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Correlation Between Magnetic Resonance Imaging (MRI) and Dynamic Mechanical Analysis (DMA) in Assessing Consistency of Brain Tumor

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***Abstract*---*Management of brain tumors require various disciplines collaboration. The choice of surgery equipment are based on accurate preoperative data of the brain tumor consistency. Non-invasive method of measuring brain tumor consistency can use MRI. Therefore, authors aim to analyze the correlation between MRI and DMA in assessing brain tumor consistency. This research is observational analytic study to find out the relationship between ADC ratio, T2-WI intensity, and FA value of brain tumor with its consistency using DMA modulus value after surgery. As comparison, we use agarose with four different concentrations. This study also looks for relationship*

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between ADC value, FA value, and T2-WI intensity of agarose with its modulus value on DMA device. We followed the patients since they have diagnosed with brain tumor until post-surgery. The Spearman correlation test shows correlation coefficient and p-value between ADC ratio, FA value, T2WI intensity and modulus in brain tumor which are r=0.026(p=0.915), r=0.549(p=0.015), and r= -0.181(p=0.459) respectively, also between ADC, FA value, T2WI intensity and modulus in agarose are r=0.600(p=0.400), r= -0.800(p=0.200), and r=0.632(p=0.368) respectively. So, there is correlation between FA values and modulus in brain tumor. However, the result of other variables did not show any correlation from this study.

Keywords---*apparent diffusion coefficient (ADC), brain tumor, dynamic mechanical analysis (DMA), fractional anisotropy (FA), magnetic resonance imaging (MRI), modulus value, T2 weighted image (T2WI)*

Introduction

Brain tumors account for about 85-90% of all central nervous system tumors. In the United States the incidence of malignant and benign brain tumors is 21.4 per 100,000 population per year (7.2 per 100,000 population for malignant brain tumors and 14.2 per 100,000 population per year for benign brain tumors). The incidence rate for malignant brain tumors worldwide based on the standard world population rate is 3.4 per 100,000 population. The mortality rate is 4.25 per 100,000 population per year. And mortality is higher in men. Men were more likely to be diagnosed with brain tumors than women, with a male: female ratio of 1.5:1. However, most meningiomas were more often found in woman than men (Strong et al., 2016).

There are several alternative options for treating brain tumors, including surgery, radiotherapy, and chemotherapy. The choice of the type of therapy depends on several factors, including the type and grading of the brain tumor, the location of the tumor in the brain, the size of the tumor, and the age of the patient and the general condition of the patient (Pruitt, 2015). Management of brain tumor requires the collaboration of various disciplines. The choice of surgery, and the use of tools are based on accurate preoperative data. The more complete the preoperative data, the better the preparation for surgery and anticipate any difficulties that may occur during surgery (Stadnik et al., 2001).

The consistency or elasticity of a brain tumor needs to be known before surgery because it is useful for surgery preparation such as the selection of a suction device, ultrasound aspirator, or cutting loop. In addition to the difficult location and hypervascularity of the tumor, the hard consistency of the tumor can make it difficult to resect. The difficulty will increase if the equipment prepared is not able to anticipate this. This situation not only has the potential to cause extended operating time but also operation failure. This can actually be prevented if we have complete and accurate preoperative management (Mauricio et al., 2001).

Magnetic Resonance Imaging (MRI) is a non-invasive procedure than can determine the consistency of brain tumors. Some of the methods or techniques used in MRI include Diffusion Weighted Imaging,DWI (Yogi et al,2014), T_2-WeightedImaging,T2WI Smith et al. (2015); Hoover et al. (2011), Diffusion Tensor Imaging, DTI Kashimura et al. (2007) and Magnetic Resonance Elastography, MRE (Kochenderfer et al., 2015; Murphy & Fox, 2017). Brain tumor consistency measurement from DWI, DTI and T2WI methods varies widely and shows different results for the same measurement method. Some studies conclude that MRE methode is more valid (Boxerman et al, 2016; Dwihapsari et al, 2011; Dwihapsari & Darminto, 2010; Kashimura et al, 2007; Pierallini et al., 2006). However, this method has not been implemented in Indonesia due to the limitations of supporting components.

