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Research

Profile of Cognitive Impairement in Patients with Brain Tumors in Dr. Moewardi Hospital, Surakarta

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ABSTRACT

Background: Brain tumor is a disease that is difficult to treat and causes high morbidity and mortality. One of the clinical manifestations of brain tumors is cognitive impairment which is the most common neurological problem. The aim of this study is to determine the profile of cognitive impairment in patients with brain tumors.
Subjects and Method: The design of this study was a retrospective cross-sectional using secondary data from the Neurology Polyclinic of RSUD Dr. Moewardi in January 2021-March 2022. The subject was diagnosed with a brain tumor based on anamnesis, physical examination, and neuroimaging. Cognitive impairment was inferred through the MoCA-Ina test. The analysis used was univariate descriptive analysis, independent T test, Mann-Whitney test, and Pearson correlation test.
Results: There were 29 subjects with a mean MoCA-Ina score (17.97). Primary brain tumors (79.3%), more than metastatic tumors. The majority of patients were diagnosed with meningioma (55.2%). This study showed that there were differences in abstraction scores (p=0.015) and total MoCA-Ina scores (p=0.042) between patients with tumors located in the temporal lobe and non-temporal lobe; differences in abstraction scores (p=0.034) and orientation scores (p=0.042) between patients with supratentorial and infratentorial tumors; and differences in memory scores (p=0.028) between patients with and without radiation history. In addition, this study also found an association between the number of lobes affected by brain tumors with attention score (p=0.027; r=-0.409), abstraction score (p=0.004; r=-0.524), orientation score (p=0.021; r=-0.426), and the total score of MoCA-Ina (p=0.018, r=-0.435).
Conclusion: There is an association between brain tumors and cognitive impairment which is concluded through the MoCA-Ina test. The clinical manifestations of cognitive impairment in the patient are in accordance with the neuroanatomical function of the brain affected by the lesion.

Keywords: Cognitive, Tumor, MoCA-Ina

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BACKGROUND

Brain tumor is a disease that is difficult to treat and causes high morbidity and mortality. During 2012-2016, 23.41 cases of Central Nervous System tumor occur per 100,000 people in the United States (Ostrom et al., 2015). In 2016, it discovered a significant increase of global incidence by 17.3% during 1990-2016. In that year there were 330,000 cases with the incidence level of 4.63 per

100,000 people per year (GDB, 2019). Meanwhile according to Johnson et al, 2017, the data indicated that 85–90% of CNS tumors are brain tumors (Johnson et al., 2017). Furthermore, the primary brain tumors are acknowledged to have high mortality rate and to be the leading cause of death in age group 0-14 years (31%) and 12-24 years (22%), in UK, below leukemia (McNeill, 2016). In Indonesia, the prevalence data of hospitals related to brain tumor diagnosis reveal various results.

One of the clinical manifestations of brain tumor is cognitive impairment. Related to brain tumor, cognitive impairment is the most common neurological problem (Boake and Meyers, 1993). Cognitive impairment/disfunction due to neoplastic process is a secondary manifestation of shifting/ pressure of intracranial structure and related cerebral edema which is recognized during the diagnosis of 50%-80% patients (Tucha et al., 2000). Cognitive changes are also reported occurring during and post radiation and chemotherapy including among brain tumor patients with clinical manifestation such as: memory loss, reduced attention and information processing, personality and mood changes (Tumors and Weitzner, 1999). Moreover, it is revealed that complementary medicine provided for brain tumor patients, such as glucocorticosteroid, anticonvulsant, and psychoactive medicine may also generate harmful effect toward cognitive functions (Klein et al., 2001). Eventually, medical complications that are often experienced by primary tumor patients, including endocrine disfunction, seizures, infections, anemia, and sleep disorders, may contribute on neurobehavioral changes.

Cognitive impairment level is assessable by using, for example: Mini Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA). MoCA is considered to have a superior sensitivity in terms of assessing cognitive impairment due to its ability to more extensively examine the executive functions, delayed memory, and abstraction (Olson et al., 2011). MoCA-Ina is Montreal Cognitive Assessment in Bahasa Indonesia version that has been validated (Husein et al., 2010). There are still limited number of studies concerning cognitive impairment profile in brain tumor patients in Indonesia. Therefore, the study aims to elaborate further the profile of cognitive impairment in brain tumor patients in Dr. Moewardi Hospital, Surakarta by using MoCA-Ina.

