare with that of healthy control population**(Table: 5, Graph 5)**

DISCUSSION

The present study design was undertaken to evaluate EEG changes in temporal lobe epileptic patients suffering from complex partial seizures, as compared to that of healthy controls. The EEG recording was run during the interictal period (period between ictal and post ictal) with the subjects during eye open The significant difference was observed in TLE patients suffering from focal seizures. The results of power spectral analysis of different EEG waves (Delta, Theta, Alpha, Beta and Gamma) observed highly significant results mainly in low frequency wave mainly theta and high frequency wave beta during eye open session.

Power Spectral Density (PSD) in low frequency EEG waves in focal epileptic patients (theta) – According to our finding's delta wave was observed significant at frontal (FP1, FP2, F8, Fz), occipital (O2), central (Cz). No significant changes were observed at temporal regions of focal epileptic patients then controls. Theta wave of EEG was found more significant when compare to delta. Over 16 channels out of 20 were observed significant in focal epileptic patients in which topographically temporal regions was found maximum epileptic discharge (T3, T4, and T5). While other topographic regions like frontal (FP1, FP2, F3, F8, Fz), central (C4, Cz), parietal (P3, P4, Pz) and occipital (O1, O2, Oz) also showed significant results in TLE patients during interictal period then controls. Our findings are similar to some studies that we observed significant results by using Power spectral analysis (PSD) of EEG waves between focal patients who are on anti-epileptic drugs then controls. Several studies (Clemens et al, 2000; Dauw L et al, 2010; Sunder et al, 2012) have reported enhanced θ power in children with epilepsy, with and without medication in comparison to controls. It has been shown that the increased theta power in some cerebral regions is more pronounced in epileptic patients taking anti-epileptic drugs during eye closed sessions of electroencephalography (Bela et al, 2007; Clemens B et al,2006) This paper highlights the general information regarding the use of scalp EEG in TLE, EEG patterns resembling epileptiform discharges, and the interictal findings in mesial temporal lobe epilepsy. The utility of the automated seizure detection and computerized mathematical models increasing yield of non-invasive localization In presurgical evaluation of patients with TLE, the identification of seizure focus is the most important prerequisite for surgery (Kikumoto et al, 2006; Sadler M et al, 2000; Jan et al, 2010).The spectral content was evaluated by means of Fast Fourier Transform (FFT) analysis as per norms (Hughes and John, 1999) and mean absolute power values were calculated accordingly. The present study was so designed to get an insight into neural dynamics during the interictal phase of temporal lobe epileptic patients that could act as a window into the disease process of temporal lobe epilepsy. The present study was undertaken to assess

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the underlying operational architectonics of temporal lobe epileptic patients during manuvers of eye open

It was also observed during eye open session in the present study that an increase in PSD in the beta band zone (high frequency band) frequency was profiled in TLE patients (when compared to that of control healthy population), a finding that is not in accordance with the results of Quraan et al (2013) who documented an increase in PSD only in the alpha band frequency in fronto-central region of brain. In present study mean absolute spectral power was observed to be increased in lower frequency band zone of theta waves, an observation that is similar to the findings of Clemens et al (2012) who documented in the regions of fronto-central parieto occipital areas of brain. Drake et al (1998) also demonstrated that temporal lobe epileptic patients with abnormal interictal EEG had decreased ratio of PSD in the high frequency wave zone to low frequency wave zone across the EEG leads in fronto-central and parieto-occipital region of brain.

Adebimpe et al (2015) found significant differences in terms of both spectral power and cortical source densities between controls and patients. Patients were characterized by significantly increased absolute spectral power in θ, α, β_1 and β_2 bands in the right centrotemporal areas over the spike zone and in the right temporo-parieto-occipital junction, a finding that has also been replicated in the present study. This observation is consistent with results from other studies conducted on Temporal Lobe Epileptic patients (TLE). Several studies (Clemens, 2004; Clemens et al, 2000) have reported enhanced θ power in children with epilepsy with and without medication in comparison to controls (Clemens et al, 2010). However, it has been shown that the increased theta power in some cerebral regions is more pronounced in epileptic patients taking anti-epileptic drugs (Béla et al, 2007; Clemens, 2008; Clemens et al, 2006; Kikumoto et al, 2006) during eye closed and eye open sessions of electroencephalography. The human brain is a vast network of connected pathways that communicate through synchronized electric brain activity along fiber tracts. The synchronized activity within this neuronal network can be detected by MEG and EEG then imaged using network connectivity analysis. Connectivity analyses of the brain are performed to map out the communication networks needed for the brain to function. Our findings are in accordance with above studies.

CONCLUSION

The application of linear analysis for detection of interictal discharge of epileptogenesis allowed obtaining information on scale free properties and modularity, which improve our understanding on brain mechanisms at the systems levels and the dysfunction in neurological diseases. Dynamical analysis of EEG recordings from patients with epilepsy has provided novel perspectives regarding epileptogenesis. In this light, linear analysis seems to be a potentially sensitive instrumentation marker of temporal lobe epilepsy (TLE) and needs to be clinically validated through replication in more such numerous and independent patient cohorts.

LIMITATIONS

The sample was small though the algorithm so proposed and designed in the present study needs to further tested and validated in the field for confirmation of the final outcome and the conclusion of the signature of the disease process that has been so underscore and highlighted in the present study.

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