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The Region of Interest in Determining the Proper Value of Full-Width at Half Maximum during Magnetic Resonance Spectroscopy

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ABSTRACT
Background: *MRS is an advanced examination of MRI producing a spectra that describe metabolite information of tissues. ROI setting becomes very important in generating the spectral diagnostic value called Full-Width at Half Maximum (FWHM). All collected FWHM data will assist physicians to determine the stage of brain tumors. In clinical applications, Radiographers select several ROIs in obtaining FWHM values without any particular benchmark which directly affects the accuracy of the brain tumor stage.*
Objective: *The purpose of this study is to examine the FWHM profiles based on the ROI selections and to determine the effect of selected ROIs on to FWHM values.*
Methods: *This research is a quantitative study with an experimental approach. Data were collected by an expert Radiographer during 30 days in June 2016 at Department of Radiology, Siloam Hospital Kebon Jeruk Jakarta using a particular bottle phantom MRI 2000 ml. The phantom was scanned with 1.5 Tesla MRI scanner, from which various selection of the ROIs sized 20 mm, 25 mm, 30 mm, 35 mm and 40 mm; at the several positions. The positions employed were the centre, 12 o'clock, 3 o'clock, 6 o'clock and 9 o'clock. The analysis was performed to define the adequate size of ROI generating an optimum FWHM values. Linear regression applied to conclude whether or not there is an influence of the ROI size in generating FWHM values.*
Results: *The results showed the optimum FWHM values of 12-20 were generated from the ROI size 20-30 mm at the center position. Regression analysis deemed significant (p-value <0.05) leading to a conclusion that the ROI size setting affects the FWHM values. The smaller the ROI size, FWHM value will decrease with higher homogeneity and vice versa.*
Conclusion: *ROI size setting affects FWHM value, and optimum FWHM value is generated by ROI size of 20 – 30 mm at the center position.*
Keywords: *Magnetic Resonance Spectroscopy, Region of Interest, Full Width at Half Maximum,*

Introduction

One of the diagnostic methods chosen to diagnose brain tumors is Magnetic Resonance Imaging (MRI). Organic functional examination using an MRI scanner with a brain tumor diagnosis would be more informative when an additional, advanced magnetic resonance spectroscopy (MRS) was added.

MRS is a procedure available on clinical MRI scanners that can provide clinically relevant information on types of diseases such as tumors, metabolic disorders, and systemic diseases. MRS is commonly used to view tissue metabolites such as liver, prostate, breast and most often utilized in the brain. The output of the MRS is a collection of multiple peaks representing each chemical element of the brain metabolite of a selected area. The multiple clusters form a spectrum that needs to be interpreted to make the diagnosis (Blüml, 2013).

If the MRI image describes the distribution and interaction of water on the network, on the contrary, the MRS analyzes the signals of hydrogen protons that are bound to other molecules in the brain metabolite. Metabolites in the brain containing protons that can be measured with MRI scanner 1.5 Tesla is a chemical element of several substances.

In benign tumors, there is increased choline and decreased creatine and N-acetyl aspartate (NAA), whereas in malignant tumors there is a greater increase in choline and increased lipid and lactate (John, 2004).

In MRS there are two techniques, namely single voxel spectroscopy (SVS) and chemical shift imaging (CSI) technique. SVS is a method used to record the spectrum of one brain region at a time, while CSI can simultaneously record the range of some areas to describe the spatial distribution of metabolites in the brain. SVS techniques were chosen to evaluate brain tumors for optimal metabolite information (Horská 2011).

MRS is different from MRI as it takes an important additional step which is setting the region of interest (ROI) using the image that has been obtained from routine MRI. Because detectable MRI chemicals have low concentrations, MRS is restricted to analyzing at specific ROIs that have a resolution far greater than MRI resolution. Not only does the operator need to decide the appropriate location, but there are also other factors such as size, averaging needed to get the spectrum of optimum quality, minimizing partial volume with surrounding tissue, avoiding bone, blood, air and cerebrospinal fluid objects.