SUBJECTS AND METHOD

1. Study Design

It was a descriptive observational study of patients' medical records. The study was conducted in Neurological Polyclinic of Dr. Moewardi Hospital Surakarta during the month of April 2022.

2. Population and Sample

The population of the study was all patients with brain tumor diagnosis since the month of January 2021 - March 2022 who met inclusion and exclusion criteria. The inclusion criterion was patient with MoCA-Ina test data within their medical records, while the exclusion criteria were patient with brain tumor who was not confirmed by using neuroimaging, aphasia language disorder, prior mental illness, and other condition that may affect cognitive function.

3. Study Variables

The independent variables were sex, age, onset of cognitive symptoms, onset of non-cognitive neurological symptoms, side of lesion, location of tumor (based on lobes of cerebrum), location of tumor (based on tentorium cerebelli), tumor classification (based on the origin of the tumor), and radiation history. Dependent variables included MoCA-Ina total score and each section of MoCA-Ina score: visuospatial/

executive, naming, memory, attention, language, abstraction, delayed recall, and orientation.

4. Operational definition of variables

Sample's sex was divided into male and female. Sample's age was in years. MoCA-Ina score was the result of the Indonesian version of Montreal Cognitive Assessment test which included several sections, such as score of visuospatial/ executive (scale 0-5), naming (0-3), memory, attention (0-6), language (0-3), abstraction (0-2), delayed recall (0-5), and orientation (0-6), as well as the total score of the sections (0-30). Onset of cognitive symptoms and onset of non-cognitive neurological symptoms were in months. Lesion side was side/part that was affected by tumor based on hemispherium cerebri namely right (dextral hemisphere), left (sinistral hemisphere), or bilateral. Tumor location (based on lobes of cerebrum) whether it was located in frontal, temporal, parietal, occipital lobes, or other location. Tumor location (based on tentorium cerebelli) whether it was supratentorial, infratentorial, or both. Tumor classification (based on the origin of the tumor) whether it was primary intracranial or metastasis. Radiation history (yes or no) elaborated whether the sample obtained any radiation exposure either from radiotherapy or others.

5. Study Instruments

Cognitive impairment was assessed by using MoCA-Ina. MoCA-Ina test is able to assess the functions of various cognitive domains in 10 minutes. Based on a study by Husein et al in 2010, it concluded that Indonesian version of MoCA (MoCA-Ina) the short cognitive screening instruments has been valid based on the structural validity standard of World Health Organization (WHO) and has been declared as reliable therefore it can be used by neurologists as well as general practitioners (Husein et al. 2010). Medical records of patients with brain tumor diagnosis, who met the inclusion and exclusion criteria, would be reviewed. Subsequently, the author would record the variable data needed.

6. Data analysis

The analysis conducted by using SPSS version 25.0. Within univariate analysis, the data presented in categoric scale were frequency and percentage, whereas the data in numerical scale were tested by using Shapiro-Wilk normality test and analyzed for the mean, median, minimum value, maximum value, and/ or deviation standard. Bivariate analysis was conducted by using independent T-test, Mann-Whitney test, Anova test, Kruskall-Wallis test, Spearman correlation test and Pearson correlation test. The significance value of the study was 0.05.

7. Research Ethics

The study has obtained ethical clearance from the Health Research Ethics Committee of Dr. Moewardi Hospital Surakarta number 544/IV/HREC/2022.

RESULTS

1. Sample Characteristics

The study utilized patients' medical record data in Neurological Polyclinics of Dr. Moewardi Hospital, Surakarta during the month of April 2022. The study sample was all patients of Neurological Polyclinics of Dr. Moewardi Hospital, Surakarta with a total sample of 29 patients. Sample's basic characteristics are presented in Table 1. The majority of study sample had tumor lesion on the left side (48.3%) and meningioma diagnosis (55.2%), followed by other diagnosis: brain metastasis (20.7%), HGG (6.9%), and pituitary adenomas, glioblastoma, pontine glioma, cerebral cavernoma, and primary malignant brain tumor (3.4% respectively). Based on tumor location, the majority of patients had tumors located in supratentorial (86.2%) and located in frontal lobes (48.3%). On the other hand, based on the classification of tumor origin there were 23 samples (79.3%) were primary intracranial the rest were metastatic tumor. Furthermore, the majority of samples have no radiation history (89.7%).

