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Comparing SPIR and SPAIR Fat Suppression Techniques in Magnetic Resonance Imaging (MRI) of Wrist Joint

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ABSTRACT

Introduction: *In many clinical situations, the radiologist wants to eliminate the contributions of fat from the total signal without affecting the water signal including in wrist joint. Frequency Selective Inversion Pulse is one of fat suppression methods where SPIR and SPAIR are among the two methods applying Frequency Selective Inversion Pulse.*

Objective: *This study aims to compare two fat suppression techniques SPIR and SPAIR in the magnetic resonance images of the wrist joint and to evaluate the best image quality for the clinical usefulness.*

Methods: *This is a quantitative research with experimental approaches conducted in Premier Bintaro Hospital. Data in form of 56 images of coronal T2WI-FSE wrist joint from 28 volunteers with two variations of the method, SPIR, and SPAIR Fat Suppression are presented. Assessment of anatomical information carried out by the radiologist and analysed with Wilcoxon Signed-Rank Test at 95 % confidence level.*

Results: *This research shows that there is a difference of anatomical information in MRI Wrist joint sequence coronal of T2WI-FSE between SPIR and SPAIR Fat Suppression.*

Conclusion: *SPAIR is the method which is clearer to show the anatomical information of wrist joint. The application of selective adiabatic inversion pulse in SPAIR makes suppression of amplitude and modulation of frequency.*

Keywords: *Fat Tissue, Wrist Joint MRI, Fat Suppression.*

INTRODUCTION

The distribution of hydrogen nuclei was very important in anatomical and pathological imaging of an organ on the Magnetic Resonance Imaging (MRI). The whole core of hydrogen will contribute to the imaging signal, but most of the time, the decay of nuclei cells (such as hydrogen of fatty acids chain in the cell membrane) are too fast to contribute into measurable signals. Actual signals are mainly composed of the contribution of hydrogen nuclei in water and fat molecules in adipose tissue (Cameron, 2012).

There are many clinical situations where the radiologist wants to eliminate the contribution of fat from the total signal without affecting the signal of water, as well as on the wrist joint. Fat suppression technique can be used to increase the tissues contrast (cartilages, ligaments, metastases)

and enhancement optimization of lesions to determine the fat content and minimizing chemical shift artifacts. The suppression of hyper intense signal of fat can also be useful in post-contrast imaging in which the lesion will be clearly visible (Filipo, 2014).

T2 weighted image (T2WI) Fast Spin Echo (FSE) is one of the sequences in MRI which is derived from the Spin Echo Echo sequences with the application of Train Length (ETL) to streamline the scanning time. Basically, T2WI demonstrate the difference of a T2 tissue relaxation times. The fat on T2WI-FSE has a relatively high signal (intermediate) because it has the T2 relaxation time of 10-100 ms. T2WI-FSE presents a picture of an organ pathology. On the wrist joint which consists of very complex tissue, the T2WI sequence is able to show the variations in tissues contrast clearly, but in some conditions, it requires the application of fat suppression method to display the tissues contrast without a substantial contribution from the surrounding fatty signal (Jeremy, 2011).

European Society of Musculoskeletal Radiology (ESSR) states that the routine protocol of wrist joint MRI is the axial PD FSE, Coronal T1WI-FSE, coronal T2WI-FSE (Fat Suppression), sagittal T2WI-FSE (Fat Suppression), and 3D-VIBE. T2WI FSE Fat-suppression sequences both coronal and sagittal sequences are created as a comparison to other sequences to confirm and to assess the abnormalities that occur in the wrist joint without a significant contribution from the surrounding fat signal. The wellness of the T2WI-FSE Fat suppression sequence as a comparison sequence depends on the type of fat suppression techniques used.