According to Xu (2012), to get the diagnostic value of the MRS, the technical factors that need to be considered one of them is the pre scan adjustment shimming defined by the full-width at half maximum (FWHM) in the frequency domain. Prescan adjustment shimming is performed to increase the homogeneity of the magnetic field of the ROI to be assessed on the MRS. This practice determines the ability of MRS to produce a good spectrum. At the beginning of the emergence of MRS, spectroscopist always performs shift adjustment. Currently, MRI device can automatically perform shift change, but the use of manual shift adjustment can produce a more optimal spectrum. A sound spectrum is obtained from an ROI that is not too small and not too large and is not in the area of bleeding, calcification, bone, and air. If the voxel size is too small, it will produce a spectrum with low signal to noise (SNR) (Bluml, 2013).

On the MRS examination, there is uncertainty in the selection of ROI by the radiographer. The choice of ROI size is set to 20x20x20 or ROI size of tumor size. Change in the range of this ROI will affect the subsequent MRS procedure, which is in the process of prescan adjustment shimming in yielding FWHM value that determines the quality of MRS generated spectrum.

Materials and Methods

This study is a quantitative research with an experimental approach. Data collection was done in June 2016 at Radiology Department of Siloam Hospital Kebon Jeruk, Jakarta, Indonesia. Population and sample of research are ROI on scanning phantom MRS axial at ROI size: 20 mm, 25 mm, 30 mm, 35 mm and 40 mm; and at the position of ROI center, direction of clock 12, 3, 6 and 9. Respondent criterion is radiographer that inspect MRS with experience of MRS examination for more than five years and have followed MRI training. Variable control in this research was MRI 2000 ml phantom bottle, MRS protocol with localizer at center sequence and single voxel spectroscopy (SVS) sequence and invalidate adjustment.

Data analysis was done by descriptive analysis to see FWHM profile from different ROI selection on MRS, then statistic test with application of SPPS 16 using Linear Regression test to determine the effect of ROI size selection to FWHM value with α = 0,05 ($p < 0.05$).

Results and Discussions

A. Result

In this study, the authors observed the FWHM values of different size and ROI position settings. The author uses phantom MRI to control the sample used. The phantom is placed in the middle of the MRI inspection table, then scanning the localizer at center to make sure the object is in the iso center gantry of MRI.

Figure 1, Position of phantom MRI

Figure 2, Phantom sagital, coronal and axial localizer

After obtaining the sagittal, coronal and axial localizer (Figure 2), the SVS sequence 30 is added, then different ROI sizes (20 mm, 25 mm, 30 mm, 35 mm and 40 mm) in various ROI positions are adjusted at the following:

a. Location of ROI center in the middle of phantom

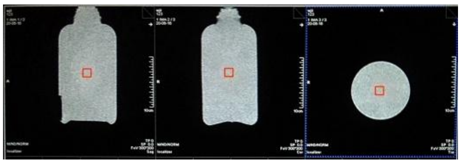

Figure 3, Position of ROI center

After adjusting the ROI at the center position, different ROI sizes are arranged (20 mm, 25 mm, 30 mm, 35 mm and 40 mm). ROI at the center position produces an average FWHM value of 15.75 - 22.16.

b. ROI position at 12 o'clock direction on axial slices

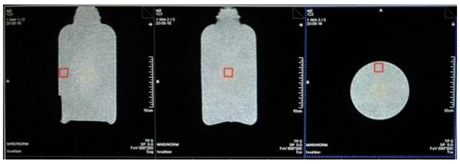

Figure 4, ROI position at 12 o'clock direction

ROI at 12-hour direction leads to an average FWHM value of 27.375 - 37.02

c. ROI position at 3 o'clock direction on axial slices

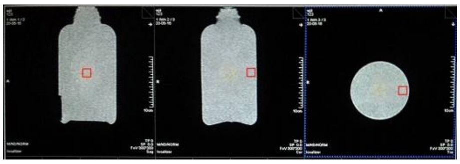

Figure 5 ROI position at 3 o'clock direction

ROI at 3-hour direction leads to an average FWHM value of 21.175 – 30.46.

d. ROI position at 6 o'clock direction on axial slices

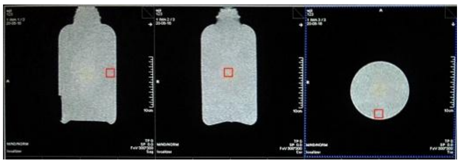

Figure 6, ROI position at 6 o'clock direction

ROI at 6-hour direction leads to an average FWHM value of 9.15 – 10.28.

e. ROI position at 9 o'clock direction on axial slices

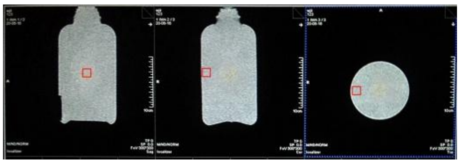

Figure 7 ROI position at 9 o'clock direction

ROI at 9-hour direction leads to an average FWHM value of 22.05 – 29.56.