Table 1. Sample characteristics (categorical data)

Characteristics		Category	Frequency	Percentage
Sex		Male	9	31%
		Female	20	69%
Educational Level		Primary (<9 years)	8	27.6%
		Secondary (9-12 years)	14	48.3%
		Higher (>12 years)	7	24.1%
Lesion side		Left	13	44.8%
		Right	6	20.7%
		Bilateral	10	34.5%
Diagnosis		Meningioma	16	55.2%
		Others	13	44.8%
Tumor location	**Based on tentorium cerebelli**	Supratentorial	25	86.2%
		Infratentorial	4	13.8%
	Frontal lobe	Yes	14	48.3%
		No	15	51.7%
	Parietal lobe	Yes	16	55.2%
		No	13	44.8%
	Temporal lobe	Yes	8	27.6%
		No	21	72.8%
	Occipital lobe	Yes	1	3.4%
		No	28	98.6%
Number of lobes of cerebrum affected by lesion		0 lobe	4	13.8%
		1 lobe	11	37.9%
		2 lobes	12	41.4%
		3 lobes	2	6.9%
		4 lobes	0	0%
Tumor classification (based on the origin)		Primary intracranial tumor	23	79.3%
		Metastatic tumor	6	20.7%
Radiation history		Yes	3	10.3%
		No	26	89.7%

The average of samples age in the study was (mean= 49.38; SD= 12.869) years with the average onset of cognitive symptoms was (mean=7.32; SD=5.43) months and neurological non-cognitive symptoms was (mean=6.25; SD=5.24) months. Meanwhile, in terms of MoCA-Ina score, the samples average for each section was: visuospatial (mean= 2.39; SD=1.499), naming (mean= 2.46; SD=0.838), memory (mean= 1.71; SD=0.713), attention (mean=2; SD-=1.01), language (mean=1.39; SD=0.567), abstraction (Mean= 1; SD= 0.72), delayed recall (Mean= 2.71; SD= 1.30), and orientation (Mean= 3.79; SD=1.13). The average of the MoCA-Ina total score was (Mean= 17.97; SD= 5.729) (below normal) that indicated there was a cognitive impairment in patients with brain tumor. On the other hand, normality test of numerical variables indicated that only the data of MoCA-Ina score which were normally distributed. The data of numerical variables univariate analysis result are described in table 2.

2. Bivariate Analysis

Bivariate test results were exposed in table 3 (bivariate comparative analysis) and 4 (bivariate correlative analysis). Data in the table revealed the analysis result that was statistically significant, namely a comparative analysis that indicated a difference in scores of abstraction (p=0.015) and total MoCA-Ina (p=0.042) between patients with tumors located in temporal lobe and non-temporal lobe tumor; a difference in scores of abstraction (p=0.034) and orientation (p=

0.042) between patients with tumors in supratentorial and infratentorial; and a difference in memory score (p=0.028) between patients with and without radiation history. Moreover, bivariate correlative analysis also discovered the occurrence of correlation which was statistically significant between the number of lobes affected by brain tumor and the score of attention (p=0.027; r=-0.409), abstraction (p=0.004; r=-0.524), orientation (p=0.021; r=-0.426), and total score of MoCA-Ina (p=0.018; r=-0.435).