Diffusion-weighted Magnetic Resonance Imaging Current (DW MRI) has more advantages compared to Magnetic Resonance Imaging conventional(MRI) as it can provide information on water diffusion in tissues. Nowadays, we can calculate the value of the Apparent Diffusion Coefficient (ADC) from DW MRI. ADC is useful in providing additional useful information in diagnosing patients with brain tumors, evaluating intra-axial tumors, and distinguishing between solid tumors, edema and normal brain (Yogi et al., 2013). Several quantitative indications can be obtained from DT MRI, including Fractional Anisotropy (FA), relative anisotropy and volume ratio. Fractional Anisotropy (FA) can measure precisely the degree of deviation from the isotropic diffusion. The result is influenced by histological findings such as the content of connective tissue within the tumor, which is generally recognized as a major factor determining the consistency of a meningioma (Kashimura et al., 2007).

The limitations of the components and the variability of measurement results as mentioned above require new and more accurate methods of measuring the consistency of non-invasive materials. In a previous study conducted by Cahyono (2010), regarding the relationship between ADC ratio values and T2WI signal intensity with brain tumor consistency, it was concluded that there was a relationship between brain tumor ADC ratio values and their consistency. The higher the value of the ADC ratio, the softer the tumor, on the contrary, the lower the value of the ADC ratio, the more elastic the tumor. The subsequent conclusion that brain tumor T2-WI signal intensity is related

to its consistency as well. The more hyperintense the brain tumor picture on T2-WI, the softer the tumor (Sener, 2001; Herneth et al., 2003).

Based on these studies, a non-invasive method of measuring the consistency of brain tumors can be developed using MRI. Brain tumor consistency was obtained from the measurement of the ADC ratio, the intensity of the T2WI signal and FA values on DTI and the results will be compared with the results of the modulus measurement from thetool Dynamic Mechanical Analysis (DMA). In this study also used samples in the form of agarose with various concentrations as a comparison (Xing et al., 1997; Giannotti et al., 2015).

Methods

This research is an observational analytic study with the aim of finding the relationship between brain tumor ADC ratio values, brain tumor T2-WI signal intensity, brain tumor FA values and brain tumor concistensy using DMA modulus values after surgery. As a comparison, we use samples in the form of agarose with four different concentrations This study also look for the relationship between ADC agarose ratio values, T2-WI agarose signal intensity, and FA agarose values with the agarose modulus value on the DMA device. The study population was all patients with suspected brain tumors who met the inclusion criteria. The research subject is the research population that meets the sample criteria. In this study, 33 samples were obtained for MRI examination, but only 19 samples were successfully examined with the DMA device. We followed the patient since the day they have diagnosed with brain tumor until after surgery. This research was conducted in RSUD Dr. Soetomo, RSAL Dr. Ramelan, and the Physics Department of the Sepuluh Nopember Institute of Technology Surabaya in September 2020 – March 2021. The examination of the brain tumor density test and agarose with the DMA device was carried out together with a Physics lecturer at the Sepuluh Nopember Institute of Technology Surabaya (Sajjad et al., 2019; Gordillo et al., 2013).

Result and Discussion

We analyze the data using Spearman correlation test. The correlation coefficient between the ADC ratio with the value of the DMA modulus in brain tumors is 0.026, with p = 0.915 (Table 1). These results shows that there is no correlation between ADC ratio with the value of the DMA modulus in brain tumors.

Table 1
Spearman correlation test between ADC ratio and DMA modulus in brain tumor

Spearman Correlation Test (Brain Tumor)		
ADC ratio and DMA modulus	p value	0.915
	r	0.026
	N	19

The correlation coefficient between FA values and DMA modulus values in brain tumors is 0.549, with p = 0.015 (Table 2). These results shows that there is a significant positive correlation between FA values with the DMA modulus value in brain tumors.

Table 2
Spearman correlation test between FA values and DMA modulus in brain tumor

Spearman Correlation Test (Brain Tumor)		
FA values and DMA modulus	p value	0.015
	r	0.549
	N	19

The correlation coefficient between T2WI signal intensity and DMA modulus values in brain tumors is -0.181, with p = 0.459 (Table 3). These results shows that there is no correlation between T2WI signal intensity with the value of the DMA modulus in brain tumors.