In short, FWHM values are displayed in table form as follows:

Table 1.FWHM values at different ROI positions and sizes

ROI	20 mm		25 mm		30 mm		35 mm		40 mm	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0	15.75	0.0548	18.04	0.0548	19.44	0.0548	20.9	0	22.16	0.05477
12	27.375	0.0447	29.88	0.0447	32.88	0.0447	35.04	0.0548	37.02	0.04472
3	21.175	0.0447	23.66	0.0548	25.9	0	28.6	0	30.46	0.05477
6	9.15	0.0548	9.2	0	9.4	0	9.7	0	10.28	0.04472
9	22.05	0.0548	24.32	0.0447	26.78	0.0447	28.62	0.0447	29.56	0.05477

The mean value is derived from the average FWHM value of each position, and the ROI is measured five times. The SD (Standard Deviation) score is calculated from the standard deviation of 5 FWHM values at each post and ROI size. The SD value is sought to see the large difference in sample value against the average or sample diversity.

Based on Table 1 on FWHM values on different sizes and ROI positions, it can be seen from the standard deviation value that the comparable data is generated from the ROI position at the 6 o'clock direction and the least similar data is generated from the ROI position in the 9 o'clock direction. The overall standard deviation of the FWHM value data on different sizes and ROI positions is still at a low standard deviation value, which means the FWHM value data at various sizes and ROI locations has a moderately small degree of diversity.

The optimum FWHM value is the value of 12-20 resulting from the ROI size of 20-30 mm at the center ROI position. The 20 mm ROI size at different positions yields the lowest FWHM values compared to the 25 mm, 30 mm, 35 mm and 40 mm ROI sizes. Similarly, the 40 mm ROI size at different positions yields the highest FWHM values compared to the 25 mm, 30 mm, 35 mm and 40 mm ROI sizes. The minimum FWHM value is generated from the 20 mm ROI size at six o clock direction, while the maximum FWHM value is generated from the 40 mm ROI size at the center position.

The lowest FWHM value is generated from setting the ROI size of 20 mm. The larger the ROI size, the higher the FWHM value. The highest FWHM value is made from ROI at 12 o clock direction. ROI at six o clock direction yields almost the same FWHM value on different ROI sizes. ROI at 3 o'clock direction and 9 o'clock direction has FWHM value in almost the same range.

A Linear Regression test is performed to determine the effect of ROI size to the value of FWHM produced. Before the linear regression test, the data normality is tested by using Shapiro Wilk test to find out whether the data is normally distributed.The results of the linear regression analysis on the FWHM value against the ROI size setting are shown in the following table:

Table 2 Regression test result of FWHM value to ROI size

Position of ROI	r	*R Square*	*P value*
Center	0.993	0.986	
12 o'clock direction	0.997	0.994	
3 o'clock direction	0.999	0.998	< 0.05
6 o'clock direction	0.941	0.885	
9 o'clock direction	0.853	0.727	

Based on Table 2. R Square value of regression test result is close to 1 meaning that there is a strong correlation between ROI size setting to FWHM value with very strong correlation coefficient. Thus, it is concluded the use of a large ROI size will result in a high FWHM value when compared to the use of smaller ROI sizes. However, the ROI arrangement on MRS examination is regulated based on the size and type of tumor or tissue to be assessed for its metabolite value.

Discussion

In this study, the object used is the phantom MRI to see the profile of FWHM values resulting from different ROI size settings. In Table 1 the FWHM value on various ROI sizes indicates an increase of FWHM value against magnification of ROI size. This means the greater the regulated ROI, the higher the FWHM value which means the homogeneity is decreasing or inhomogeneous. The FWHM value at different ROI positions indicates that the location or position of the ROI also affects the FWHM value. The increase of FWHM value to the increased ROI size is shown in Table 3.