Table 2. Sample characteristics (continuous data)

Variables	Mean	SD	Min.	Max.
Age (years)	49.38	12.869	21	73
Number of lobes of cerebrum	1.46	0.793	0	3
Onset of cognitive symptoms (months)	7.32	5.43	2	24
Onset of neurological non-cognitive symptoms (months)	6.25	5.24	1	24
MoCA-Ina Score				
Visuospatial	2.39	1.499	0	5
Naming	2.46	0.838	0	3
Memory	1.71	0.713	0	3
Attention	2	1.018	0	5
Language	1.39	0.567	0	2
Abstraction	1	0.72	0	2
Delayed Recall	2.71	1.301	0	5
Orientation	3.79	1.134	2	5
Total	17.97	5.729	6	28

DISCUSSION

Cognitive function is divided into nine domains: attention, concentration, visuospatial skill, construction, sensory function, perception, language, memory, executive function, intellectual, mood, mind, contents, personality, and behavior (Hickey and Hock, 2003). Each cognitive domain has its own neuroanatomic path and some of them overlap as well as vary in each study.

An article related with the anatomic correlation of cognitive function and its impairments indicated that the occurrence of frontal lobe lesion is related with the executive impairment and language deficit; the occurrence of lesion in temporal lobe is related with memory and language impairment; lesion in parietal lobe is related with visual deficit, spatial relations impairment and language processing disorder; lesion in brain stem is related with decreased attention (Fox et al., 2006).

This study reviewed the anatomic correlation of brain tumor patients and cognitive impairment symptoms assed by using MoCA-Ina. Cognitive deficit in brain tumor patients may be generated by tumor, tumor-related epilepsy and its therapy, and psychological stress (Taphoorn and Klein, 2004). However, this study did not investigate tumor-related epilepsy, the therapy (surgery, anti-epilepsy, chemotherapy, or corticosteroid), and patients' psychological stress.

The majority of the study samples had meningioma diagnosis. Meningioma is the most common type of brain and CNS tumor that accounted for a half of cases of non-malignant tumor in the US (Ostrom et al., 2015). The prevalence of brain tumor types in Indonesia varies in each region.

Table 3. Result of Bivariate Comparative Analysis

Variables	Sex		P	Tumor classification		p	Diagnosis		p	Radiation History		p
	Male	Female		Primary Intracranial Tumor	Metastatic Tumor		Meningioma	Others		Yes	No	
MoCA-Ina Score												
Visuospatial	12.06	16.33	0.201	15.26	14	0.741	14.44	15.69	0.686	18	14.65	0.51
Naming	17.5	13.88	0.215	15.91	11.5	0.186	15.94	13.85	0.442	16	14.88	0.802
Memory	16.61	14.28	0.453	14.43	17.17	0.442	14.53	15.58	0.718	16	14.88	0.028
Attention	17.78	13.75	0.174	13.72	19.92	0.067	14	16.23	0.419	16.5	14.83	0.71
Language	11.22	16.7	0.068	15.35	13.67	0.624	15.5	14.38	0.69	18.33	14.62	0.415
Abstraction	17.11	14.05	0.332	15.09	14.67	0.907	14.63	15.46	0.776	14.67	15.04	0.938
Delayed Recall	16.39	14.38	0.542	14.83	15.67	0.824	14.69	15.38	0.82	19.83	14.44	0.283
Orientation	17.89	13.7	0.204	15.07	14.75	0.933	13.97	16.27	0.454	18.5	14.6	0.436

Variables	Lesion Side			P	Tumor classification											
					Tentorium cerebelli		P	Frontal lobe		P	Parietal lobe		P	Temporal lobe		P
	Left	Right	Bilateral		Supra-tentorial	Infra-tentorial		Yes	No		Yes	No		Yes	No	
MoCA-Ina Score																
Visuospatial	14.81	18.58	13.1	0.44	14.7	16.88	0.627	15.82	14.23	0.608	14.03	16.19	0.487	11.69	16.26	0.186
Naming	13.85	18.25	14.55	0.459	14.12	20.5	0.104	14.32	15.63	0.628	13.91	16.35	0.37	11.38	16.38	0.098
Memory	13.73	19.17	14.15	0.333	14.62	17.38	0.51	16.61	13.5	0.281	13.03	17.42	0.129	11.38	16.38	0.12
Attention	15.31	16.58	13.65	0.729	14.32	19.25	0.215	13.96	15.97	0.466	13.25	17.15	0.157	11.25	16.43	0.091
Language	12.69	18.33	16	0.272	14.84	16	0.773	17	13.13	0.164	13.75	16.54	0.318	15	15	1
Abstraction	12.96	20	14.65	0.19	13.76	22.75	0.034	13.86	16.07	0.45	13.25	17.15	0.184	9.25	17.19	0.015
Delayed Recall	13.23	20.33	14.1	0.198	14.32	19.25	0.266	14.89	15.1	0.946	13.41	16.96	0.247	11.5	16.33	0.157
Orientation	13.62	20.5	13.5	0.184	13.76	22.75	0.042	14.29	15.67	0.651	13.25	17.15	0.203	11	16.52	0.106