There are several techniques that can be used to perform suppress the fat signal, one of which is to implement Frequency Selective Inversion Pulse (Wu, et.al 2012). Frequency Selective Inversion Pulse technique is a combination or hybrid of Fat Saturation techniques and Short Tau Inversion Recovery (STIR), which is based not only on the resonant frequency of fatty tissue but also in short Time Inversion (TI). There are two types of techniques that apply a combination of these principles, namely Spectral Pre-saturation with Inversion Recovery (SPIR) and Spectral Attenuated Inversion Recovery (SPAIR). SPIR sequence is a combination of spectral saturation and STIR routine (Ribeiro, 2013). Spectral involving fat suppression RF pulse prefixes only sets to a frequency of fat only. This is possible because of the differences in the molecular environment of the magnetization of hydrogen protons in fat, which means fat precision occurs at slightly different frequencies. In this technique, the precession frequency RF pulse is applied to the fat imaging of 100^{o} – 140^{o}. The magnetic moment of fat will be inverted to the z-axis. After passing the Time Inversion (TI) corresponding to the zero point of the fat, excitation pulses of 90˚ is then applied. As fat does not have a longitudinal magnetization at the point, the excitation pulses do not produce transverse fat magnetization, hence the fat signal will be zero or appear dark in the image. SPIR has several advantages over STIR. SPIR is far less susceptible to the inhomogeneous magnetic field (Bo), for the removal of fat signals also occur by choosing the appropriate inversion time with fat zero points. It depends on the T1 recovery time than the precession frequency of fat itself, and relaxation time is not affected by small changes of inhomogeneous Bo.

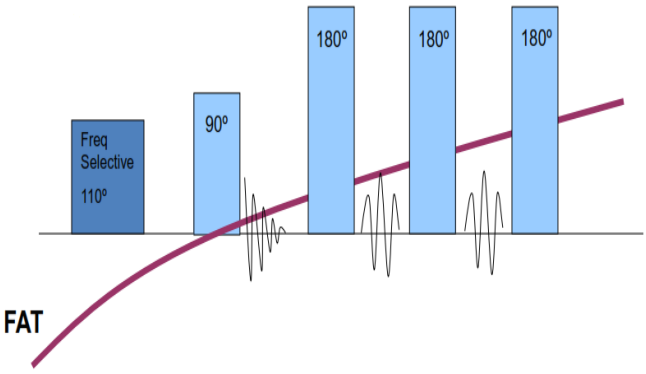

Figure 1. Diagram of SPIR (Philips, 2013)

Unlike the SPIR, SPAIR keeps using pulse inversion angle of 180˚ as yet applied to the adiabatic pulse. Both SPIR and SPAIR can be applied to all types of sequences which is very

different from the STIR as whole sequences (Wu, et.al, 2012). The SPAIR technique is one of the powerful techniques to suppress fat, which has a variety of advantages over conventional fat suppression techniques. This technique is characterized by low sensitivity towards the nature of inhomogeneous RF pulse and only suppressed/ inverted fat spin (Ribeiro, 2013). SPAIR using inverted pulse in selective spectral adiabatic to invert the fat spin in volumes analyzed.

After giving the adiabatic pulse, the big spoiler is used to negate the rest of the transverse magnetization. The fat spin will experience a recovery in accordance with the T1 relaxation rate, and after a certain characteristic time (TI null) longitudinal magnetization will be zero. At this point, the excitation pulses are applied. When the spin has no longitudinal magnetization of fat, the fat will not contribute to the MR signal to be displayed in the image. Implementation SPAIR as fat suppression techniques will result in more homogeneous fat saturation compared to other fat suppression techniques.

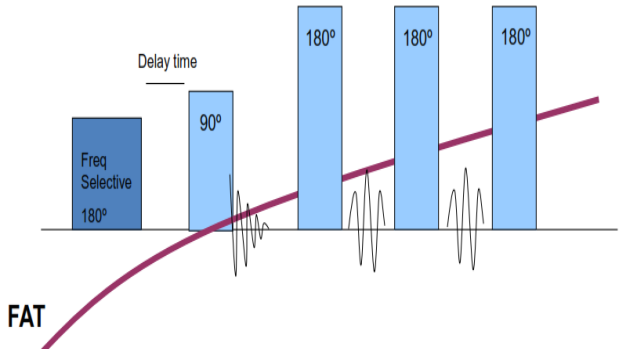

Figure 2. Diagram of SPAIRat *Fast Spin Echo* (Philips Healthcare, 2011)

The purpose of this study is to determine the anatomical information differences of wrist joint MRI in coronal T2WI FSE fat suppression sequences between SPIR and SPAIR method. In addition, it aims to determine the best fat suppression methods to display anatomical information of wrist joint.

