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The Differences of Frontal Delta-Alfa (DAR) Ratio and Alfa-Beta Interhemispheric Coherence between Iscemic Stroke Patients with and without Cognitive Impairment

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Abstract

Stroke is the second leading cause of death worldwide and the leading cause of long-term disability. Post-stroke cognitive impairment is one of the common complications that can be found after a stroke. Quantitative Electroencephalography (QEEG) is an ideal biomarker to complement neuropsychological testing in the study of cognitive impairment, or cognitive decline, among patients with cerebral infarction. Early and accurate identification of post-stroke cognitive impairment is important for the management and rehabilitation of patients. This study aims to determine the differences in the frontal delta-alpha ratio (DAR) and alpha-beta interhemispheric coherence between ischemic stroke patients with and without cognitive impairment as measured by QEEG. The delta-alpha ratio (DAR) was obtained from global frontal electrodes as well as alpha-beta interhemispheric coherence in all electrode pairs in 30 subjects with first-time ischemic stroke with onset > 7 days - < 3 months. The Indonesian version of the Montreal Cognitive Assessment (MoCA-Ina) was administered prior to EEG recording. Data analysis used independent t-test and Mann Whitney test to identify differences between ischemic stroke groups with and without cognitive impairment. The results of the research showed that The ischemic stroke group with cognitive impairment showed a higher frontal DAR (p = 0.002) than the group without cognitive impairment. On the other hand, the alpha-beta interhemispheric coherence (alpha p = 0.792; beta p = 0,852) did not show a significant difference between the ischemic stroke group with and without cognitive impairment. The data generated by the frontal electrode supports the identification of an increase in the frontal DAR value as an early marker of cognitive impairment after ischemic stroke, while the alpha-beta interhemispheric coherence value was not significant but in the cognitive impairment group showed a decrease in coherence.

Key Words: Frontal DAR, cognitive impairment, alpha-beta interhemispheric coherence, QEEG

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Introduction

Stroke is a clinical syndrome in the form of focal or global neurological deficits, lasting more than 24 hours or causing death, due to cerebrovascular disease (Sacco et al., 2013). Stroke was the second leading cause of death worldwide in 2015 and the leading cause of long-term disability (Benjamin et al., 2019). Post-stroke cognitive impairment is one of the common complications that can be found after a stroke (Kim et al., 2020). The likelihood of post-stroke cognitive impairment was 17% greater per 1 year of follow-up for each 10-year increase in age of onset (Levine et al., 2018). Data from the Indonesia Stroke Registry in 2013 stated that 60.59% of stroke patients had impaired cognitive function (Ong et al., 2015).

Post-stroke cognitive impairment is a broad concept that has been used to define cognitive decline, meeting established criteria for cognitive impairment in the first six months after stroke (Yang et al., 2020). This condition is a frequent but neglected consequence of other neurological deficits such as sensory or motor disturbances (Kalaria et al., 2016). The cognitive domains most commonly affected in post-stroke cognitive impairment are attention and executive function (Aam et al., 2020).

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In general, it is known that the cost of stroke care in patients with cognitive impairment is three times higher than in patients without cognitive impairment, where most ischemic stroke patients first show cognitive impairment on neuropsychological tests in the first few weeks after stroke (Gareau, 2011; Aminov et al., 2017). Exploratory studies of reliable and applicable biomarkers for early diagnosis will benefit patients with cerebral infarction, by delaying, or even preventing, cognitive impairment (Song et al., 2015).

Electroencephalography (EEG) is a widely available, relatively inexpensive and non-invasive tool, which can be useful for the evaluation of cognitive impairment. This is especially true for Quantitative Electroencephalography (QEEG), which is an ideal biomarker to complement neuropsychological testing to study cognitive impairment, or cognitive decline, among patients with cerebral infarction (Aminov et al., 2017). Coherence is one of the indicators to measure functional connectivity and is used to investigate changes in brain activity during cognitive and meditation tasks (Lee et al., 2017). One finding in Alzheimer's disease is decreased EEG coherence as an index for decreased functional connectivity, the most common finding being decreased EEG coherence at fast wave frequencies i.e. alpha and beta (Babiloni et al., 2020; Laptinskaya et al., 2020).

