Determination the Ischemic Stroke of Brain MRI Based On Apparent Diffusion Coefficient (ADC) with b Value Variation

A. Zuhriyah¹, A. Muzzamil¹, S.D. Astuti¹, Suhaningsih*¹

¹Department of Physics, Faculty of Science and Technology, Airlangga University, Surabaya, Indonesia
E-mail: suhaningsih@fst.unair.ac.id

Abstract. The Research to Determination the Ischemic Stroke of Brain MRI Based on Apparent Diffusion Coefficient (ADC) with b Value variations. The purposes of this study were to find b value variations of Diffusion Weighted Image (DWI), determining the optimum b value to find out the Contrast to Noise Ratio (CNR) ischemic stroke lesion in DWI image, and To determine the Diffusion Coefficient range obtained from the ADC (Apparent Diffusion Coefficient) value between old ischemic stroke and new ischemic stroke. In this research, used are 0, 500, and 1000 s/mm². The result obtained b value influence on the quality of DWI were analyzed in 30 patients suspected with old ischemic stroke and new ischemic stroke. Data analysis was done quantitatively with the Region Of Interest (ROI) directly on computer MRI image planes and were conducted statistical tests Signal to Noise Ratio (SNR) and Contrast to Noise Ratio (CNR). The highest Signal to Noise Ratio (SNR) found in b 0 s/mm², while the highest Contrast to Noise Ratio (CNR) on the b 1000 s/mm². The statistics test show that significant SNR value of the Lesion, around the lesion, Liquor, WM, GM tissue is about 0,000 (p<0,05), while for the Contrast to Noise Ratio (CNR) of the lesion and around the lesion tissue is about 0,000 (p<0,05). This results showed that b value variation have a difference at lesion, around the lesion, Liquor, WM, GM tissue for MRI imaging quality. SNR and CNR are important aspect on imaging optimization process to give the diagnose information. In this research, the diffusion coefficient value in new ischemic stroke is < 1 x 10⁻³ mm²/s, whereas the old ischemic stroke is > 1 x 10⁻³ mm²/s, the results showed that 15 patients have new ischemic stroke and 15 patients have old ischemic stroke.

1. Introduction
The brain is an organ that has many parts and functions those specific and different. Ischemic stroke is a disease that occurs due to blockage of the brain blood vessels or rupture of blood vessels in the brain [1], so that due to blockage or rupture of the arteries. This will cause various symptoms. These symptoms can be detected by using an examination (Magnetic Resonance Imaging) MRI. MRI is a method of diagnostic testing in medical science [2], especially radiology that produces images of human body pieces using magnetic fields with out using X-rays [3]. MRI imaging techniques are relatively complex because the resulting image depends on many parameters that must be set before inspection [4]. If the selection of parameters is correct, the quality of the detailed description of the human body will be apparent .One of the MRI sequence parameters that is very good and very related
to the concept of physics is diffusion to display the brain abnormalities that occur above is DWI-ADC [5].

DWI MRI sequences are used to describe the movement of molecules randomly on a tissue (diffusion). Diffusion sensitivity is controlled by b value. b value can be expressed in units s/mm². The used b value variations are 0 s/mm², 500 s/mm² dan 1000 s/mm² where b 0 is the starting point, b 500 is the midpoint and b 1000 is the maximum limit of MRI 1.5 Tesla [6], so the b value is the length of the gradient working for each particular area (s/mm²). The existence of the b value is to obtain the relationship between each b value, then it is necessary Apparent Diffusion Coefficient (ADC). ADC is post processing from DWI by calculating 3 sets of DWI that having different values. The direct clinical application of diffusion imaging is to diagnose ischemic stroke.