Table 3
Spearman correlation test between T2WI signal intensity and DMA modulus in brain tumor

Spearman Correlation Test (Brain Tumor)		
T2WI signal intensity and DMA modulus	p value	0.459
	r	-0.181
	N	19

The correlation coefficient between the ADC value with the value of the DMA modulus in agarose is 0.600, with p = 0.400 (Table 4). These results shows that there is no correlation between ADC value with the DMA modulus value in agarose.

Table 4
Spearman correlation test between ADC value and DMA modulus in agarose

Spearman Correlation Test (Agarose)		
ADC ratio and DMA modulus	p value	0.400
	r	0.600
	N	4

The correlation coefficient between FA values and DMA modulus values in agarose is -0.800, with p = 0.200 (Table 5). These results shows that there is no correlation between FA values with the DMA modulus value in agarose.

Table 5
Spearman correlation test between FA values and DMA modulus in agarose

Spearman Correlation Test (agarose)		
FA values and DMA modulus	p value	0.200
	r	-0.800
	N	4

The correlation coefficient between T2WI signal intensity and DMA modulus values in agarose is 0,632, with p = 0.368 (Table 6). These results shows that there is no correlation between T2WI signal intensity with the value of the DMA modulus in brain tumors.

Table 6
Spearman correlation test between T2WI signal intensity and DMA modulus in agarose

Spearman Correlation Test (agarose)		
T2WI signal intensity and DMA modulus	p value	0,368
	r	0,632
	N	4

In Spearman correlation test results between ADC ratio values and DMA modulus values in brain tumors, the value of r = - 0.218 (p = 0.371). This value indicates that there is no correlation between the ADC ratio and the DMA modulus value.

These results are different from the research conducted by Oh et al, which found a significant correlation between the ADC ratio values and the consistency of brain tumors. Consistency of brain tumors in study done by Oh et al was assessed by categorizing tumors obtained after surgery as cystic, gelatinous, friable, soft, firm, or hard. A significant correlation was found between ADC ratio values and consistency of tumor. Tumors with cyctic consistency have higher ADC ratio values than those with gelatinous, friable, soft, firm, or hard consistency (Oh et al., 2011). However, no examination was carried out by Oh et al with the DMA tool like our study (Işın et al., 2016; Jones, 1999).

In addition, the study from Al-Sharydah et al also stated that there was a relationship between the value of the ADC ratio and tumor consistency (Al-Sharydah et al., 2019). This is also different from the results of this study. This difference may be due to differences in the measurement of tumor consistency used. Where Oh et al and Abdulaziz et al measure tumor consistency by classifying the surgical findings. Meanwhile, in this study, tumor consistency was assessed by the DMA modulus .

From our result we can see the correlation between FA values and DMA modulus values in brain tumors, with the value of r = 0.549 (p = 0.015). This value means that there is a strong and significant correlation between the FA value and the DMA modulus value. From these data it can also be concluded that the higher the FA value, the higher the DMA modulus value in brain tumors. The results obtained in this study are in accordance with the research of Shiroishi et al which stated that the FA value was higher in tumors that had a hard consistency compared to tumors that had a soft consistency (Shiroishi et al., 2016). A prospective study with 110 meningioma samples also stated that the quantitative value of FA is a predictive value that can be used to assess the consistency of meningiomas (Kashimura et al., 2007; Romani et al., 2014).

In the Spearman correlation test results between T2WI signal intensity and DMA modulus value in brain tumors, we found the value of r = -0.181 (p = 0.459). This value indicates that there is no correlation between the intensity of the T2WI signal and the value of the DMA modulus in brain tumors. The results of this study differ from the study conducted by Oh et al which stated that the T2WI signal intensity value was correlated with tumor consistency. Tumors with soft consistency had a higher T2WI signal intensity than tumors with harder consistency. Oh et al's study concluded that the softer the consistency of the tumor, the higher the T2WI signal intensity value. It can also be seen from the results of the study which showed that tumors withconsistency cystic had a higher T2WI intensity value than those with hard consistency (Oh et al., 2011). This difference may be due to the different ways of assessing the consistency of brain tumors. In this study, the consistency of brain tumors was assessed by the value of the DMA modulus. While in Ohstudy the et al's consistency of brain tumors was assessed by categorizing tumors obtained after surgery. The tumor consistency after surgery was classified as cystic, gelatinous, friable, soft, firm, or hard (Oh et al., 2011; Shiroishi et al., 2016).

