Analysis of flip angle (fa) toward image anatomical information in sagital T2* w merge: (study of knee joint magnetic resonance imaging in anterior cruciate ligament tear case)

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Abstract. The sagittal T2* W MERGE sequence is a sequence in Magnetic Resonance Imaging (MRI) examination of the knee joint in the radiology department of Panti Rapih Hospital Yogyakarta. The value of Flip Angle (FA) on the T2* W MERGE sequence will affect to anatomical information. The right FA can produce good image contrast of fluid and tissue. This study aims to find out the relationship between FA variations toward anatomical information and to determine the optimum FA. Ten patients with Anterior Cruciate Ligament (ACL) Tear were scanned by 1.5 Tesla MRI using Sagittal T2* W MERGE with five flip angle variations: 15°, 20°, 25°, 30°, and 35°. The anatomical informations were assessed by two qualified radiologists in ACL Tear, Posterior Cruciate Ligament (PCL), Quadriceps Tendon, Joint Effusion, and Hoffa Fat Pad. Data were analyzed by Cross Tabulation, Spearman Rank test and Freadman test. Result showed that there was a significant correlation (p-value < 0.05) between flip angle value to anatomical information (correlation value was -0.55), increasing the FA will reduce the clarity of the anatomical image. Based on Friedman test results, the highest mean rank of image information was 3.89 obtained by FA 20°.

1. Introduction
Magnetic Resonance Imaging (MRI) is a valuable diagnostic modality. It is superior in visualizing the anatomy of soft tissues in the body such as nervous system, muscles, and ligaments compared to other modalities [1].

Knee joint is one of the most complex joints in the human body, many cases of knee injuries are torn ligaments which can cause extreme pain and can change bone position [2]. The anterior cruciate ligament (ACL) is one of the ligaments in the knee joint that extends obliquely from the posteromedial aspect of the lateral femoral condyle along 15 mm from posterior to anterior [3].

Gradient Recalled Echo (GRE) is an imaging technique in MRI with an radiofrequency (RF) pulse of less than 90° so that the time required is shorter and signals from tissues with high water content and at T2* can be displayed clearly depicted [4]. Multiple-echo Recombined Gradient Echo (MERGE) is a improvement of GRE in General Electric™ that uses multi-echo in each pulse, that applied on T2 weighting using relatively fast Time Repetition (TR), long Time Echo (TE) and small flip angle [4]. Excitation using a large FA for excitation will reduce transverse magnetization and will result in better stationary tissue suppression and greater signals from blood vessels and fluids [5].
There are various ranges FA for T2 * GRE weighting such as using FA of 15º-20º [4], FA of 20º, 30º, or 35º [6], and a FA 30º-45º [7]. The flip angle varies in clinical field application, from flip angle 20º to 25º.

The purpose of this study is to find out the relationship of FA to ward the differences in anatomic information. This study also aims to determine the optimum FA on knee joint MRI with sagital T2*W MERGE in ACL tear case.

2. Methods
This is an experimental approach to determine the MRI anatomical information of the knee joint on the GE 1.5T MRI with T2*W MERGE sagittal slice in the case of ACL tear.

Ten patients of knee joint MRI examinations with Anterior Cruciate Ligament Tear in Panti Rapih Hospital –Yogyakarta were scaned using the sagital T2*W MERGE sequence. The FA was set in five variations for each patient: 15º, 20º, 25º, 30º, and 35º. The controlled parameters are is Time Echo (TE)=7,6 ms, Time Repetition (TR)=550 ms, FOV=16,00, Slice Thickness=3 mm, Slice Gap=0,5 mm, and matriks=288x288.

The images were printed and the identities for each variation was masked to ensure assessment objectivity. This method was approved by ethical comitee. Anatomical image information were assessed by two qualified radiologists with at least 5 years experienced in reading MR images of the knee joint. To find out the similarity in the assessment of the respondent's, the kappa test was previously carried out. Visualization of ACL tear, PCL, quadriceps tendon, joint effusion and Hoffa fat pad was assessed using scoring criteria: 3 "very clear", 2 "clear", and 1 "unclear".

The assessment result were analyze using descriptive statistic for each variable, kappa agreement test. Spearman rank test was use to determine the strength and significance of the relationship. The optimum flip angle was determined based on the highest mean rank results of the Friedmantest.

3. Results and discussion

3.1. Sample characteristics

| Characteristics | Sample | total | %  |
|-----------------|--------|-------|----|
| Gender          | Male   | 5     | 50 |
|                 | Female | 5     | 50 |

The sample used in this study was 10 samples. Based on Table1 that the sample between men and women is equal, 50% on each. On MRI examination of the knee joint with ACL Tear, there were no anatomical differences in the image between male and female.

