Optimization image of magnetic resonance imaging (MRI) T2 fast spin echo (FSE) with variation echo train length (ETL) on the rupture tendon achilles case

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Abstract. The research was done the optimization image of Magnetic Resonance Imaging (MRI) T2 Fast Spin Echo (FSE) with variation Echo Train Length (ETL) on the Rupture Tendon Achilles case. This study aims to find the variations Echo Train Length (ETL) from the results of ankle’s MRI image and find out how the value of Echo Train Length (ETL) works on the MRI ankle to produce optimal image. In this research, the used ETL variations were 12 and 20 with the interval 2 on weighting T2 FSE sagittal. The study obtained the influence of Echo Train Length (ETL) on the quality of ankle MRI image sagittal using T2 FSE weighting and analyzed in 25 images of five patients. The data analysis has done quantitatively with the Region of Interest (ROI) directly on computer MRI image planes which conducted statistical tests Signal to Noise Ratio (SNR) and Contras to Noise Ratio (CNR). The Signal to Noise Ratio (SNR) was the highest finding on fat tissue, while the Contras to Noise Ratio (CNR) on the Tendon-Fat tissue with ETL 12 found in two patients. The statistics test showed the significant SNR value of the 0.007 (p<0.05) of Tendon tissue, 0.364 (p>0.05) of the Fat, 0.912 (p>0.05) of the Fibula, and 0.436 (p>0.05) of the Heel Bone. For the contrast to noise ratio (CNR) of the Tendon-FAT tissue was about 0.041 (p>0.05). The results of the study showed that ETL variation with T2 FSE sagittal weighting had difference at Tendon tissue and Tendon-Fat tissue for MRI imaging quality. SNR and CNR were an important aspect on imaging optimization process to give the diagnose information.

1. Introduction
Radio diagnostic, a radiological branch, aims to diagnose an abnormality experienced by the patient. The radio diagnostic equipment has a wide range of advanced tools for instance CT-Scan, Magnetic Resonance Imaging (MRI), Mammography, Fluoroscopy, Angiography, and X-ray. MRI is the main imaging modality in evaluating the soft tissue and central nervous system because of its ability to multilane. Besides, it also provides detailed description of the human body with good contrast and differences in anatomical imaging.
In order to obtain the quality image of MRI, it has to consider many things related to imaging techniques of MRI. One of them in the calculation the sequences and contrast to suit the purpose of inspection are the determination of the parameters Time Repetition (TR), Time Echo (TE), Echo Train Length (ETL), Number of Excitation (NEX), slice thickness and the other parameters that can affect the results of MRI images [1].

Magnetic resonance imaging (MRI) is a non-ionizing scanning tool [2], which is capable to imaging the organs were examined based on the principle of magnetic resonance of atomic nuclei of hydrogen by using a radio frequency signal (RF) and magnetic field at a certain scale [3].

Fast Spin Echo (FSE) is one of the sequence spin echo (SE) with fast scan time. FSE awards pulses with one pulse of 90° followed by a multiple pulse of 180° rephasing within one repetition time (TR). Application of multiple pulses per TR will produce the sequence of echo called Echo Train Length (ETL). Each echo has differences depending phase encode each of the TR and full fill different lines in k-space which equal to the image formation [4].

Determining the value of ETL considerable influences the results of MRI image for base of the patient (cooperative and non-cooperative). Echo train length on weighted T2 FSE can cause a blur image affecting the value of the Signal to Noise Ratio (SNR) and Contrast to Noise Ratio (CNR) which considered as one of the weaknesses of the FSE [4].

K-space is a space of propagation frequency where the signal of frequency derived from the patient. K-space will be filled quickly so that the scanning time will be shorter because of ETL effective which consider as the excess of the FSE and it creates a strong signal to liquid and imaged nerve in detail [5].

T2 weighting is very important in showing the image of the structure of the Achilles tendon, especially in sagittal slices compared to conventional SE technique [6-9].

Signal to Noise Ratio (SNR) and Contrast to Noise Ratio (CNR) obtained under the provisions of Bryan, [10] is:

\[ SNR = \frac{S_1}{N} \]  \hspace{1cm} (1)

Contrast to Noise Ratio (CNR) is:

\[ CNR = \frac{S_1 - S_2}{N} \]  \hspace{1cm} (2)

Where:
- S1 is the first sign that will be measured its region of interests value. It has matched with the anatomy information which will be evaluated.
- S2 is the second sign that will be measured its region of interests value. It has matched with the information which will be evaluated.
- N is stand for noise that is signal distraction in the ROI measurement on background.