A study conducted by Aminov et al, comparing stroke patients with healthy individuals by assessing single electrode EEG showed abnormal delta and alpha indices after stroke can affect attention capacity, which appears to be a major determinant of functional and cognitive outcomes, including maintaining optimal cerebral activity (Aminov et al., 2017; Leon-Carrion et al., 2009). Frontal delta-alpha ratio (DAR) and global relative alpha power were associated with cognitive outcomes in the analysis by Doerrfuss et al., (2020). QEEG has proven valuable for screening for post-stroke cognitive deficits, but this study has not been widely reported to date (Schleiger et al., 2014). This study aimed to assess the differences in frontal DAR and alpha-beta interhemispheric coherence in ischemic stroke patients with and without cognitive impairment as measured using QEEG.

Methods

Patient

Approval to carry out this research was obtained from the Ethics Committee of the Faculty of Medicine, Hasanuddin University. Patients were determined by consecutive sampling from December 2021 to January 2022 at the Neurology Brain Center Polyclinic, Wahidin Sudirohusodo Hospital, Makassar. Written informed consent was obtained from each patient or surrogate decision maker. Patients with onset >7 days and <3 months aged between 36-65 years after the first stroke were eligible to participate. All patients underwent a CT scan of the head without contrast. Time of stroke onset was defined as the time the patient was last seen without stroke symptoms, as documented in the medical record. Individuals with a history of loss of consciousness, history of epilepsy, history of neurological disorders other than stroke or previous psychiatric illness, were excluded.

Early Assessment of Cognitive Function

Cognitive function was assessed using the Indonesian version of the Montreal Cognitive Assessment (MoCA-INA) prior to EEG recording. The cognitive function screening instrument consisted of 12 across the domains of orientation, attention, language, visuospatial, memory, and executive function. MoCA-INA has been validated according to the rules of transstructural and reliable validation (Nadia Husein) and demonstrated validity in stroke (Cumming et al., 2013), and is widely used to assess outcomes after acquired brain injury (Lumempouw & Ramli, 2010). MoCA-INA with the highest score of 30 while a score below 26 indicates cognitive impairment (Lumempouw & Ramli, 2010).

EEG Data and Analysis

Continuous EEG was recorded for approximately 5 minutes at rest, awake with eyes closed using a Cadwell Easy III Electroencephalograph device. Nineteen electrodes were applied according to the International 10-20 system. The dominant electrode impedance is 5-10 Ωk or less. Alertness or drowsiness was assessed throughout the EEG recording.

NeuroGuide Deluxe QEEG software was used to analyze the EEG data. The raw EEG waveform data was amplified with a 0.5–30 Hz band-pass filter, and manually examined to identify

movement or muscle artifacts. The identified parts are marked and excluded from further processing. An artifact-free 2-minute EEG is sent to Fast Fourier Transforms (FFT) from the power spectrum resulting absolute power in the following frequency bands: delta (0-3 Hz), theta (4-7 Hz), alpha (8-13 Hz), and beta (13–30 Hz). Frontal DAR is calculated as the absolute power ratio for each desired frequency band. The specific frontal QEEG index was calculated by averaging the size of each of the 7 frontal electrodes (Fp1, Fp2, F3, F4, F7, F8 and Fz). This electrode location was chosen because the frontal lobe is critical for a variety of cognitive processes and also because, at least in MCA and anterior circulation stroke, scalp delta strength is usually highest at these electrodes (Finnigan & van Putten, 2013). Functional connectivity was calculated using the spectral coherence method, which shows functional connectivity in brain activity between two cortical regions and is calculated as a function of frequency (Laptinskaya et al., 2020). Since we were interested in the functional connectivity between the left and right hemispheres, we calculated the spectral coherence for all alpha-beta interhemispheric electrode pairs and then averaged all these values as an index for global coherence (1–30 Hz).

Procedure

After obtaining approval, a physical examination was performed to assess the extent of stroke-related neurological deficits and functional disability as well as the results of a non-contrast CT scan of the head. Assessment of cognitive function with MoCA-INA to assess the presence or absence of cognitive impairment before EEG recording was performed. Continuous EEG for 5 minutes artifact-free with eyes closed and awake. Laying of nineteen electrodes based on the international system 10-20 with an electrode impedance of 5-10 Ωk. Raw EEG data will be converted into QEEG to identify frontal DAR values and alpha-beta interhemispheric coherence by comparing groups of ischemic stroke patients with and without cognitive impairment. This study was approved by the Ethics Commission of the Hasanuddin University Faculty of Medicine, and each participant (or companion) provided written consent for voluntary participation.