Therefore, in this study an analysis of variation in b value was carried out, with 3 b values 0 s/mm², 500 s/mm² dan 1000 s/mm². B value variation will affect the image of the DWI, the value of SNR and CNR, to assess the most optimal image in ischemic stroke cases can be seen from the value of Contrast to Noise Ratio (CNR). CNR is the difference in Signal to Noise Ratio (SNR) between adjacent organs. When it is correlated between the process of ischemic stroke / blockage with the diffusion process that occurs in it, it can be studied more deeply about the length of diffusion that occurs until it produces an intensity signal that indicates a flow disturbance which can be seen the value of Contrast to Noise Ratio (CNR) in b value and range of diffusion coefficients in the ADC image, so that it can inform the doctor about when this ischemic stroke occurs and will make it easier for doctors to categorize the occurrence of the ischemic stroke,

2. Material and Methods

This research was conducted at Brain Clinic Surabaya by using an MRI Siemens aircraft on 30 patients. The research sample is scanning. Scanning by adjusting the transverse crossing of the brain as a whole with patients suspected of ischemic stroke The research sample is scanning. Other general parameters that need to be controlled in a homogeneous state are Average, FOV, Resolution and FA. Scanning with b value variation of 3 variations as the independent variable examined for the dependent variable, the ADC value. The tissue being analyzed are lesion, Edge of the lesion, Liquor, Gray Matter (GM), White Matter (WM). The diffuse SNR, CNR and coefficient values. The tissue and diffusion coefficient are analyzed for the magnitude of the signal by the technique Region of Interest (ROI).

![Figure 1. Determining ROI](image)

The ROI technique is used by researchers in signal capture in an area getting special attention so that the area can represent the existing tissue. The requirement for ROI is to take an area with a cross-sectional area with the minimum standard deviation possible. The area in ROI must have a homogeneous intensity.

3. Result and Discussion

The results obtained DWI images with axial intersections using 3 variations in values from thirty respondents in each b value, carried out from the analysis of SNR and CNR by taking the mean value
which is a signal from tissue lesions, lesion edges, liquor, white matter (WM), Gray Matter (GM) and SD values are taken as the background noise. Tissue and background are analyzed for the signal size by the Region of Interest (ROI) technique.

3.1 Signal to Noise Ratio (SNR) Analysis

![Figure 2. Graph of the effect of variations in b value on SNR Value](image)

From Figure 2 it can be seen that the greater of b value, the SNR value falls on each tissue, namely lesions, edges of lesions, liquor, white matter (WM), Gray Matter (GM).

3.2 Contrast to Noise Ratio (CNR) Analysis

![Figure 3. Graph of Effect of Variation in b value on CNR Value](image)

Figure 3 can be seen that the CNR value of the adjacent tissue is the lesion and lesion edge tissue has increased, at b values 0, 500 and 1000 s / mm2.

3.3 Analysis of Apparent Diffusion Coefficient (ADC)

Apparent Diffusion Coefficient (ADC) is the diffusion coefficient obtained from DWI sequences with a specific set of b values. Then the DWI image will appear in each b value, then the three DWI images will become one image, namely ADC. The ROI results of the ADC image are divided by 1,000,000 so that the diffusion coefficient (ADC) value is obtained from 30 patients which can be seen in Table 1.
Table 1. The results of the analysis of the value of the diffusion coefficient in each category of ischemic stroke

| No | Stroke iskemik lama | Stroke iskemik baru |
|----|---------------------|---------------------|
| 1  | 3.0480 \times 10^{-3} | 0.6038 \times 10^{-3} |
| 2  | 1.9976 \times 10^{-3} | 0.9335 \times 10^{-3} |
| 3  | 1.1719 \times 10^{-3} | 0.5629 \times 10^{-3} |
| 4  | 2.5576 \times 10^{-3} | 0.6462 \times 10^{-3} |
| 5  | 1.9197 \times 10^{-3} | 0.9268 \times 10^{-3} |
| 6  | 1.7423 \times 10^{-3} | 0.5503 \times 10^{-3} |
| 7  | 2.0314 \times 10^{-3} | 0.6336 \times 10^{-3} |
| 8  | 1.4297 \times 10^{-3} | 0.6168 \times 10^{-3} |
| 9  | 3.1991 \times 10^{-3} | 0.5369 \times 10^{-3} |
| 10 | 2.5604 \times 10^{-3} | 0.8829 \times 10^{-3} |
| 11 | 1.9058 \times 10^{-3} | 0.8453 \times 10^{-3} |
| 12 | 2.0096 \times 10^{-3} | 0.5638 \times 10^{-3} |
| 13 | 2.3343 \times 10^{-3} | 0.6408 \times 10^{-3} |
| 14 | 3.0419 \times 10^{-3} | 0.717 \times 10^{-3} |
| 15 | 2.061 \times 10^{-3}  | 0.9513 \times 10^{-3} |