2. Method

The research subject was the result of MRI imaging as many as 20 images on each variation Echo Train Length (ETL) on T2 weighted Fast Spin Echo (FSE) sagittal from some patients (at least 4 patients) which performed in the radiology Haji Hospital of Surabaya. Spin Echo T2 weighted image in MRI ankle obtained by several procedures prepared by patients for instance equipment preparation materials, patient positioning, scanning, image acquisition, determining ROI, evaluating the SNR and CNR. Scanning began with the protocol, then the variation ETL assumed as other constant parameters.

Determining Region of Interest (ROI) made directly on the computer of MRI with direct ankle ROI method. Computer MRI signal value determined on Tendon Tissue, Fat, Fibula,
Heelbone and outside the tissue or noise (noise). Selection of these tissues connected to the composition of the most tissue, then obtained the evaluation of SNR and CNR values as well as the time of the examination. Example of determining ROI is presented in Figure 1.

![Figure 1. Determination of ROI](image)

3. **Analysis**

To obtain the average value of the signal that has been processed by Fast Fourier Transform (FFT), in the form of the mean signal of direct ROI on tissue were 1 (tendons), the tissue 2 (FAT), the tissue 3 (fibula), and 4 (heelbone), and noise on the background tissue. In addition, the sending acquired scanning inspection time of each variation of Echo Train Length (ETL).

The obtained data was analyzed to determine the value of Echo Train Length (ETL) optimal results and obtain the best image of the optimal scan time. Both of them can be used as the standard in MRI examination diagnosis of Achilles tendon rupture in the hospital who had Radiology.

The quantitative data analysis on ROI method was used to determine the influence of ETL in k-space to image-quality value SNR and CNR significantly on any determined tissue to do ANOVA (Analysis of Variance) [4].

4. **Result and discussion**

After acquiring the sagittal T2 Fast Spin Echo ankle MRI images of five patients on any variation of ETL, there were more than 20 results matched with the pictures. In scanning process, it was selected a suitable picture project from all pictures. Thus, it showed the identified tissue areas namely tendon tissue, fat, fibula, heelbone (Calcaneus) and background and collected the signal from each tissue to be identified directly with the technique of ROI (Region of Interest) on the computer MRI of each image to analyze quantitatively the value of signal to Noise Ratio (SNR) and the Contrast to Noise Ratio (CNR). From the results of the calculations of normality test data and statistical significance test to ANOVA (Analysis of Variance) test, there was a meaningful difference in every variation given to each patient.
4.1. Analysis signal to noise ratio (SNR)

From the results of research data showed that the effect of variations in the value of SNR to ETL was unstable or linear as follow variation given produce certain SNR. The decrease of SNR in each tissue can be influenced by the molecular structure of the tissue. If it has the composition of the hydrogen atoms, it will produce a lot of high SNR. The life time factor also affects the results of MRI image due to the composition of the hydrogen atom in each tissue decreases with life time.

In this study, the main focus was fatty tissue for the MRI imaging ankle with weighting T2 Fast Spin Echo. FAT with effective factors ETL sensitive imaging in tissues that contain a lot of liquid. Although the most sensitive was the water, but in this case, ankle MRI water had the lower percentage than the Fat to determine the value of SNR.

The application of ETL which too long caused any fat and hyperintens fluid. It was occurred due to the application of re-phasing pulse Radio Frequency (RF) 180° which reduced the interaction of spin in the FAT. Thus, T2 decay increased and fat would be gray in colour (J-coupling) which is a limitation of sequences of Fast Spin Echo (FSE) [8] (Westbrook, 2002). ETL excessive application caused the amplitude of the signal decreases because the application ETL is quite large with Time Echo (TE) which led increasingly to the phase encode for filling the faster K-Space [9]. As a result, it can reduce the occurred signal amplification but the scanning time will be more fast.

4.2. Analysis contrast to noise ratio (CNR)

Figure 2. Influence Graph ETL variation of the SNR

Figure 3. Influence Graph ETL variation of the CNR
The result of this study showed that the effect of variations in the value of CNR ETL was unstable or linear as any variation given to produce the CNR value. Due to distinguish contrast between one tissue to the other tissues, the hydrogen role atom composition affects significantly to the image hyperintens and hypointens. It led the contrast seen clearly. The main focus of the study was the tissue of tendons and fat because these two tissues have a different structure. The tendon has a clay structure with a large of density and it is susceptible to resonant radio frequency as the contribution to image hypointense. Fat structure remained liquid although in small amount so they were sensitive to radio frequency resonance and contributed slightly to the image of the comparison hyperintense. In addition, both tissues can be used for making CNR good value. Application ETL excessive FSE sequences as well as affect the signal and the contrast occurred between other tissues are getting lower.

4.3. The relation effect of ETL to SNR and CNR

![Figure 4. ETL variations influence the of SNR and CNR](image)

Based on Figure 4, it could be concluded that when the value of the variation ETL 12 generates a graph of the increasing in value of SNR and CNR while the variation ETL 14 generates a graph of the decreasing between SNR and CNR values, the graphs can rise back to the ETL 20. This variation can be used as consideration for the technologist to determine the value of ETL variations that will be used for MRI examinations ankle resulting SNR and CNR values were high.

