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Comparison of Electroencephalography Power Spectral Density between Duramater and Brain Cortex

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Authors' contributions

This work was carried out in collaboration between all authors. All authors designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed literature searches. All authors read and approved the final manuscript.

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Short Research Article

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ABSTRACT

The intracranial electroencephalo- graphy (EEG) or electrocorticography (ECoG) is an invasive type of EEG which its electrodes are placed on the brain surface. It might be increases the amplitude of a recorded brain signal compared with the common EEG due to an impedance reduction. This study tries to analyze the difference by comparing the Power Spectral Density (PSD) of brain signals between duramater and brain cortex. The result shows that there is a distinction between the two sites, where the EEG recorded from brain cortex has a higher PSD than from duramater.

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Keywords: Electroencephalograph (EEG); intra operative EEG; fast fourier transform (FFT); power spectral.

1. INTRODUCTION

The electroencephalography (EEG) is the main, common way to acquire electrophysiological signal from the brain. There are multiple approaches that can be implemented to obtain these signals, one of it is by using an intraoperative or intracranial EEG / electro-corticography (ECoG). This EEG differs from the conventional one as its electrodes or probes are directly placed on the brain surface rather on the scalp – hence its name.

An intraoperative EEG may be used in a condition aimed where an amplitude of a recorded brain signal is in its highest possible condition. It may reach amplitude at millivolt (mV) order, thousands higher from conventional EEG due to an impedance reduction [1]. ECoG has been used as far back as 1940s to localize epileptogenic tissue prior in the treatment of epilepsy and has evolved ever since [2]. Nowadays, ECoG has been used for many researches involved in a vast scope of brain and neurophysiology like [3,4].

This study tries to find any connection from the possible impedance difference of electrode site/position from multiple subjects by using intraoperative EEG instruments. These positions then are grouped into two main electrode placement categories: Above and below the duramater.

The main instrument mentioned above is ADS1299 EEG-FE, an analog to digital converter (ADC) commonly used for EEG, modified to fulfill the safety standards. To analyze the signals, the main feature extraction is fast fourier transform (FFT) algorithm [5]. FFT transforms signal from time to frequency domain, so its power spectral density (PSD) could be measured afterwards. The signal PSD is used as it represents an amplitude [6].

In order to characterize the signals that coming from intraoperative EEG according to particular brain injuries, this study proposes power spectrum analysis [7] as basic method used.

The basic method used in calculating power spectrum is the Fast Fourier Transform (FFT) algorithms. This algorithm transforms the signal from time domain into frequency domain [6,8].

2. METHODOLOGY

2.1 Patients and Acquisition

During a period from November 2015 until March 2016 there were 10 patients that underwent craniotomy for treatment of their respective diseases. All of the surgical procedures were carried out at Hasan Sadikin General Hospital Bandung. Patient must be an adult and agreed the informed consent to be included in this study. A total of 11 records of brain signals had been obtained from those patients in which the electrodes were placed on their brain surface, either on duramater (8 patients) or the brain cortex (3 patients).

Eligible patients were aged 18 years and over and admitted to the Department of Neurosurgery, Faculty of Medicine, Universitas Padjadjaran – Dr. Hasan Sadikin Hospital, Bandung, Indonesia from 19 June 2015 to 19 June 2016.

Ethical approval was obtained from the Faculty of Medicine, Universitas Padjadjaran Ethics Committee (No. 413/UN6.C1.3.2/KEPK/PN/ 2015).

During a period from November 2015 until March 2016 there were 10 patients (Table 1) that underwent craniotomy for treatment of their respective diseases. All of the surgical procedures were carried out at Department of Neurosurgery, Dr. Hasan Sadikin General Hospital Bandung. Patient must be an adult and agreed the informed consent to be included in this study.

The EEG instrument used for this study is ADS1299EEG-FE, an ADC set with 250 sampling rate, whereas the electrodes are sterilized 2x4 channels Pl-plated Si-based probe, specialized for intraoperative usage. The acquisition process takes 60 seconds by using those 8 channel electrodes placed on the surface of patient’s brain. This data then recorded and saved into computer as .txt and .xls file.

2.2 Signal Processing

The steps involved in the signal processing are shown in the Fig. 1. For processing the signal, each of the data has to be normalized first before applying the 50 Hz notch filter, this filter is needed to remove the electrical wire noise. Next step is to apply a 40 Hz low pass filter and the band pass filter associates with four EEG bandwidths: Theta (4-7 Hz), alpha (8-13 Hz), beta (14-30 Hz), and gamma (31-40 Hz). The example signal from each step is shown in Fig. 2. All processes were done with MATLAB.

