Early Detection of Mild Cognitive Impairment, Dementia and Alzheimer's Using qEEG

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Abstract

This article reports the biomarkers of the Mild Cognitive Impairment (MCI) among the elderly group aged around 60 -75 years old by analyzing the EEG signals recorded by using the quantitative electroencephalograph (qEEG). There is growing evidence that EEG analysis in resting state condition are useful in early detection of neural signatures of Alzheimer's and dementia. EEG findings and analysis shows potential of discriminating MCI, Alzheimer's and dementia. In this research, the purpose is to 1) develop the indexes for each of the EEG bands and sub-bands such as delta (1.5 – 3.5 Hz), theta (3.3 – 7.5 Hz), alpha (8 – 12 Hz), beta 1 (15 – 18 Hz) and beta 2 (22 – 30 Hz); 2) provide reference for early diagnosis; 3) extract and analyze the brainwave pattern of MCI and cognitively healthy group. This study involved 19 channel resting state EEG from a total of 30 subjects, 18 diagnosed as having MCI and 12 cognitively healthy elderly with criteria for inclusion if the mini mental state examination (MMSE) score is more than or equal to 28, based on the age and educational level. Development of qEEG index started by decomposition of EEG by performing Fourier analysis, averaging and normalizing the value from the 19 channels to obtain the z-score. Findings showed promise of utility in early detection of Alzheimer's. Notably, 1) Increases in delta/ theta posterior temporal and prefrontal area i.e., H(6.64) vs. MCI(26.29); beta temporal region, 2) Decreases in alpha at sensory motor region i.e., H(0.27) vs. MCI(0.23).

Keywords: Mild cognitive Impairment, qEEG, Alzheimers

1. Introduction

Early detection of MCI can help in slowing down the memory loss and can maximize the efficacy of treatment in future (Milwain, E. (2000)). Burns and Zaudig (2002) defined MCI as a transitional stage between normal ageing and dementia, and reflect the clinical situations where a person has memory complaints and objective evidence of cognitive impairment but no evidence of dementia. MCI is important in terms of recognising memory loss among the elderly as well as identifying a group of individuals at high risk of developing dementia and who may benefit from preventive strategies.

There is evidence in electroencephalography that alpha, theta and delta band oscillations reflect cognitive and memory performances. The most usual EEG findings are the displacement of background frequency into delta and theta ranges and the decrease or dropout of alpha central frequency (Klass & Brenner, 1995). Pucci et.al (1999) proposed the "alpha" rhythm as a diagnostic AD marker as there is a decrease in the alpha frequency to 6.0-8.0 Hz in mild AD patients. However, none of the research provides a reliable indexes for each of the band as a basis of comparison from the cognitively healthy normals. It is necessary to develop the indexes for each of the EEG bands to indicate the level of cognitive impairment and memory loss among the elderly group.

The main idea of the study is to develop an index as a reference between MCI and cognitively healthy elderly. This study will benefit most to the community as it is a practical contribution to the early detection of cognitive deficit and slowing down the progress of Alzheimers In addition, this is a feasible study- community approached. Therefore, the first aim of this study is to develop an index for each EEG band and sub-band, i.e. alpha, beta 1, beta 2, delta and theta. The second aim is to provide the reference for earlier diagnosis of Alzheimer's diseases and basis comparison to other EEG measures or different psychological tests. The final aim is to extract and analyse the brainwave patterns of MCI and cognitively healthy elderly group from same bended EEG.

2. Definition of Terms

2.1 Mild Cognitive Impairment (MCI)

MCI is define as a cognitive function deficit in spite of age and education level, but does not interfere the daily activity but in clinical view, MCI is a transition between early normal elderly cognition and late severe dementia and considered different because some MCI sufferers develop dementia (Al- Qazzaz et. al, 2014). Several studies suggest 5 to 20 percent of the elderly have some form of mild cognitive impairment of one form at any one time (Alzheimer's society UK, 2013).

In studies carried out at the memory clinics, 10 to 15 percent of people with MCI went on to develop dementia in each year (Alzheimer's society UK, 2013). Since the number of individual with AD is expected to increase considerable in the near future, reliable treatment and early diagnosis of MCI is critical. Early detection helps in obtaining the maximum treatment before significant mental decline occurs (Al- Qazzaz et. al, 2014).