Statistical Analysis

All data will be analyzed using IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, N.Y). Previously, the distribution of the data will be tested using the Saphiro Wilk test. If the data distribution is normal, the independent t-test will be used, while if the data distribution is not normal, the Mann Whitney test will be used. Hypothesis assessment is said to be meaningful if the p value <0.05 obtained. The frontal DAR values between the group with cognitive impairment compared with the group without cognitive impairment were published using the Mann Whitney test, while the values for interhemispheric coherence used the independent t-test and the Mann Whitney test

Results and Discussion

This study is an observational analytic study by assessing the ratio of frontal delta-alpha (DAR) and alpha-beta interhemispheric coherence in ischemic stroke patients consisting of 2 groups with each group consisting of 15 people. The cognitive impairment group is the ischemic stroke patient group with the MoCA-Ina score <26. The group without cognitive impairment is the ischemic stroke patient group with the MoCA-Ina score 26. Demographic data and patient characteristics are shown in table 1.

Table 1. Demographic Data of the Research Sample

Characteristics		Cognitive Impairment			Without Cognitive Impairment			*p* Value
		(n)	%	Mean	(n)	%	Mean	
Gender	Male	8	53,3		14	93,3		0,035***
	Female	7	46,7		1	6,7		
Age (SD)				52,73 (SD±7,17)			51,53 (SD±7,87)	0,666*
Lession Location	Left cerebral hemisphere	9	60,0		2	13,3		0,021***
	Dextra cerebral hemisphere	6	40,0		13	86,7		
Onset (SD)				29,73 (SD±23,89)			23,60 (SD±11,53)	0,916**
Risk Factors	Hipertensi	10	47,6		11	52,4		1,000***
	HT + DM	5	33,3		4	26,7		1,000***
MoCA-Ina (SD)		15	100	12,67 (SD±6,04)	15	100	27,0 (SD±0,76)	<0,001**

*Source: Primary Data, *Independent t-test, **Mann Whitney test, ***Chi-square test*

Table 1 shows the distribution by sex, age, lesion site, stroke onset, risk factors and cognitive function based on MoCA-INA. The gender of all samples were male (73.3%) and female (26.7%) where the sample was male more than female with p value = 0.035. In the group with cognitive impairment, the number of males was 53.3% and females were 46.7%, while in the group without cognitive impairment, males were 93.3% and females were 6.7%. The mean age of the cognitive impaired group with a mean age of 52.73 (SD±7.17) while the group without cognitive impairment had an average age of 51.53 (SD±7.87) with p value = 0.666. The location of the lesions in the cognitive impaired group was in the left hemisphere as many as 9 people (60%) and the right hemisphere as many as 6 people (40%) while the group without cognitive impairment in the left hemisphere was 2 people (13.3%) and the right hemisphere was 13 people (86.7%), with p value = 0.021. The mean stroke onset of the group with cognitive impairment was 29.73 (SD±23.89) while the group without cognitive impairment was 23.60 (SD±11.53), with p value = 0.916. The risk factors for stroke in the total sample (30 people) were hypertension and with diabetes mellitus (DM) there were 9 people (36.7%) consisting of 5 people in the cognitive impaired group and 4 people in the group without cognitive impairment with p = 1,000. The mean MoCA-Ina score in the cognitively impaired group was lower than the group without cognitive impairment with p < 0.001.

Table 2. Frontal DAR Measurements in the Stroke Group with Cognitive Impairment and Without Cognitive Impairment

Groups	Cognitive Impairment			Without Cognitive Impairment			*p Value*
	Median	Minimum	Maximum	Median	Minimum	Maximum	**
FP1	6,07	1,71	18,95	1,58	0,43	6,24	0.001
F3	5,12	0,34	20,69	1,37	0,32	3,41	0.003
F7	5,62	0,51	22,04	1,44	0,59	5,67	0.005
FP2	5,15	2,36	20,69	1,63	0,41	6,23	0.003
F4	2,82	0,39	16,51	1,26	0,24	4,39	0.006
F8	3,11	0,67	17,72	1,99	0,42	8,20	0.015
Fz	4,97	0,35	20,23	1,11	0,20	2,78	0.002

*Source: Primary Data, **Mann Whitney test*

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Table 2 shows a comparison of the results of frontal DAR measurements between the ischemic stroke group with cognitive impairment and without cognitive impairment. On all EEG electrodes FP1, F3, F7, P2, F4, F8, and Fz, the mean frontal DAR was higher in the group with cognitive impairment than the group without cognitive impairment, from the statistical test results obtained p value <0.05, which means there is a difference DAR test results between the cognitively impaired group with no cognitive impairment.