Table 1. Patient database

Patient no.	Age	Sex	Brain lobe site	Electrode placement
1	57	Male	Right frontoparietal	Duramater
2	60	Male	Left parietal	Duramater
3	17	Male	Left frontal	Duramater
4	29	Female	Left temporoparietal	Duramater
5	19	Female	Mid-frontal	Duramater
6	50	Female	Right temporoparietal	Cortex
7	20	Male	Right temporoparietal	Duramater
8	28	Male	Right temporoparietal	Duramater
9	53	Male	Right temporal	Cortex
10	58	Male	Mid-occipital	Cortex

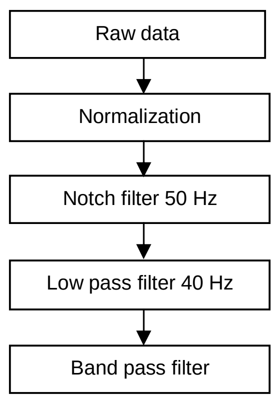

Fig. 1. Flow charts of the steps involved before measuring the PSD

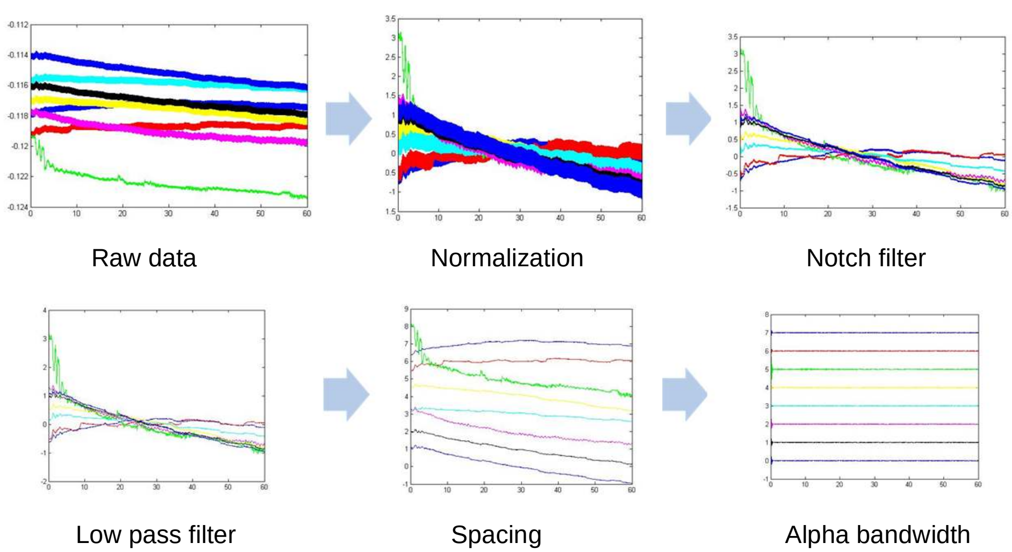

Fig. 2. Signal example from each process

2.3 Power Spectral Density Measurement

After four EEG bandwidths have been collected, then the next step is to measure the PSD. PSD is an intensity of signal power in a frequency domain. It may be described as equation below.

$$P = \sum_{k=-\infty}^{\infty} |Ck|^2$$

Where P is the Power and Ck is the set of energy from superposed signals [3].

From each patient, there has to be 8 channel of data separated into 4 bandwidths of theta, alpha, beta, and gamma. So there are total of 32 data of PSD from one patient or mentioned otherwise. The data was analyzed using Microsoft Excel.

3. RESULTS

From section 2 we already know that there are 8 patients whose EEG recorded from duramater, and other 3 from brain cortex. The age range from 17-60 years old. The results of the average PSD from each patient can be seen from Table 2. In their respective bandwidth, the PSD from an EEG in which electrode placed on the brain cortex (brain surface) are significantly higher than from duramater.

There were ten subjects with various type of brain injury. Particular medical treatment done by operatively under standard neurosurgery procedure. Intraoperative EEG signals obtained on this neurosurgery. Details data about the subject can be seen on Table 3. Beside the data as basic information of the patients, it will be used for clustering the patient also.

Fig. 3 draws a graphic to compare both placement that shows that the average PSD from the brain cortex are 4.86-, 6.31-, 6.35-, and 4.66-times higher than duramater in consecutive theta, alpha, beta, and gamma bandwidth.

4. DISCUSSION

The intraoperative EEG signals are taken from ten subjects. The subjects have different types of brain injury and operated with different approach. The signal acquired when the subjects in neurosurgery for particular medical treatments. The EEG instruments has eight channels and 250 Hz sampling rate. The channels grouped into two probes. On power spectrum calculation among the channels, shows that brain cortex measurement has power spectrum value higher than the durameter measurement. Based on comparison of power spectrum value and data cluster visualization, the signal taken from intraoperative EEG reflects some different pattern of brain injury depend on depth of location measurement.