2.2 Quantitative Electroencephalogram (QEEG)

Even though a clinical diagnosis accuracy approximately 85 percent of detection rate is commonly achieved, by a procedure of exclusion after structural or functional imaging tests – including quantitative electroencephalogram (QEEG), laboratory, and psychometric test, there are no consensus on methods to estimate and measure the diagnosis and progression of patients with MCI.

Recent research has demonstrated that QEEG is useful for investigating AD (Leucter, 1993; Babiloni et al., 2004). Topographical EEG power changes are believed to reflect early signs of the cortical atrophy and / or compensatory cortical reorganization during the early stages of the disease. More specifically, it is commonly believed that AD induces enhanced mean power of slow rhythms (0.5 – 8 Hz) and loss of fast (8 – 30 Hz) rhythms.

In the EEG of healthy subjects, recorded in resting condition with closed eyes, usually, the alpha rhythms are mostly distributed in the occipital area; in AD patients, the alpha rhythms increasingly relocate towards anterior areas as the disease progresses. Associated early stages of AD have been linked with an increase of theta activity and a decrease of alpha activity. In a more severe condition of AD, there is an increase in theta and delta activities and vice versa in alpha and beta frequency (Knott et al., 2001; Kwak et al., 2006).

2.3 Spectral analysis of EEG

According to a longitudinal study, the mean posterior dominant frequency declined by 0.08 Hz per year over 60 years (Wang & Busse, 1969). There is great evidence in the literature to consider an average alpha frequency of less than 8.5 Hz as abnormal, measured with the patient fully alert. Although posterior frequency decline is usually unspecific and cannot differentiate any particular disorder, it has been common electroencephalographic sign described in many conditions evolving to cognitive alterations, and is frequently encountered in AD individuals (Raicher et al., 2008). Current study reported increase of high alpha frequency power band on the occipital region in MCI subjects compared to normal and Alzheimer's disease patients.

2.4 Power Spectral Density (PSD)

Power spectral density function (PSD) shows the strength of the variations (energy) as a function of frequency. In other words, it shows at which frequencies variations are strong and at which frequencies variations are weak. The unit of PSD is energy per frequency (width) and you can obtain energy within a specific frequency range by integrating PSD within that frequency range. Computation of PSD is done directly by the method called FFT or computing autocorrelation function and then transforming it.

In this context, Qualitative electroencephalogram (Qeeg) measures different brainwaves within the brain where electrodes are placed based on the 10 – 20 system. Qeeg measured the voltage of electrical impulse signal μV^2 is propositional to the power of the signal on specific sites on scalp to detect and record the electrical impulses. PSD resulted in the strength of a signal which is distributed in the frequency domain, relative to the strength of other ambient signals (Oppenheim, A. V., & Verghese, G. C., 2010). Delta and Gamma (30 - < 60 Hz) denoted an adult slow component, which is sparsely represented whereas the Alpha and Beta is a predominate and a fast component wave.

3. Methodology

3.1 Subjects

3.1.1 Sample size

For the purpose of this research, sample size estimation and statistical power analysis has been done using Gpow3 software power analysis. Statistical power (P) can be defined as P = 1- β, where 0.95 or 95% has been set for this conventional purpose and another 5% is a possibility to accept the null hypothesis (Prajapati, Dunne, & Armstrong, 2010). However, it is a must to consider a potential error. Then, with the large effect size (d), then the numbers of the sample would be 35 in each group, (Normal vs. MCI). However, this study involved 30 participants, 18 diagnosed as having MCI and 12 cognitively health normal screened using mini mental state Examination (MMSE) score is more than or eqal to 28, based on the age and educational level.

3.2.2 Demographic data

All the subjects recruited in the study were pensioners' age 60 to 75 years old in Sarawak. All experiment protocols had been approved by the local ethics committee. Informed consent were obtained from all participants before recording takes place. The difference in the size of the populations is due to the technical reasons linked to the EEG analysis.