3.2. Diagnostic image results
Sample according to the research criteria 10 patients were subjected to MRI scanning of the knee joints with the T2 * W MERGE sequence with a variation of flip angle of 15º, 20º, 25º, 30º, and 35º. The resulting image results selected from each variation of the flip angle on the T2 * W MERGE sequence according to the anatomical criteria assessed, namely ACL, quadriceps tendon, joint effusion, PCL, and Hoffa Fat Pad.

| Kappa Measure of Agreement | Approx. Sig. |
|----------------------------|--------------|
| 0.656                      | 0.001        |
Figure 1. T2*W MERGE image visualization of ACL (1), Quadriceps Tendon (2), Joint Effusion (3), PCL (4) and Hoffa Pad (5) on various flip angle: 15º as shown in picture A, flip angle: 20º as shown in picture B, flip angle 25º as shown in picture C, flip angle 30º as shown in picture D, and flip angle 35º as shown in picture E.

Table 2 shows the level of agreement based on the results of the Kappa test of respondents 1 and 2 with an agreement value of 0.656 which means that both respondents had moderate level agreement in assessing MRI image of the knee joint of the sagittal slices of the T2*W MERGE sequence. Based on the results of the Kappa test, there is a similarity in perception between 2 observers, where the data used are the results of the respondents who have the longest working time.

3.3. Descriptive analysis
Cross tabulation data of the assessment of variation of the flip angle is calculated on anatomic information by the two observers are as follows.

Table 3. Cross tabulation of FA variations and ACL anatomical information

| Flip Angle | Anatomical Information of ACL | Total |
|------------|-------------------------------|-------|
|            | Not clear | Clear | Very clear |
| 15º        | Frequency | 0     | 4       | 6       | 10  |
|            | %         | 0     | 40      | 60      | 100 |
| 20º        | Frequency | 0     | 0       | 10      | 10  |
|            | %         | 0     | 0       | 100     | 100 |
| 25º        | Frequency | 0     | 2       | 8       | 10  |
|            | %         | 0     | 20      | 80      | 100 |
| 30º        | Frequency | 0     | 7       | 3       | 10  |
|            | %         | 0     | 70      | 30      | 100 |
| 35º        | Frequency | 1     | 8       | 1       | 10  |
|            | %         | 10    | 80      | 10      | 100 |

Based on Table 3 anatomical information of the ACL obtained the highest (very clear) value of 100% on FA 20º, while the lowest was 10% on FA 35º.
Table 4. Cross tabulation of FA variations and anatomical information of quadriceps tendons

| FA  | Anatomical Information of Quadriceps Tendon | Total |
|-----|--------------------------------------------|-------|
|     | Not clear | clear | Very clear |
| 15° | Frequency 0 | 1 | 9 | 10 |
|     | %         0 | 10 | 90 | 100 |
| 20° | Frequency 0 | 0 | 10 | 10 |
|     | %         0 | 0 | 100 | 100 |
| 25° | Frequency 0 | 0 | 10 | 10 |
|     | %         0 | 0 | 100 | 100 |
| 30° | Frequency 0 | 3 | 7 | 10 |
|     | %         0 | 30 | 70 | 100 |
| 35° | Frequency 1 | 4 | 5 | 10 |
|     | %         10 | 40 | 50 | 100 |

Based on Table 4, anatomical information of Quadriceps Tendon obtained the highest (very clear) value of 100% on the FA 20° and 25°, while the lowest was 10% on FA 35°.

Table 5. Cross tabulation of FA variations and anatomical information of joint effusion

| FA  | Anatomical Information of Joint Effusion | Total |
|-----|------------------------------------------|-------|
|     | Not clear | clear | Very clear |
| 15° | Frequency 0 | 3 | 7 | 10 |
|     | %         0 | 30 | 70 | 100 |
| 20° | Frequency 0 | 0 | 10 | 10 |
|     | %         0 | 0 | 100 | 100 |
| 25° | Frequency 0 | 0 | 10 | 10 |
|     | %         0 | 0 | 100 | 100 |
| 30° | Frequency 0 | 3 | 7 | 10 |
|     | %         0 | 30 | 70 | 100 |
| 35° | Frequency 0 | 9 | 1 | 10 |
|     | %         0 | 90 | 10 | 100 |

Based on Table 5, anatomical information of joint effusion obtained the highest (very clear) value of 100% on the FA 20° and 25°, while the lowest was 10% on FA 35°.

Table 6. Cross tabulation of FA variations and anatomical information of PCL

| FA  | Anatomical Information on PCL | Total |
|-----|-------------------------------|-------|
|     | Not clear | clear | Very clear |
| 15° | Frequency 0 | 4 | 6 | 10 |
|     | %         0 | 40 | 60 | 100 |
Based on Table 6, anatomical information of the PCL obtained the highest (very clear) value of 80% in the flip angle 20º, while the lowest was 20% on FA 20º.

**Table 7. Cross Tabulation of FA variations and anatomical information of Hoffa Fat Pad**

| FA   | Anatomical Information of Hoffa Fat Pad | Total |
|------|----------------------------------------|-------|
|      | Not clear | clear | Very clear |      |
| 15º  | Frequency | 0     | 0          | 10   |
| %    | 0          | 0     | 0          | 100  |
| 20º  | Frequency | 0     | 0          | 10   |
| %    | 0          | 0     | 0          | 100  |
| 25º  | Frequency | 0     | 0          | 10   |
| %    | 0          | 0     | 0          | 100  |
| 30º  | Frequency | 0     | 9          | 1    |
| %    | 0          | 90    | 10         | 100  |
| 35º  | Frequency | 4     | 6          | 0    |
| %    | 40         | 60    | 0          | 100  |

Based on Table 8, anatomical information of Hoffa Fat Pad obtained the highest (very clear) value of 100% on FA of 15º, 20º, and 25º. Whereas at the FA of 35º there is no (very clear) value.