In Dr. Cipto Mangunkusumo Hospital most cases are astrocytoma (47%) followed by meningioma (26%) and in Dharmais Cancer Hospital in the period of 1993-2012 most diagnosis were glioma (67%) (J Strong and Garces, 2016). The data related with sex, educational level, lesion side, location, radiation history, onset of symptoms, and average score of MoCA-Ina in brain tumor patients also vary.

This study indicated the occurrence of correlation between brain tumor and cognitive impairment, indicated by the average of MoCA-Ina total score of the study sample which was (mean=17.97; SD=5.29) (below normal rate). This study also discovered a statistically significant correlation between the number of lobes affected by tumor and MoCA-Ina score, that indicated the number of lobes had a strong negative correlation to abstraction score ($p=0.004$; $r=-0.524$) also had a sufficiently negative correlation to attention score ($p=0.027$; $r=-0.409$), to orientation ($p=0.021$; $r=-0.426$), and MoCA-Ina total score ($p=0.018$, $r=-0.435$). The study also had eliminated the occurrence of bias by exposing the absence of score difference between each domain and MoCA-Ina total score in patients with different educational level.

Most cognitive functions are conducted by neuroanatomy path of CNS located in supratentorial. However, the study only exposed the significant difference occurred in abstraction and orientation scores that concluded patients with tumor located in supratentorial had relatively lower score average for those scores. Other studies with bigger samples may give more meaningful descriptions. Moreover, the study also discovered the difference in the abstraction score and MoCA-Ina total score between patients with tumor located in temporal lobe and non-temporal lobe, that indicated the score average was higher in patients with tumor located on non- temporal lobe. However, it was still uncertain why it happened that way.

Radiotherapy is one the therapy modalities for patients with brain tumor. It may prolong the life expectancy despite its effect toward cognitive function. The study discovered the significant difference of memory score between patient with radiation history and without radiation history. It indicated that patients with radiation history had worse memory score. It is in line with another study that stated patients who obtain radio-chemotherapy are more susceptible to endure memory disorder compared to patients who do not (Klein, 2015). It is also discovered in pediatric brain tumor patients who obtain radiotherapy. They indicate reduced relative performance in experimental measurement of working memory, alertness process, and attention after subacute reaction toward the therapy (Raghubar et al., 2017). Memory and neurological/ other cognitive impairment is due to functional deficit of sub-granular hippocampal zone (SGZ) (Barani et al. 2007) or a part of hippocampus generated by the radiation exposure (Ghia et al., 2007). However, the study did not investigate the duration of radiation exposure, total dosage, dosage per fraction/other radiation parameters toward the patients. It requires other studies to investigate those matters and cognitive assessment including episodic memory that may provide clarity toward the effect of the exposure and it can be used as a reference for rehabilitation.

The study concludes that there is a correlation between brain tumor and cognitive impairment that is determined by using MoCA-Ina test and clinical manifestation of cognitive impairment discovered in patients correlated with neuroanatomy function of the brain which is affected by lesion. It is expected to conduct a multi-center study with bigger samples to be able to describe the more tangible prevalence and correlation. It needs further study on uninvestigated matters such as the difference of cognitive disfunction between patients with occipital lobe tumor and non-occipital as well as studies on patients with multiple tumor diagnosis.

AUTHORS CONTRIBUTION

The authors contributed to drafting, research design, data analysis, and discussion.

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CONFLICT OF INTEREST

There is no conflict of interest.

REFERENCE

Barani IJ, Benedict SH Lin PS (2007). Neural Stem Cells: Implications for the Conventional Radiotherapy of Central Nervous System Malignancies. Int. J. Rad. Oncol. Biol. Phys. 68(2): 324–333. Doi: 10.1016/j.ijrobp.2007.01.033.