Table 1: Demographic data

Group	N	Age	MMSE
MCI	18 (3 Female)	61.89	24.56
Health	12 (1 Female)	65.17	26.25

3.2.3 EEG Recordings

All recordings were obtained in the morning with subjects resting in the chair comfortably. The EEG activity was recorded continuously from 19 sites by using electrodes set in an elastic cap positioned according to the 10- 20 International systems for 25 minutes (Electro - cap International, Inc). Data were recorded with a band- pass filter of 0.3 – 70 Hz and digitized at a sampling rate of 250 Hz (BrainAmp, BrainProducts, Germany). The electrodes skin impedance was set below 5kOhm. The recording lasted 10 minutes, where 5 minutes with subjects eyes open (EO) and another five with eyes close (EC) task. The EEG data of eyes close task were then analysed and artifacts were discarded.

4. Result and Discussion

4.1 QEEG Patterns of MCI compared to Normal group

After recordings, data during eyes close (EC) were then extracted and analysed. Eyes close task is chosen because it is the best condition, where the minimum noise and artifacts either from muscular or non muscular tension produced. Findings revealed the presence of excessive fast wave activity (beta 1 and beta 2) at the left anterior and central, generally and specifically at point FP1, F3, F7, Fz, C3, T3, T4,and C4). The power spectral density for the five EEG bands were plotted to allow visual inspection of Qeeg patterns of MCI compared to the normal group. Refer to Figure 1,2,3,4 and 5)

Figure 1

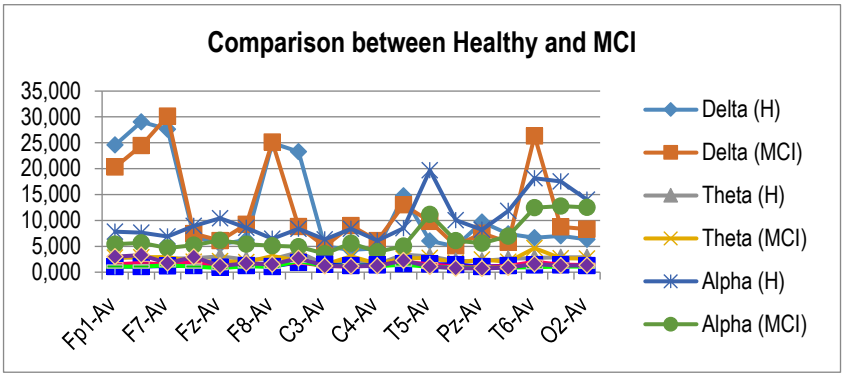
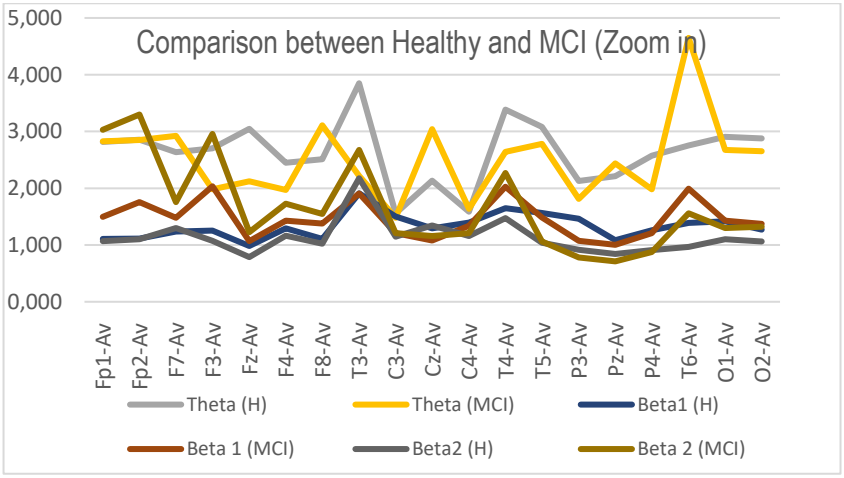


Figure 2



Findings showed promise of utility in early detection of Alzheimer's. Notably, 1) Increases in delta/ theta posterior temporal and prefrontal area i.e., H(6.64) vs. MCI(26.29); beta temporal region, 2) Decreases in alpha at sensory motor region i.e., H(0.27) vs. MCI(0.23**) . Look at Figure 4a, 4b, 4c.**