Based on the data analysis result of the diffusion coefficient value shown in table 1, it was found that the range of the diffusion coefficient value in the new ischemic stroke is $< 1 \times 10^{-3}$ mm$^2$/s, whereas in the old ischemic stroke the range of diffusion coefficient values is $> 1 \times 10^{-3}$ mm$^2$/s [7].

3.4 Effect of Variable Value on SNR and CNR Values

Based on the values that have been obtained from the results of quantitative calculations, it can be seen the relationship between SNR and CNR on b value variation was given. The SNR and CNR relationship is shown in Figure 4.

![Figure 4. Effect of Variable Value on SNR and CNR Values](image-url)

Based on the graph it is known that with b value variation (0.500,1000s/mm$^2$) SNR value has decreased while the CNR value of each patient has increased. If reviewed in theory and seen from the results of the quantitative calculation of SNR and CNR, then there is suitability when the SNR value is low, the CNR value will be high, and vice versa.
Physically the b value is the length of the broad unity gradient field. If the scanning time is long, the scanned area produces thinner slices so that each slice will produce a detailed image. Therefore, a large b value will produce a strong signal with bright contrast. Conversely, if the scanning time is short, the slices in the area to be scanned will be thick. The resulting image has a weak signal with a darker image contrast [8]. This is related to the formula:

\[
\frac{S}{S_0} = e^{-bd}
\]

When b value is high, the produced Dwi signal will be low (dark) and vice versa, when used b 1000, the resulting SNR value will be low (dark) but when used b 0 then the signal intensity will be high (bright) this is because when initial RF is given [9], then the precession will occur with the unidirectional phase producing a clear signal in all areas which are normal or not so that the lesion does not appear with the detailed contrast, then given a gradient pulse which had a phase which was in the same direction as a different phase, this causes the signal to disappear (dark) due to the movement of water molecules, then the H atom will come out of the examination voxel then given refocusing (the polarity is opposite to the gradient pulse) because in principle, in theory, the opposite polarity will cause a condition of the material to vibrate so that if there are immovable water molecules /only vibrates from a voxel then the signal will be recorded or produce a high signal (white) while moving water molecules or H atoms out of the voxel, the signal will not be recorded or rephased (signal loss) which causes the color to darken at a b value of 1000 s/mm\(^2\) [10].

3.5 Effect of DWI image on Apparent Diffusion Coefficient (ADC) Value

The use of Diffusion Weighted Image (DWI) sequences in this study with b value variation of 0.500, 1000s/mm\(^2\). The DWI sequence is a parameter of MRI that applies the diffusion principle describing the random movement of water molecules [11]. Diffusion detects limited motion, so that the resulting signal is low with high contrast or brighter and can be categorized as a new ischemic stroke. The statement matches the equation

\[
\frac{S}{S_0} = e^{-bd}
\]

Based on the above equation when D (diffusion coefficient) is high then Dwi signals the result will be low (dark) which can be categorized as an old ischemic stroke, while when D is low then the Dwi signal will be high (new ischemic stroke). A low diffusion coefficient produces a bright image to find the ADC value using the equation [12]:

\[
ADC = \frac{Citra\ ADC}{1.000.000}
\]

The ADC image is obtained from the signal (mean) with the ROI technique on the ADC map which is arranged from the calculation of 3 b values.