However, our study does not necessarily conclude that every electrode placed on duramater has a lower PSD than cortex as it needs more data involved. There are possibilities that the gender [9] or age [10] might also contribute to this difference. It might be helpful in the future work if the EEG comparison were recorded from a same subject as well.

Table 2. Average PSD from each bandwidth

Patient no.	Average (mV^2)			
	Theta	**Alpha**	**Beta**	**Gamma**
Electrode on Duramater				
1	0.13	0.03	0.01	0.00
2	10.83	2.35	0.87	0.54
3	3864.57	498.05	109.87	36.71
4	7.13	1.55	0.24	0.13
5	234.38	52.99	6.10	0.69
7	574.11	172.50	40.14	13.05
8	876.00	128.45	15.30	2.88
Electrode on Brain Cortex				
6	9361.75	1822.37	372.08	90.14
9	1393.94	313.58	53.62	5.17
10	832.40	177.38	43.84	12.61

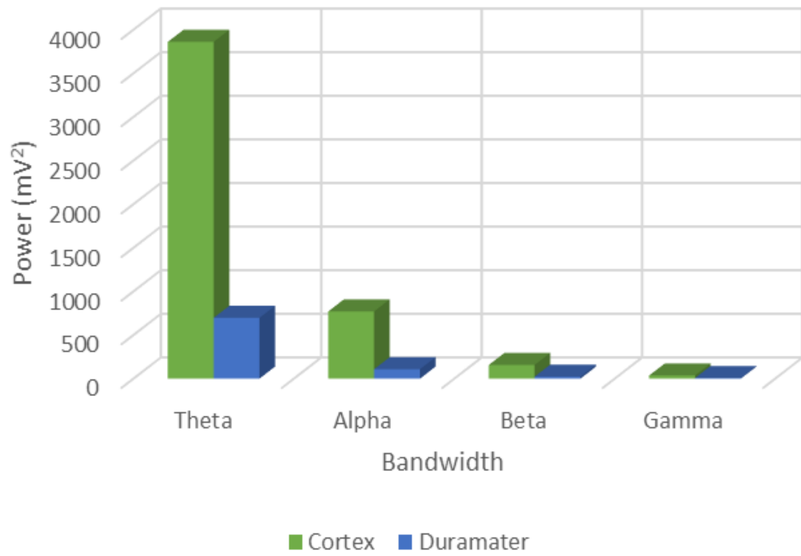

Fig. 3. Comparison graphic of average PSD from every bandwidth

Legend: x axis represent each bandwidth (Theta 4-7 Hz, Alpha 8-13 Hz, Beta 14-30 Hz, and Gamma 31-40 Hz) and y axis represent the average PSD (mV^2)

Table 3. Subject medical data

Subj[a] no.	Sex[b]	Age[c]	Injury	GCS[d]	Time[e]
1	M	57	Epidural hematoma	14	11
2	M	60	Epidural hematoma	9	5
3	M	17	Epidural hematoma	12	19
4	F	29	Skull defect	14	2160
5	F	19	Epidural hematoma	15	5
6	F	50	Brain stroke	13	12
7	M	20	Epidural hematoma	15	6
8	M	28	Epidural hematoma	13	15
9	M	53	Brain stroke	15	2160
10	M	58	Tumor	15	1440

[a]Subject, [b]Sex: M as Male and F as Female, [c]Age in years, [d]Glasgow coma scale, [e]Delay before medical treatment (hours)

There were many experiments that utilize EEG as instrument for intraoperative monitoring while brain surgery. Levy [11], used intraoperative EEG to compare between the patients undergoing anasthetic inductions and the patients undergoing cardiopulmonary bypass. Levy found that there is the signal characteristic belong to the patient condition showed by two peak averaged 7.6 Hz. The Levy experiment was little bit different with ours. However, still can be used as reference because the intraoperative EEG able to characterize for many patient conditions.

Murashita et al. [12] utilized intraoperative EEG in aortic arch surgery. Result obtained by Murashita that intraoperative EEG is reliable monitoring tool for safe circulatory arrest. This result based on intraoperative EEG with abnormal or different pattern.

5. CONCLUSION

From the results there is possibility that the PSD of an EEG signal might be influenced by its electrode location/depth. There is a difference in PSD between an electrode that placed on duramater and brain cortex, where the average PSD on cortex is higher than its duramater counterparts as much as 6.35 times.

Our conclusion is "intraoperative *Electroence-phalography"* (EEG) as a potential tool to characterize of particular brain injuries or lesion by exploring the signal output from the instrument.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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