4.4. Effect of variations ETL to the scanning time

The result showed that the scanning process performed on five patients in each variation ETL scanning time were produced relatively the same in a variation ETL lower scanning process of 2:42 minutes. The resulted ETL was quicker scanning but the obtained signal was reduced. The analysis of SNR and CNR was decrease. In accordance with the equations to calculate the time scanning of ETL factors as follows:

\[
time Scanning = \frac{TR \times PE \times NEX}{ETL}
\]

Example of the calculation of time scanning with TR of 5450 ms, PE is 320, NEX 1 and ETL 12-20 as follows.
| ETL Value | Scanning Time | Figure |
|-----------|---------------|--------|
| 12        | 2.42 minute   |        |
| 16        | 1.81 minute   |        |
| 20        | 1.45 minute   |        |
| 14        | 2.07 minute   |        |
| 18        | 1.61 minute   |        |
From the analysis, the calculation of scanning time was reduced if the obtained results using ETL large variation value. This is because the process of encoding the K-space would be faster, causing the scanning time would be faster as well, then it can be used as a consideration in the determination of the value of the variation ETL to get the value of the signal and the contrast is quite high.

4.5. Determination of optimal value ETL variations on image quality
The determination of the optimal ETL variations obtained from a graph showing the value of high SNR and CNR. Values optimal SNR and CNR were determined not only by the high or maximum value but also the intersection graph. The results required a proper selection on variations ETL that produce the good value of SNR and CNR. The graphs influence on the value of variations ETL SNR and CNR for five patients are shown in Figure 5 to 9.

![Graph of relation SNR and CNR](image1.png)

**Figure 5.** Influence Graph ETL variation of the SNR and CNR Patient 1

![Graph of relation SNR and CNR](image2.png)

**Figure 6.** Influence Graph ETL variation of the SNR and CNR Patient 2
Figure 7. Influence Graph ETL variation of the SNR and CNR Patient 3

Figure 8. Influence Graph ETL variation of the SNR and CNR Patient 4

Figure 9. Influence Graph ETL variation of the SNR and CNR Patient 5

From the varies connection ETL to SNR, CNR and the scanning time, it was concluded that the value of ETL 12 units generated the high value of SNR and CNR. It can be used by
the technologist to determine the value of ETL to generate the value of SNR and CNR optimal time scanning. In addition, to require analysis of the value of SNR, CNR, and the scanning time, the image processing required as a supporting influence the selection of optimal ETL variation values of the MRI image.

5. Conclusion
Based on the research, it can be concluded as follows:
1. Variation of ETL affected to the results of an MRI examination on Ruptures of Achilles Tendon.
2. Setting of ETL equal to 12 will produce high SNR and high CNR for two patients by scanning time 2:45 minutes.

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References
[1] Notosiswono M and Susy S 2004 Utilization of Magnetic Resonance Imaging (MRI) as a means of diagnosis of patients Media Research Health XIV 3.
[2] Forshult and Stig E 2007 Magnetic Resonance Imaging- MRI- An Overview Karlstad university Swedia
[3] Bushbreg J T, J A Siebert, E M Leidholdt and J M Boone 2002 The Essensia Physic of medical Imaging second edition second edition Lippincott Williama and Wilkins Philadelphia USA 377-462
[4] Josepa ND Simanjuntak, Muhammad Nur and Eko Hidayanto 2014 Studi Analisis Echo Train Lenght dalam K-Space serta Pengaruh Terhadap Kualitas Citra Pembobotan T2 FSE pada MRI 1.5 T. 17 1.
[5] Westbrook and Catherine 2002 Handbook of MRI Technique DP photo setting Lesbury Bucks Printed and Bound in Great Britain, Cambridge.
[6] Carmichael D W, Thomas D L, and Ordidge R J, 2009 Reducing ghosting due to k-space discontinuities in fast spin echo (FSE) imaging by a new combination of k-space ordering and parallel imaging Journal Magnetic Resonance, 200,119-125
[7] Maksymowych and Walter P 2007 Magnetic Resonance Imaging for Spondyloarthitis Avoiding the Minefield The Journal of Rheumatology Publishing Company Canada.
[8] Goethem V J W M, Parizel P M and Jinkins J R 2002 Review Article: MRI of the Postoperative Lumbar Spine, 44,723-739.
[9] Houghton and Victor 2006 Imaging Intervertebral Disc Degeneratio Journal of Bone and Joint Surgery 88-A, Supplement 2
[10] Bryan R N 2010 Introduction to the science of medical Imaging 67-171 University Press Cambridge New York