MATERIAL AND METHOD

This research is a quantitative study with an experimental approach that aims to identify the anatomical information differences of wrist joint MRI in coronal T2WI FSE fat suppression sequences between SPIR and SPAIR. 28 volunteers of wrist joint MRI examination in Radiology Unit Bintaro Premier Hospitals are taken as samples. The eligible samples of this study 1) aged around 20-40 years, 2) weight with 4 categories (underweight, normal, overweight, and obesity). Respondents giving an assessment of the wrist joint MRI image in coronal FSE T2WI FS sequences is one radiologist and 1 additional radiologist.

The procedures in this study were:

1. Volunteers were informed of the consent, the intent and the purpose of the study, as well as an explanation of the examination procedure, and were assured that this study was not harmful to them.
2. MRI imaging of the wrist joint was started with 3 plane localizers.
3. MRI imaging of the wrist joint T2 weighted Fast Spin Echo coronal with Fat suppression was conducted.
4. Each volunteer was scanned with two variations of the method of fat suppression: SPIR, and SPAIR.
5. The images as the results of these studies were stored on a CD with DICOM format without any identifying information, just given an image serial code.
6. Two radiology specialist experienced in the field of 1.5 Tesla MRI are requested to observe the image produced by each technique. Qualitative assessment is conducted by assessing the image contrast in general including Triangular Fibrocartilage Complex (TFCC), cartilage, marrow, fluid, bone, ligament, joint space, and then choose the best image from the two variations of fat suppression method.
7. Assessment of the radiology specialist is performed by marking (√) in the questionnaires provided. The clarity of the image is valued 1 for less clear, 2 for clear and 3 for very clear sense,

Data obtained are tested with Wilcoxon Signed-Rank Test to assess whether there is a significant difference in the two methods of suppression with the confidence level of 95%. The calculation is aided with SPSS 20 software.

RESULT

Research carried out on 28 (twenty-eight) male and female volunteers, ranged in age from 20 years to 40 years, with four categories of body mass index (BMI): underweight, normal, overweight, and obesity.

Table1. Volunteers Characteristics by Gender

Gender	Quantity	Percentage
Male	14	50%
Female	14	50%
Total	28	100%

Table 2. Volunteers Characteristics by Age

Age	Quantity	Percentage
20 – 29	16	57%
30 – 49	12	43%
Total	28	100%

Table 3. Volunteers Characteristics by BMI

Body Mass Index	Quantity	Percentage
Underweight	7	25%
Normal	7	25%
Overweight	7	25%
Obesity	7	25%
Total	28	100%

From the 28 volunteers are obtained anatomical information of wrist joint MRI in Coronal T2-FSE fat suppression sequences between SPIR and SPAIR. Each fat suppression method produces 56 images that can reveal the anatomy of the cartilage, TFCC, bone, marrow, fluid, tendons /ligaments, joints space on each method of fat suppression.

Figure 1.MRI Wrist Joint MRI Image with SPIR

Figure 2. MRI Wrist Joint MRI Image with SPAIR

Before conducting a statistical test to determine the anatomical information differences between SPIR and SPAIR method, Kappa test was done to determine the suitability or the common perception of respondents in the questionnaire assessment. The Kappa test results are:

Table 4. Kappa Test Results in Two Respondents

Fat Suppression Method	Value Kappa	p-value
SPIR	0.878	<0.001
SPAIR	0.837	<0.001

Kappa test results showed The Kappa value on SPIR method = 0.878 (p-value <0.001) and for SPAIR showed the Kappa value = 0.837 (p-value <0.00). These results indicate that there is a match or a shared understanding between the two respondents in assessing the anatomical information of wrist joint either on SPIR or SPAIR methods.