Figure 3a: Delta Anterior

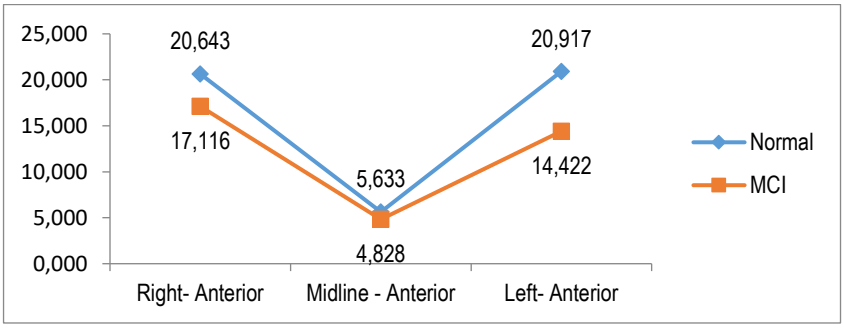


Figure 3b: Delta Central

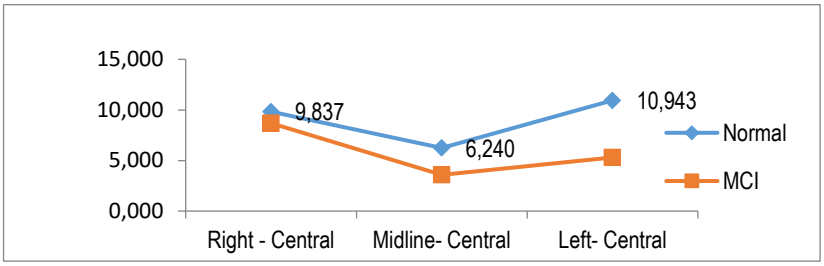


Figure 3c: Delta Posterior

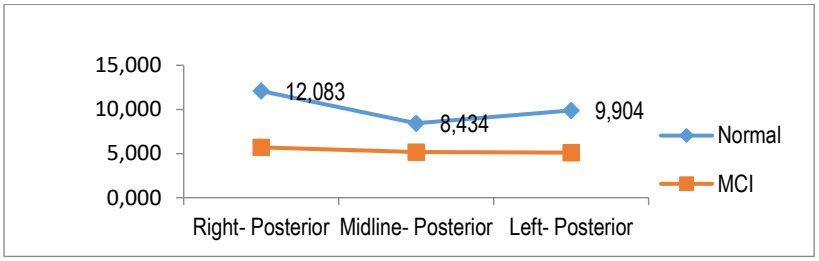


Figure 4a,4 b, 4c

Frequency Bandwith

Figure 4a:

Increasing Delta/theta at posterior temporal & Prefrontal

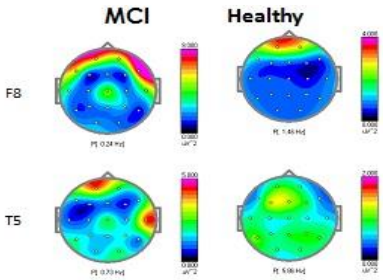


Figure 4b:

Decrease alpha wave at Central region

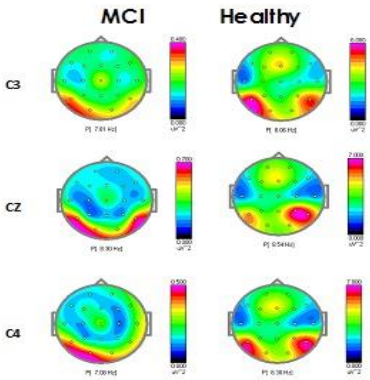
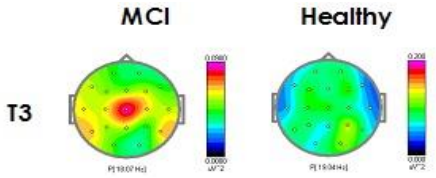