Table 3. Measurement of Interhemispheric Alpha Coherence in the Stroke Group with Cognitive Impairment and Without Cognitive Impairment

Groups	Cognitive Impairment			Without Cognitive Impairment			*p Value* **
	Median	Minimum	Maximum	Median	Minimum	Maximum	
FP1-FP2	62,24	44,98	95,50	70,22	24,45	94,44	0.313*
C3-C4	27,37	0,80	87,09	26,75	0,28	74,93	0.724**
O1-O2	23,36	0,36	58,11	28,20	9,24	54,29	0.659*
T3-T4	15,25	0,11	37,76	15,49	1,39	41,05	0.633**
F3-F4	33,92	0,15	90,58	62,34	19,16	88,35	0.206*
P3-P4	42,29	2,28	82,36	28,14	3,98	70,45	0.476*
F7-F8	34,06	1,87	69,62	25,47	0,29	60,02	0.633**
T5-T6	14,45	0,27	42,16	12,35	0,36	51,11	0.576**

*Source: Primary Data, *Independent t-test, **Mann Whitney test*

Table 3 shows the results of measuring the interhemispheric coherence of alpha waves between the ischemic stroke group with cognitive impairment and without cognitive impairment, the decrease in alpha coherence was only found at the Fp1-Fp2 (frontal pole), O1-O2 (occipital), T3-T4 (midtemporal) electrodes. F3-F4 (frontal), while at the other electrodes there was no decrease in coherence. Statistical test results obtained p value > 0.05, which means that there is no difference in test results between the group with cognitive impairment and the group without cognitive impairment.

Table 4. Measurement of Beta Interhemispheric Coherence in the Stroke Group with Cognitive Impairment and Without Cognitive Impairment

Groups	Cognitive Impairment			Without Cognitive Impairment			*p Value*
	Median	Minimum	Maximum	Median	Minimum	Maximum	
FP1-FP2	39,78	13,13	90,51	46,47	13,41	74,64	0.942*
C3-C4	25,65	0,86	62,16	14,08	0,70	49,81	0.120**
O1-O2	22,28	2,83	75,36	26,36	3,80	45,01	0.745*
T3-T4	6,27	0,20	34,13	5,71	0,05	29,69	0.950**
F3-F4	21,41	5,51	67,00	23,61	1,71	51,25	0.917**
P3-P4	43,33	4,57	72,65	27,44	0,01	58,55	0.093**
F7-F8	17,13	0,48	53,09	9,99	0,31	57,67	0.820**
T5-T6	11,06	0,01	56,48	4,33	0,02	38,34	0.983**

*Source: Primary Data, *Independent t-test, **Mann Whitney test*

Table 4 shows the results of measuring beta wave interhemispheric coherence between the ischemic stroke group with cognitive impairment and without cognitive impairment, the decrease in beta coherence was only found at the electrodes Fp1-Fp2 (frontal pole), O1-O2 (occipital), F3-F4 (frontal), while at the other electrodes, no decrease in coherence was found. Statistical test results obtained p value > 0.05, which means that there is no difference in test results between the group with cognitive impairment and the group without cognitive impairment.

Table 5. Comparison of DAR and Alpha-Beta Interhemispheric Coherence in the Stroke Group with Cognitive Impairment and Without Cognitive Impairment

Groups	Cognitive Impairment			Without Cognitive Impairment			*p Value*
	Median	Minimum	Maximum	Median	Minimum	Maximum	
DAR	4,30	0,91	19,55	1,55	0,42	4,16	0.002**
Alpha Coherence	27,66	19,08	62,62	33,98	14,37	52,79	0.792*
Beta Coherence	20,42	13,77	55,05	23,34	6,71	34,11	0.852**

*Source: Primary Data, *Independent t-test, **Mann Whitney test*

Table 5 shows the comparison of DAR in the ischemic stroke group with cognitive impairment compared to the group without cognitive impairment, from the statistical test results obtained p value = 0.002 which means there is a difference in the cognitive impaired group with a higher DAR value than the group without cognitive impairment. While the comparison of alpha-beta interhemispheric coherence in the ischemic stroke group with cognitive impairment compared to the group without cognitive impairment from the statistical test results obtained alpha coherence p value = 0.792 and beta coherence p value = 0.852 which means there is no difference in interhemispheric coherence alpha-beta between the cognitively impaired groups versus those without cognitive impairment.