Compare-Means test with Wilcoxon Signed-Rank Test. for each anatomical criteria obtained the following results:

Table 5. Test of difference Result between SPIR and SPAIR

Anatomical Information	p-value
SPIR vs SPAIR	< 0,001

With p-value <0.001, it can be stated that there are anatomical information differences of wrist joint MRI in coronal T2WI-FSE Fat Suppression sequences between SPIR with SPAIR method. To determine the fat suppression methods that more clearly describes the anatomical information differences of wrist joint MRI in coronal T2WI-

FSE Fat Suppression sequences is done by observing the mean rank of Wilcoxon Signed-Rank Test as shown in Table 6.

Table 6. Result of Mean Wilcoxon Signed- Rank Test

Anatomical Information	Mean Rank
SPIR	0
SPAIR	8.5

The SPAIR method obtains a value of 8.5, and SPIR method gets a value of 0, indicating that SPAIR method is more clearly in describing the anatomical information differences of wrist joint MRI in coronal T2WI-FSE Fat Suppression sequences compared with SPIR method. Compare means for each anatomical criterion conducted to determine the differences between the test criteria in an image. The results can be seen in Table 7.

Table 7 Test of difference Result on each criterion between SPIR and SPAIR

Anatomical Information SPAIR vs SPIR	p-value
Cartilage	0.002
Marrow	<0.001
Bone	<0.001
TFCC	<0.001
Fluid	0.008
Ligament	0.001
Joint Space	0.002

Three of the seven anatomical criteria (marrow, bone, TFCC) has a p-value <0.001, cartilage p-value = 0.002, ligament p-value = 0.001, fluid, p-value = 0.008, and joint space p-value = 0.002. This shows that there are anatomical information differences on anatomical criteria Cartilage, marrow, bone, TFCC, ligament, and joint fluid space between SPIR and SPAIR method. To determine which methods are more clearly describe any anatomical criteria can be seen in the results of mean rank as follows:

Table 8. Result of Mean Rank on Each Criterion

Anatomical Information	Mean Rank
Cartilage SPIR	0
Cartilage SPAIR	5.5
Marrow SPIR	0
Marrow SPAIR	7
Bone SPIR	0
Bone SPAIR	8.5
TFCC SPIR	0
TFCC SPAIR	7.5
Fluid SPIR	0
Fluid SPAIR	4
Ligament SPIR	0
Ligament SPAIR	6.5
Joint Space SPIR	0
Joint Space SPAIR	5.5

Based on the mean rank result, cartilage anatomy SPAIR scored 8.5, marrow SPAIR 7, bone SPAIR 8.5, TFCC SPAIR 7.5, fluid SPAIR 4, ligament SPAIR 6.5, joint space SPAIR 5.5. The entire anatomical criteria on SPIR method obtaining mean rank 0, indicating that SPAIR method is more clearly in describing the anatomical information of wrist joint on each criterion compared to SPIR method.

To show the difference in the anatomical information as a result of variations in body mass index (BMI) of volunteers, the test of difference conducted by using anatomical information results in SPAIR method is shown in Table 9.

Table 9. Anatomical Information Test of difference with BMI Variation

Anatomical Information	p-value
SPAIR Image	0.235

With p-value 0.235 (p> 0.05), it can be stated that there are no anatomical information differences of the wrist joint in SPAIR method on body mass index variation, which means SPAIR method can be applied to all categories of body mass index.

CONCLUSION

Fat tissue appears bright in most of the sequences in MRI imaging. The ability to selectively suppress fat signal will help determine abnormalities in other tissues or lesions without significant contributions from the fat signal in the imaging

area. Selection of appropriate suppression techniques can help radiologists interpret the image precisely and accurately. The test results of this study indicate p-value <0.001 (p <0.05), which means that there are anatomical information differences between SPIR and SPAIR method. The SPAIR method is more clearly displays anatomical information of wrist joint MRI in coronal T2WI-FSE Fat Suppression sequence when compared with SPIR method.

This way, SPAIR is recommended as a fat suppression method of wrist joint MRI in coronal T2W-FSE Fat Suppression. Application of the SPAIR method in other sequences must be accompanied by an inversion Time settings that are appropriate to the Repetition Time value (TR) of sequences used.

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