Figure 4c:Increase in beta in Temporal region



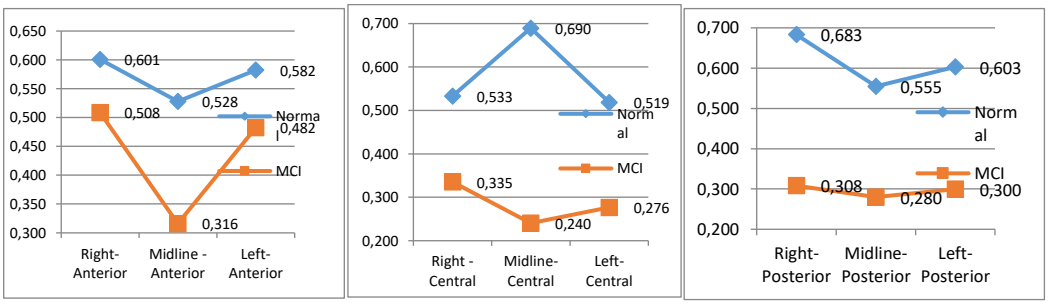
4.1.1 Delta wave

Anna Wise, 2004 in her book 'The High Performance Mind' reported that delta wave needed in order to produce hormones i.e human growth hormone. In addition, delta wave can boost anti ageing hormones. Refer to Figure 3a and 3c, Delta wave for MCI is excessively low at the left and right posterior compared to the normal.

According to Chase, B., an amino acid known as GABA is produces during the sleep and 30% extra GABA is produced for a regular sleeping pattern compared to insomniacs. Many researchers agreed that during the sleep without dream, the dominant wave is delta. Volgushev et al.(2006) reported that the slow wave spread preferentially from anterior to the posterior direction.

4.1.2 Theta wave

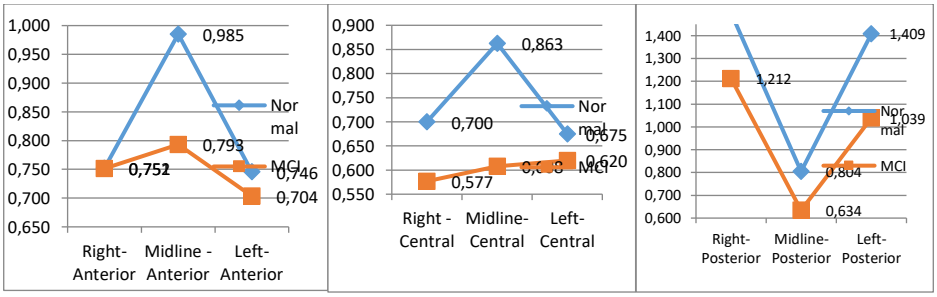
Figure 5a:Theta Anterior Figure 5b: Theta Central Figure 5c:Theta posterior



Refer to Figure 5a, 5b,5c, there is a significant difference between normal and MCI elderly theta at most region. This is supported by the research done by Prishep, L.S. et al. (2005) reported that alpha and theta mean values is significantly different from left temporo-occipital region compared to MCI. Theta waves is equivalent to the learning process as we can predicted human memory strength by the theta oscillation and medial temporal lobe is vital for learning (Rutishauser, U., Ross, I. B., Mamelak, A. N., & Schuman, E. M., 2010). Theta wave is generated by anterior cingulated cortex which the deficits at the frontal midline and central denoted them as MCI (Al- Qazzaz et al., 2014)

4.1.3 Alpha Wave

Figure 6a Alpha Anterior Figure 6b:Alpha Central Figure 6c: Alpha Posterior



Obviously, in resting state for normal elderly, alpha will dominate the brain as the eyes were close. But, in this situation, alpha for MCI is reported to be excessively low for MCI compared to the normal at the central region and notable low at the midline anterior (Refer to Figure 6a, 6b,6c). Alpha inadequacy in MCI power density can be supported by Weber, E. which reported that alpha wave worked best for incoming sensory and motor information which is synonym with the sensorimotor rhythm (SMR). Moreover, it is also claimed to disperse from the central region and mostly observed in the posterior region (Al- Qazzaz et al., 2014).