In the current study, we explored the ability of the EEG device to see differences in frontal delta-alpha ratio (DAR) values as well as alpha-beta interhemispheric coherence. This study also used a standardized measure of cognitive function with the MoCA-INA scoring system (total score <26 is considered impaired cognitive function), and compared the EEG results in ischemic stroke patients with and without cognitive impairment.

Studies investigating the association between risk factors and cognitive decline in old age on a global scale show that global cognition composite scores for males are lower than for females among whites, but vice versa in Asians (Lipnicki et al., 2019). Increasing age is the strongest risk factor for stroke that occurs in both men and women (Kalaria et al., 2016). Based on a study by Gorelick et al, cognitive impairment 3 months after ischemic stroke in patients aged 55-85 years, 62% of them occurred in one domain and 35% in two domains (Gorelick et al., 2016). In this study, the proportion of male and female was almost the same with the highest age being between 56-65 years. Cognitive domains involved after stroke can vary depending on stroke characteristics such as stroke type, volume, number, location, and acute severity (Kalaria et al., 2016). Impaired cognitive function develops in two thirds of stroke patients within 14 days and 3 months after stroke (Wang et al., 2021).

Hypertension has been confirmed as a potential risk factor for post-stroke cognitive impairment. Based on previous meta-analysis studies showed that hypertension was a significant risk factor for vascular dementia in the absence of age differences (Sun et al., 2014). When diabetes and hypertension are found, it will increase a higher risk of stroke and cognitive impairment (Kalaria et al., 2016). Evidence also links diabetes to poorer cognitive performance and greater decline, as well as an increased risk of dementia (Lipnicki et al., 2019).

Monitoring the neurophysiological correlation of stroke with conventional multielectrode EEG montage has been shown to correlate with the assessed outcome of long-term cognitive function (Aminov et al., 2017). We explored the capabilities of the EEG device by comparing frontal delta-alpha ratio (DAR) and alpha-beta interhemispheric coherence associated with cognitive decline in ischemic stroke patients with onset less than 3 months. Here, we first confirmed the EEG pattern of absolute power values in the frontal delta and alpha waves and combined these values determined by the delta-alpha ratio) and alpha-beta interhemispheric coherence in the cognitively impaired ischemic stroke group. Second, we observed the ischemic stroke group without cognitive impairment that they tended to show lower frontal DAR values and higher alpha-beta coherence (Schleiger et al., 2014; Lv et al., 2020).

Changes in delta wave activity were identified as potential biomarkers of early cognitive decline, while alpha waves would increase when performing cognitive tasks so that when alpha wave abnormalities were found it could be

associated with cognitive impairment (Lv et al., 2020; Ajčević et al., 2021). The frontal DAR value in our study is in accordance with several previous studies which showed that delta and alpha waves at the lateral frontotemporal electrodes have a significant relationship with the frontal lobe which is very important for cognitive processes and abnormal frontal deltas are usually increased at the frontal and temporal electrodes (Finnigan & van Putten, 2013). Frontal alpha activity is associated with prognostic cognitive outcomes, with the adoption of frontal electrode montage (F3, F7, F4, F8) this could help assess the DAR measure significantly correlated with a sample of anterior circulation stroke patients (Schleiger et al., 2014). In particular, excessive delta power is usually detected at the pre-frontal electrode after stroke (Aminov et al., 2017; Cuspineda et al., 2007).