Based on these results, FA 20º gets the greatest (clear value) in each anatomy, which means that the FA 20º can visualize the best anatomical information compared to other FA value. According to the previous review [3] the use of the MERGE sequence in the knee joint will produce images with signal intensity at low/intermediate fat signals, very high fluid signals, low/intermediate muscle signals, very low signal ligament fibers. FA is one of the parameters that can affect the image quality. The smaller the flip angle used, the faster a nucleus recovery and generating a signal [5]. According to the theoritical concept [7] the greater the FA used by the image will be more hyperintense because the more signals received otherwise the smaller the FA used the image will be more hypointense because the less the signal received so it will be increasingly difficult to distinguish the clarity of the image from each anatomy.

3.4. Bivariate analysis

Data were analysed by Spearman or Kendall's Tau rank to determine the strength and significance of the relationship between different FA toward the anatomical information.

3.4.1. Spearman rank relationship analysis. Based on table 8, significance value (p-value) = 0.001 <0.05 then means that there is a relationship of variation of the FA to differences in anatomical information. The correlation coefficient value -0.550 indicates a moderate downhill (negative) relationship.
Table 8. Spearman rank statistics test results of FA variations and anatomical information

| Correlation Coefficient | Significance |
|-------------------------|--------------|
| -0.550                  | 0.001        |

Table 9. Spearman statistical test results of FA variations and individual anatomical information of the knee joint

| Anatomy             | Correlation Coefficient | Significance |
|---------------------|-------------------------|--------------|
| ACL Tear            | -0.496                  | 0.001        |
| Quadriceps Tendon   | -0.409                  | 0.003        |
| Joint Effusion      | -0.463                  | 0.001        |
| PCL                 | -0.637                  | 0.001        |
| Hoffa Fat Pad       | -0.850                  | 0.001        |

Based on the table 9, of the spearman test from the assessment of each anatomy, p-value <0.05 means that there is a correlation between the FA variation to the anatomical information. Correlation coefficient value varies from “weak”, “strong” and “very strong” and negative direction means that increasing the FA will reduce the anatomical information obtained.

The MERGE sequence has the ability of fat saturation to provide high resolution in T2* cervical imaging, cartilage, joint and musculoskeletal imaging by optimizing the contrast between ligaments and soft tissue [8]. The smaller the FA that used, the faster a nucleus recovery and yield signal, the greater the FA the more time to receive the signal [5]. Based on the results of the resulting image, the greater the FA used the image will be more hyperintense because the more signals received, and vice versa.

According to the researchers [9] the contrast changes caused by changes in the magnitude of the flip angle will affect the clarity of each anatomy, such as if ACL and PCL are more hyperintense or hypointense, it will reduce the anatomical clarity in the case of tear ligaments, it will not clear the tear experienced if only partial or total.

3.4.2. The friedman test statistics method. To find out the most optimal value of the flip angle because the data is in the form of an ordinal scale so it uses the mean rank friedman test. The results of mean rank friedman test are as follows:

Table 10. Friedman statistics test results

| Flip Angle Variations | Mean Rank | Asymp. Sig. |
|-----------------------|-----------|-------------|
| FA 15°                | 3.40      |             |
| FA 20°                | 3.89      |             |
| FA 25°                | 3.60      | 0.001       |
| FA 30°                | 2.46      |             |
| FA 35°                | 1.65      |             |

Based on table 10 Friedman statistical test results by two observers is p = 0.001 means that there are differences in the value of image information from the FA variations. Then the mean rank results obtained the highest value of 3.89 at the FA 20° means that the use of FA 20° can visualize optimal
anatomical information on the MRI examination image of the knee joint T2*WMERGE sagittal slices with ACL tear.

In accordance with the MERGE sequence function which has the ability of fat saturation to provide high resolution in T2* images joint and musculoskeletal imaging by optimizing the contrast between fluid, ligament and soft tissue [8]. Flip angle is one of the parameters that can affect the quality of the image produced, the smaller the flip angle used, the faster a nucleus recovery and generating a signal [5].

According to researchers with the use of the right flip angle can provide the right time to get signals that produce informative images. So as to be able to display optimal anatomical clarity on the MRI examination image of the knee joint the T2 * W MERGE sequence of sagittal slices with an ACL tear case with an MRI modality of 1.5 T using a flip angle of 20º.

4. Conclusion
There is a correlation between the the FA to the anatomical information on the MRI examination image of the knee joint T2*W MERGE sagittal slices with ACL tear. Correlation coefficient of -0.550 indicates that increasing FA will reduce the clarity of the anatomical image. FA 20º can visualize optimal anatomical information on the MRI examination image of the knee joint T2*W MERGE sagittal slices with an ACL tear.

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