4.1.4 Beta wave

Figure 7a: Beta 1 Anterior

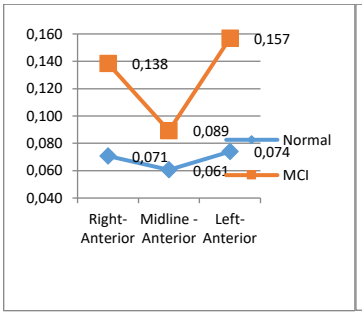


Figure 7b: Beta 1 Central

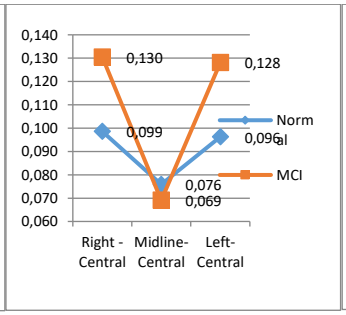
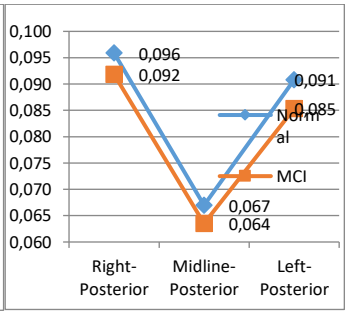


Figure 7c: Beta 1 Posterior



Occipital lobe is located at the posterior region, thus the Beta 1 posterior is not active as the beta wave will slowly disappeared as the eyes close (Refer Figure 7a, 7b dan 7c). Beta 1 anterior and central for MCI is higher than the normal group and it denoted the impairment compared to the normal. Even though beta wave is synonym with attention and concentration, but according Al-Qazzaz et al. (2014) during the resting condition, if the beta wave replaced the alpha, it remarks the cognitive impairment.

Figure 8a: Beta 2 Anterior

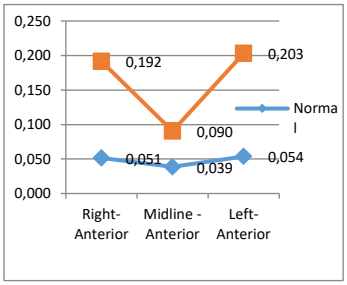


Figure 8b: Beta 2 Central

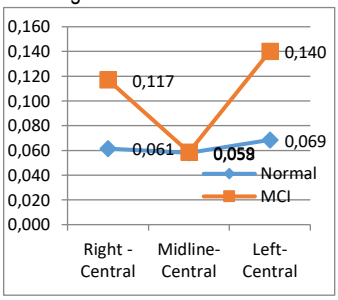
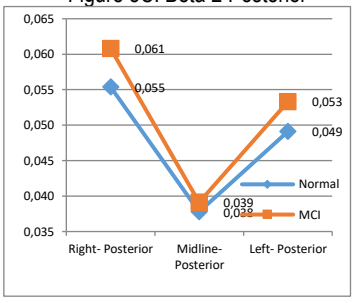


Figure 8C: Beta 2 Posterior



Most researchers reported that beta waves are observed in the parietal and frontal region and this explain the differences showed in Figure 5. The result is more likely for Beta 2, as the high beta is dominant in higher thinking order activity (Refer Figure 8a, 8b, 8c). Delta and theta activity will diminish as people reached their adulthood, whereas those alpha and beta waves increasing linearly as an outcome of cognitive impairment

Conclusion

The observation on Mild cognitive impairment group revealed the predominance posterior slowing rhythmic frequency bands reducing the alpha and beta activities whereas the occipital activity of the alpha and beta band in the normal aging is increasing. The findings showed a predominance distribution of theta and delta power or slow cerebral rhythms for both normal and the MCI. A reduction of delta at the subfrontal regions for the normal and central regions might be related to the cognitive decline at the hippocampal area. Analysis revealed statistically significant slowing in EEG activity of the MCI group. Specifically, there is an increase in delta and theta at the posterior and left temporal region (T6, T5) and prefrontal lobe (F7,F8) among the MCI over the healthy group and increase in Beta 1 and Beta 2 over the temporal regions among MCI group. Moreover, there is a significant decrease in rhythmic alpha frequency at the central or sensory motor region (c3,cz,c4) and posterior region.

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