Based on the aforementioned studies, the EEG component, namely the frontal DAR has the ability to identify the presence of cognitive impairment, besides that frontal lobe function is very important for various cognitive aspects, such as attention and strength of the frontal QEEG waves found to be correlated with measures of cognitive function in healthy adults (Finnigan & Robertson, 2011). As noted above, the frontal cortical regions support attentional and other cognitive processes analyzed in this study and as in a study by Schleiger et al. (2014) that frontal alpha is more strongly associated with cognitive outcomes than posterior alpha (Schleiger et al., 2014), and together with the frontal delta focus in stroke are also consistent with significant frontal DAR results in the cognitively impaired ischemic stroke group.

QEEG recordings are potential biomarkers for cerebral infarction leading to cognitive impairment (Song et al., 2015). In a study by Aminov et al, DAR assessed at a single prefrontal electrode was significantly increased in older adults and significantly correlated with assessment of cognitive function after 90 days (Aminov et al., 2017). The severity of cognitive decline correlates with EEG abnormalities (Al-Qazzaz et al., 2014), in line with our study that the difference in global frontal DAR values in our study, namely frontal DAR was higher in the cognitively impaired group than without cognitive impairment, so it can be used as a further research to use as a biomarker in the determination of post-stroke cognitive impairment with different assessment methods.

In addition to frontal DAR, we also assessed alpha-beta interhemispheric coherence in relation to impaired cognitive function. A higher degree of coherence between the two electrodes indicates strong functional connectivity between different brain regions (Lee et al., 2017). In assessing the difference between the cognitively impaired and no cognitively impaired groups, alpha and beta coherence was not found to be significant in all the electrode pairs that we assessed. The decrease in alpha coherence in the cognitive impairment group was limited to the Fp1-Fp2 (frontal pole), F3-F4 (frontal), T3-T4 (midtemporal), and O1-O2 (occipital) electrodes, reflecting decreased connectivity in the brain regions represented by the electrodes. The EEG, while the beta coherence for the cognitive impairment group showed a decrease in beta coherence at the Fp1-Fp2 (Frontal pole), F3-F4 (frontal) and O1-O2 (occipital) electrodes.

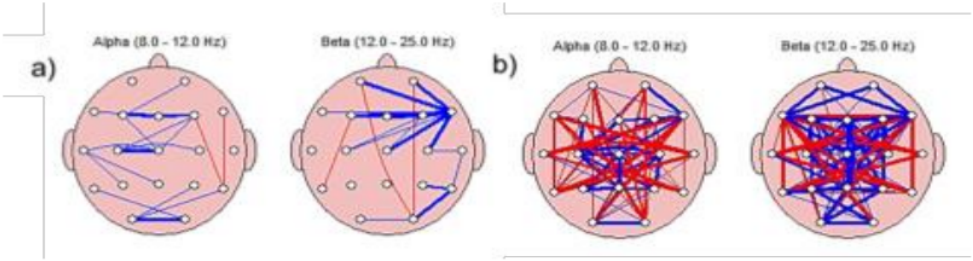

Figure 1. Topography of Brain Mapping, (a) Alpha-beta coherence of ischemic stroke subjects with cognitive impairment; (b) Alpha-beta coherence of ischemic stroke subjects without cognitive impairment

Coherence is presented as data and color-coded lines and Z-scores, where brain connectivity is objectively measured through coherence (Demos, 2019). Figure 1 shows a comparative representation of brain mapping topography based on Z-score FFT on alpha-beta wave

coherence. The blue line connecting the two lead points shows decreasing coherence while the red line shows increasing coherence (Demos, 2019). Figure 1a shows a decrease in alpha-beta coherence dominated by the blue line in the cognitively impaired group, while Figure 1b shows an increase in alpha-beta coherence dominated by the red line in the group without cognitive impairment. EEG coherence is a measure that reflects functional connectivity directly through the cortico-cortical pathway or indirectly which includes other cortical and subcortical structures, where disturbances in this pathway can lead to impaired cognitive function (Murias et al., 2007).