3.6 Determination of Optimal Value b value for DWI Images

Optimal value of b value variation 0 s/mm\(^2\), 500 s/mm\(^2\), 1000 s/mm\(^2\). In terms of the graph, the relationship between CNR values in ischemic stroke cases was the highest value at the time of b value 1000 s/mm\(^2\). To obtain optimal image quality, CNR values in cases of ischemic stroke must be high, because when b value is high the scanning time gradient is longer, diffusion signal intensity will increase and the intensity of the increasing diffusion signal in normal brain tissue will appear darker in the brain image displayed, especially in cases with pathology. The CNR value must be high so that it can distinguish between pathological regions and normal areas [13-14]:

4. Conclusion

Result of the research showed the longer the use of gradient fields at b value 0, 500 and 1000s/mm\(^2\). The further clarify the limited diffuse area (anisotropic) and the further eliminate the signal in an area that is infinitely diffused (isotropic) in the DWI image. The best b value is to explain the optimal DWI
image contrast in the lesion, namely b value 1000s/mm² because at that value the signal having a restriction of the limited area / diffuse is getting brighter. The Diffusion Coefficient value is obtained from the ADC value of the new ischemic and old stroke and for thirty samples there were 15 categorized as new ischemic strokes is < 1 ×10⁻³ mm²/s, while 15 patients in the old ischemic stroke the range of the diffusion coefficient value is >1 ×10⁻³.

References

[1] Price, Sylvia A & Lorraine M. Wilson (2005). Pathophysiology. Clinical Concepts of Disease Processes (6th ed), (Brahim U pendit, penerjemah). Memphis, Michigan : Mosby (sumber asli diterbitkan 2002)
[2] Notosiswoyo, Mulyono., Susy S. 2004. Pemanfaatan Magnetic Resonance Imaging (MRI) Sebagai Sarana Diagnosis Pasien. Dosen Poltekkes Jurusan ATRO.
[3] E. Hahn and R. Ernst, 2016. MAGNETIK RESONANS INTI ( MRI ),” pp. 1–64
[4] C. Wesbrook, 2014. Handbook MRI Technique Fourth Edition. This edition first published 2014 © 2014 by John Wiley & Sons, Ltd.
[5] Chol S, Ha DH, Kang MJ, Lee JH, Yoon SK.2013. Does The ADC Map have additional clinical significance compared to the DWI in the brain infraction. Journal of the Korea society of Magnetic Resonance In Medicine ; 17(4) : 267-274
[6] Westbrook C, Roth CK, Talbot. J.2011. MRI in practice . Edisi 4.Cambridge : Wiley-Blackwel.
[7] Nellyta L.Liza. 2014. Konsep Apparent Diffusion Coefficient (ADC) : FK Universitas Indonesia.
[8] Sutoyo,edy. 2009. Teknik Pengolahan Citra Digital : yokyakarta
[9] Priyawati, Diah., Indah Soesanti, Indriana Hidayah. 2015. Kajian Pustaka Metode Segmentasi Citra pada MRI Tumor Otak. Jurusan Teknik Elektro dan Teknologi Informasi Fakultas teknik Universias Gadjah Mada. Prosiding SNST ke-6 Fakultas Teknik Universitas Wahid Hasyim. Semarang.
[10] Peter J. Basser and Evren Ozarslan, 2009, Introduction to Diffusion MR, Elsevier Journal.
[11] Atlas, S.W. 2009. Magnetic Resonance Imaging,Philadelphia : Walter Kluwer. Bontrager, K.L
[12] Siemens Healthcare GmbH, 2017. Apparent Diffusion Coefficient : Asean Business Centre.
[13] SD. Astuti, NVI. Astutik dan A. Muzamil, 2017, Optimalisasi Parameter Bandwidth dan Time Echo untuk Mengurangi Susceptibility Artifacts dan Chemical Shift pada MRI, Jurnal Biosains Pascasarjana vol 19 no.3
[14] SD. Astuti, A. Muzamil dan N Aisyiyah, 2017, Analisis Kualitas Citra Tumor Otak Dengan Variasi Flip Angle (FA) menggunakan Sequence T2 Turbo Spin Echo Axial pada Magnetic Resonance Imaging (MRI), Prosiding Pertemuan Ilmiah Tahunan (PIT) Fisika Medis dan Biofisika Vol 1. no.1