Boake C, Meyers CA. (1993). Brain tumor rehabilitation: Survey of clinical practice. Arch Phys Med Rehabil. 74: 1247.

Fox SW, Mitchell SA, Booth-Jones M (2006). Cognitive impairment in patients with brain tumors: assessment and intervention in the clinic setting. Clin. J. Oncol. Nurs. 10(2): 169–176. Doi: 10.1188/06.CJON.169-176.

Ghia A, Tomé WA, Thomas S, Cannon G, Khuntia D, Kuo JS, Mehta MP (2007). Distribution of brain metastases in relation to the hippocampus: implications for neurocognitive functional preservation. Int J Radiat Oncol Biol Phys. 68(4):971-7. Doi: 10.1016/j.ijrobp.2007.02.016.

Hickey JV, Hock NH (2003). *Stroke and other cerebrovascular diseases. The clinical practice of neurological and neurosurgical nursing (5th ed.).* Philadelphia: Lippincott, Williams, & Wilkins.

Husein N, Lumempouw S, Ramli Y (2010). Uji Validitas dan Reliabilitas Montreal Cognitive Assessment Versi Indonesia (MoCA-Ina). Neurona. 27(4): 1–13.

J Strong M, Garces J (2016). Brain Tumors: Epidemiology and Current Trends in Treatment. J. Brain Tumors Neurooncol. 01(01): 1–21. Doi: 10.4172/2475-3203.1000102.

Johnson DR, Guerin JB, Giannini C, Morris JM, Eckel LJ, Kaufmann TJ (2017). 2016 Updates to the WHO Brain Tumor Classification System: What the Radiologist Needs to Know. Radiographics. 37(7):2164-2180. Doi: 10.1148/rg.2017170037.

Klein M, Taphoorn MJ, Heimans JJ, van der Ploeg HM, Vandertop WP, Smit EF, Leenstra S, et al. (2001). Neurobehavioral status and health-related quality of life in newly diagnosed high-grade glioma patients. J Clin Oncol. 19(20):4037-47. Doi: 10.1200/JCO.2001.19.20.4037.

McNeill KA (2016). Epidemiology of Brain Tumors. Neurol. Clin. 34(4): 981–998. doi: 10.1016/j.ncl.2016.06.014.

Olson RA, Iverson GL, Carolan H, Parkinson M, Brooks BL, McKenzie M (2011).

Prospective comparison of two cognitive screening tests: diagnostic accuracy and correlation with community integration and quality of life. J Neurooncol. 105(2):337-44. Doi: 10.1007/s11060-011-0595-4.

Ostrom QT, Gittleman H, Fulop J, Liu M, Blanda R, Kromer C, Wolinsky Y, Kruchko C, Barnholtz-Sloan JS (2015). CBTRUS Statistical Report: Primary Brain and Central Nervous System Tumors Diagnosed in the United States in 2008-2012. Neuro Oncol. 17(Suppl 4):iv1-iv62. Doi: 10.1093/neuonc/nov189.

GBD 2016 Brain and Other CNS Cancer Collaborators (2019). Global, regional, and national burden of brain and other CNS cancer, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet Neurol. 18(4):376-393. Doi: 10.1016/S1474-4422(18)30468-X.

Raghubar KP, Mahone EM, Yeates KO, Cecil KM, Makola M, Ris MD (2017). Working memory and attention in pediatric brain tumor patients treated with and without radiation therapy. Child Neuropsychol. 23(6):642-654. Doi: 10.1080/09297049.2016.1183608.

Taphoorn MJB, Klein M (2004). Cognitive deficits in adult patients with brain tumours. Lancet Neurol. 3(3): 159–168. Doi: 10.1016/S1474-4422(04)00680-5.

Tucha O, Smely C, Preier M, Lange KW (2000). Cognitive deficits before treatment among patients with brain tumors. Neurosurgery. 47(2):324-33; discussion 333-4. Doi: 10.1097/00006123-200008000-00011.

Tumors B, Weitzner MA (1999). Aspects of Patients with Primary. 17(4): 285–291.