The results of this alpha-beta interhemispheric coherence measurement show that the decrease in coherence begins with local changes in the frontal area then followed by the temporal and occipital areas. A decrease in coherence tends to be found in the frontal area which may be related to the role of the frontal lobe in one's cognitive processes whereas an increase in coherence at the frontal electrode is associated with strong cognitive function (Fleck et al., 2016). Alpha wave asymmetry has also been a predictor of behavioral function in long-term memory formation and cognitive differentiation (Meeuwissen et al., 2011). Interhemispheric coherence in a group of healthy individuals and ischemic stroke which shows an increase in alpha coherence in healthy individuals appears to be involved in the learning process, integration, or preparation of neural resources to perform cognitive activities (Guggisberg et al., 2015). The increase in beta strength is thought to reflect long-distance communication between cortical areas for working memory, focus and alertness (Gorantla et al., 2020). This finding is in line with Ambrosini and Vallesi (2016), who showed that people with decreased coherence of the prefrontal cortex area showed a decrease in cognitive domains, especially executive function (Basharpoor et al., 2021). Cognitive impairment especially in executive function and attention is associated with functional outcome after stroke (Yang et al., 2020), suggesting a decrease in alpha-beta coherence in our study at the frontal electrode related to the role of the frontal lobe in relation to the domains of attention and function executive.

Another study found that interhemispheric beta coherence in the primary sensorimotor area improved with rehabilitation (Kawano et al., 2017). In this study, on average the research subjects had received standard stroke therapy and rehabilitation that could increase the brain's ability to improve functional connectivity which could be reflected in changes in the level of coherence that could affect the results of the study. Our findings are not consistent with the response of alpha-beta waves on several pairs of electrodes, this condition can be influenced by the results of cognitive function screening using MoCA-Ina to group samples into 2 groups. In some subjects, the range of cognitive scores was quite varied, which when viewed based on the cognitive domain that was disturbed, not all subjects experienced disturbances in the same cognitive domain. In this study, cognitive impairment was assessed based on the total MoCA-Ina score and not specifically based on the impaired cognitive domain. The increase in alpha-beta interhemispheric coherence is also influenced by processes during EEG recording, especially frontal beta coherence which is associated with high attention and alertness (Fleck et al., 2016), we asked the subject to lie quietly and eyes closed but still awake. In this condition, we find it difficult to control the patient so that they are not in a drowsy state and in subjects who have cognitive impairments will have difficulty following these instructions well. Low coherence is positively correlated with cognitive performance, especially alpha and beta waves (Guggisberg et al., 2015).

Homologous interhemispheric coherence correlates with better cognitive performance, this shows that when there are differences in coherence it will affect brain functional connectivity and may reflect impaired cognitive function (Dubovik et al., 2012). Siegel et al, described 20-30% of acute stroke patients at 1-2 weeks post-onset experiencing hemodynamic disturbances that could affect functional connectivity (Baldassarre et al., 2016; Siegel et al., 2016), in which some of our subjects were examined at the time of the study. onset is more than 1 week, thus affecting functional connectivity which is described by changes in coherence. The change in coherence in this study was not in accordance with our hypothesis, where a decrease in alpha-beta interhemispheric coherence in the cognitively impaired group was only found in a few pairs of electrodes. We conclude that the increase in alpha-beta

interhemispheric coherence across multiple electrode pairs for the cognitive impairment group reflects the increased capacity to control alertness, conscious movement control, and moods and emotions we could not control in our study subjects.

Functional biomarkers obtained through magnetic resonance imaging (MRI) techniques can also identify post-stroke cognitive impairment, and combined EEG and MRI studies will allow observations of brain tissue dynamics with high spatio-temporal resolution (Aminov et al., 2017). However, despite these promising findings, EEG devices are easy to administer and offer both time and cost effectiveness. EEG is widely available, non-invasive, inexpensive and without contraindications. The QEEG provides an objective measure of brain function and dysfunction even in patients with language, visual, auditory or functional impairment, such as loss of upper limb function, who cannot fully complete screening scales such as MoCA-Ina (Aminov et al., 2017; Liao et al., 2021). The limitations of our study include that we did not consider subject characteristics representative of the patient's stroke incidence (age, gender, area and location of the lesion) where this comparison is useful in describing the observed abnormality, because a number of unmeasured physical, psychological, or environmental factors may be present. also contributed to these group differences.

Conclusion

In conclusion, early and accurate identification of post-stroke cognitive impairment would be of great benefit. The results of our present study suggest that frontal DAR obtained from frontal electrodes can inform early screening for post-stroke cognitive impairment which may corroborate the results of cognitive function screening using MoCA-Ina. Alpha-beta interhemispheric coherence in the cognitive impairment group has not shown significant results, but the cognitive impairment group has shown a decrease in coherence. Further studies incorporating a larger sample and additional assessment measures need to be undertaken.

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