Table 3. Increased percentage of FWHM value to Increased ROI Size

ROI positions	Increased percentage			
	20 – 25 mm	25 – 30 mm	30 – 35 mm	35 – 40 mm
Center	15%	8%	8%	6%
12	9%	10%	7%	6%
3	12%	9%	10%	7%
6	1%	2%	3%	6%
9	10%	10%	7%	3%

What the percentage value of FWHM increases to ROI size increase is obtained from FWHM value resulting from ROI size 25 mm minus FWHM value resulting from ROI size 20 mm, then divided by FWHM value resulting from ROI size 20 mm. The calculation is also done on the value of FWHM arising from the scale of another ROI so that the value obtained percentage increase in FWHM value to increase ROI size. Based on Table 3, the percentage increase of FWHM value to ROI size increase, it can be seen that the growth of FWHM value to increase ROI size is not constant and not always the same.

The percentage increase of FWHM value to increase ROI size with the lowest growth rate resulted from FWHM value at ROI position at 6 o'clock. FWHM value in this post has grown to increase ROI size with percentage 1-6%, whereas in ROI in other area is generated rate an increase in FWHM value of 3-15%. According to Bluml (2013), FWHM values can only be observed at one time or real time. This occurrence is because the FWHM value is produced from the metabolite content of an object or tissue, where the metabolite of an atom will always experience movement in this term commonly referred to as chemical shift. So the increase of FWHM value to ROI size increase is not constant and not always the same.

According to Hornak (2014), the optimum FWHM value is at a value of 12 - 20. In this study optimum FWHM with a value of 12-20 generated from 20-30 mm ROI size at the center position. This condition corresponds to the theory of magnetic susceptibility and B_0 inhomogeneity that the iso center portion will be more homogeneous. This is due to B_0 inhomogeneity and susceptibility. B_0 inhomogeneity distorts image in terms of spatial and intensity. Distortion power produces B_0 inhomogeneity in an area. This area has a different FID so that the resulting signal is mixed. When homogeneity is little, FID will decrease, and the resulting signal also drops. While susceptibility is the magnetic properties that a material possesses in generating a magnetic field. This causes the magnetic properties around the object to be attracted to produce different signal too. Susceptibility usually increases at the location of the magnetic field in iso center, so homogeneity increases, FID increases, and the resulting signal increases.

From the results of the research in Table 1, FWHM value at six o clock position led to small FWHM value with FWHM value of 9.15 - 10.28 with the lowest increase percentage of 1 - 6% compared to the rate increase of FWHM value in another ROI position. This is because the post of ROI at 6 o'clock direction is close to the surface coil. According to Drost (2002), the lower the FWHM value, the better homogeneity. However, this is not followed by an increase in SNR, where SNR itself is one of the factors affecting the quality of the resulting spectrum on MRS examination.

ANOVA resulted from the significance p - value <0.05 indicating the rejection of Ho and acceptance of Ha, hence there is influence significantly from ROI measure which regulated to FWHM value that produced. To see the relationship of ROI size that is set to FWHM value on different ROI position as a whole, we can see the value of equation of line with linear regression criteria with linear function shown on graph of influence of ROI size to FWHM value at ROI center position, clock direction 12,3 , 6 and 9. From the whole chart, the straight lines can be increased, so it can be concluded that the greater the ROI size that the resulting FWHM value will increase. This is in line with the theory of Bulml (2013), the higher the regulated ROI, the metabolites contained therein the more, so the FID value decreases where the FID value is inversely proportional to the FWHM value so that the resulting FWHM will increase.

This means that the smallest possible use of ROI can produce the lowest possible FWHM value, so the homogeneity is better. But in clinical practice, it cannot be applied that way. Averaging is also required to obtain a sample of the metabolites of tissue to be seen.

Limitations of this research are the object of study used is phantom to control the sample. MRS is a clinical examination of tumor cases where there are often varying sizes, locations, shapes and types of tumors with different metabolic content resulting in various FWHM values, resulting in free samples. Besides, it will take time to collect research samples with certain criteria to control the sample. Besides, the use of this phantom object can be utilized as a research object because in this study only conducts survey of ROI selection to the resulting FWHM value, not to produce MRS spectrum. With the use of phantom, researchers are also easier to control the sample that is in phantom position in the gantry, ROI position on phantom and adjustment.

Conclusion

The smaller the ROI size, the lower the resulting FWHM value and the higher homogeneity level. Conversely, the larger the ROI size, the greater the FWHM value and the low uniformity level. The optimum FWHM value is generated at a 20-30 mm ROI at center position.

Linear regression test results at sig value <0,05 so it can be concluded that there is influence from arrangement of ROI measure to FWHM value produced.

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