In the Spearman correlation test results between ADC ratio value and DMA modulus value on agarose, we found the value of r = 0.600 (p = 0.400). This value means that there is no relationship between the ADC ratio and the DMA modulus value. This is different from the research conducted by Jackson PR which stated that there was a significant opposite correlation between the ADC ratio value and the consistency of the tumor in the model. Jackson PR stated that the higher the ADC ratio value, the softer the consistency of the tumor (Jackson, 2012). This difference is probably due to the use of different agarose models and the value of the ADC ratio used. The model used by Jackson PR is Matrigel which contains a lot of extracellular matrix (Jackson, 2012). The content contained in the model can affect the difference in ADC values obtained in the results of Jackson PR's research and the results of this thesis research. In addition, the Jackson PR study only examined models with ADC values of 0.3 103 mm2/second Jackson (2012), while in this study several groups of ADC values were used, namely <0.6 103 mm2/second. ; 0.6-1.0103 mm2/sec; 1.0-1.4 103 mm2/sec; 1.4-1.8 103 mm2/sec; 1.8 103 mm2/sec.

In the Spearman correlation test results between FA value and DMA modulus value in brain tumors, we found the value of r = -0.800 (p = 0.200). This value means that there is no correlation between the FA value and the DMA modulus value. The results obtained in this study are in accordance with the results in Souza et al 's study which showed that the FA value was one of the valuable components of the imaging modality, but there was no correlation between FA values and tumor consistency in the model. The model used in Souzaresearch et al's is synthetic gel. According to Souza et al, this model is suitable for use inbiological tissueswhich will be measured with parameters on MRI including FA values (Souza et al., 2017).

In the Spearman correlation test results between T2WI signal intensity and DMA modulus value on agarose, the value of r = 0.623 (p = 0.368). This value means that there is no correlation between the intensity of the T2WI signal and the value of the agarose DMA modulus. The position of the MRI slice and the inhomogeneity of the magnetic field affect the average T2 signal intensity inagar phantom homogeneous. The highest signal intensities are usually found at the center position near the center of the gradient, and lower intensities are found at the more outward positions, indicating magnetic field inhomogeneity during scanning. The inhomogeneity found in the phantom head from ACR (American College of Radiology) was obtained fromsound radiofrequency and magnetic field gradient which had a greater effect on fast imaging sequences. Imperfect coils and poor eddy compensation that usually appears in fluid scanning using high magnetic field systems also contribute to inhomogeneity (Dwihapsari et al., 2020). This is what underlies the emergence of isointense results on 1% agarose and hyperintense on 2.5% agarose in this study (Kinoshita et al., 2008; Richardson et al., 2005).

In this study, the results obtained are different from the research conducted by Jackson PR which states that there is a significant opposite correlation between the intensity of the T2WI signal and the consistency of the tumor or tumor density. Jackson PR also mentioned, the higher the intensity of the T2WI signal, the softer the consistency of the tumor (Jackson, 2012). The difference between the results in the Jackson PR study and this study may be due to the sample used in the Jackson PR study only involving glioma tumor samples. In addition, the consistency measured by Jackson PR does not use the DMA modulus as in this study (Aryani & Lesmana, 2019; Archana et al., 2016).

Conclusion

There is a correlation between FA values and tumor consistency measured by DMA modulus in brain tumor. However, the result of this study did not shows any correlation in other variables. It is necessary to conduct a prospective study using a larger sample. Where it starts from the time the patient is diagnosed, then followed up to sampling according to MRI measurements in region of interest. It is also necessary to conduct research to analyze the ratio of ADC and FA to the types of brain tumors specifically to be able to determine the threshold value of each type of tumor.

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