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Original Article

Variation of inversion delay for wrist joint MR imaging with SPAIR technique: which ID is optimal?

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A B S T R A C T

Background: The current fat suppression technique in magnetic resonance imaging (MRI) significantly diagnoses abnormalities in musculoskeletal disorders. The spectral attenuated inversion recovery (SPAIR) fat suppression (FS) technique had an inversion delay (ID) parameter that allows choosing between full or partial FS. This was the first research related to the optimal setting of the ID time variation in the SPAIR technique on T2-weighted MRI wrist joint images.

Objectives: This study aims to find out anatomical information with the most optimal ID value of the MRI wrist joint image T2 turbo spin-echo (TSE) FS SPAIR coronal slice sequence.

Method: This study was a pre-experimental post-test only. Scanning MR wrist joint 16 volunteers took data with the qualitative analysis used three radiologists (visual grading) with statistical data analysis.

Results: Image information of the MRI wrist joint T2 TSE FS SPAIR coronal slices sequence showed differences in the variation of ID ($p<0.001$), where the ID of 85 ms produced the most optimal image information.

Conclusion: MRI image of the wrist joint of the T2 TSE FS SPAIR coronal slices sequence the most optimal with an ID variation of 85 ms compared to ID 70 ms and 100 ms.

INTRODUCTION

Currently, imaging sequences with fat suppression (FS) techniques can be used and are significant in diagnosing musculoskeletal disorders[1–3]. In many musculoskeletal MRI clinical situations, such as wrist joints, the radiologist desires to remove the total fat signal contribution without substantially affecting the water signal[4]. FS technique improves bone marrow edema and marrow lesions, confirms the presence of fat in soft tissue tumors, differentiates fat from met-hemoglobin, a fluid rich in protein and melanin[5,6]. The FS technique can also suppress signals from adipose tissue and increase tissue contrast (such as cartilage, ligaments, and bone metastases) and lesions to determine whether the examined tissue contains high or low fat, so routine MRI imaging is used to reduce artifacts. Chemical shift and improve the visualization of contrast material[7–9].

The wrist joint was a complex and fatty part of the musculoskeletal and can also be imaged with a modality MR[10,11]. Routine MRI wrist joint examination protocols include coronal STIR / TIRM, coronal T2WI TSE (fat suppression), coronal T1WI SE / GRE, axial T2WI TSE, or T1WI (fat suppression / FS), and coronal 3D FFE fat saturated[12]. The FS technique on the MRI wrist joint T2 TSE sequence displays pathological images on the wrist joint using Echo Train Length (ETL) to shorten the scan time. Fat in this sequence has a relatively high signal (intermediate) because the fat itself has a relaxation time of 10-100 ms[13]. T2 TSE coronal slice sequences can image optimal tissue contrast and a clearer image, but under certain conditions, a fat suppression technique is needed to eliminate the fat signal[14].

Several techniques can be used to reduce fat, one of which is implementing the frequency-selective inversion pulse[15]. The frequency selective inversion pulse is a combination or hybrid of fat suppression, and short tau inversion recovery (STIR) based not only on the fat tissue's resonance frequency but also on short-term inversion (TI).

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There are two hybrid techniques of fat suppression: Spectral Pre-saturation with Inversion Recovery (SPIR) and Spectral Attenuated Inversion Recovery (SPAIR)[16]. SPIR and SPAIR can be applied to weighting T1, T2, and PD. This technique lowers the contrast of detail a little, so to overcome this, Philips recommends that SPIR be used for T1 and PD images and SPAIR for T2[17].

The wrist joint's fat content is one of the factors in the need for a fat compression technique (hybrid) in wrist joint imaging. Indriati et al.[13] have conducted a study to compare a hybrid technique of fat suppression between SPIR and SPAIR. The SPAIR technique can provide more transparent anatomical information and can be recommended for MRI wrist joints T2 TSE FS coronal slice sequences compared to SPIR techniques. In the SPAIR technique, there is an ID parameter or time delay that occurs between the SPAIR pulse and the excitation pulse. Implementing SPAIR pulses can determine or control the prepulse's ID, allowing the choice between full or partial fat suppression[18]. In the Philips manual, the usable ID time is in the range of 0–2000 ms, the typical examination.

In implementing MR wrist joint imaging, radiographers often find it difficult to determine the optimal ID value, especially when scanning the MR wrist joint of the T2 TSE FS SPAIR coronal slices sequence[13]. Hornsi et al.[19] conducted a study using the SPAIR fat suppression technique but on the musculoskeletal knee joint weighting proton density FS SPAIR 2D and 3D images with ID parameters of 85 ms. Hornsi's study produces images that can optimally suppress fat in muscles and bone marrow. Indrati's study conducted an MRI wrist joint study of the T2 TSE FS SPAIR sequence was carried out with an ID of 70 ms, but further research is needed regarding the optimal setting of the ID time variation[13]. Researchers varied the ID values with 3 (three) values, namely 70 ms, 85 ms, and 100 ms, to determine the optimal ID value. This is the first study to perform ID variations on MR wrist joint images of T2 TSE FS SPAIR coronal slices sequences.

This study aims to determine the differences in the image information of the MRI wrist joint T2 TSE FS SPAIR coronal slices sequence at 70 ms, 85 ms, and 100 ms ID variations and to find out the most optimal image information from the three ID values. This study is expected to produce a more optimal fat compression image on the MRI wrist joint examination.

METHOD

Study design

This study was a pre-experimental post-test only[20].

Patients

There were 16 healthy volunteers without pathology[20] consisting of 7 men and nine women (aged 18 to 35 years) with standard body mass index (18.5-24.9 kg / m2) and willing to take part in the research at Premier Bintaro Hospital (MRI wrist joint T2 TSE FS SPAIR coronal slices sequence). Exclusion criteria included contraindications for MRI examinations (such as pacemakers, non-MRI-compatible metallic implants) and volunteers who had claustrophobia.

MR Imaging Protocol

All volunteers were subjected to MRI scanning with a Philips 1.5 Tesla with routine MR wrist joint protocol. The research was carried out on MRI wrist joint images T2 TSE FS SPAIR coronal slices sequence with the examination parameters in Table 1.

Table 1. Parameters of the MRI wrist joint T2 TSE FS SPAIR coronal slices sequence

Parameter	T2 TSE coronal wrist joint
Time Echo (TE)	60ms
Slice thickness	3mm
Number of Excitation (NEX)	2
Number of slices	20
Field of View (FOV)	115
Matrix	512x512.
Fat suppression	SPAIR

Image analysis

MRI wrist joint images of T2 TSE FS SPAIR coronal slices sequences at the ID variation of 70 ms, 85 ms, and 100 ms. Three observers (radiologists) performed visual grading image information analysis was performed by three observers with more than five years of experience in MR imaging. The visual grading assessment uses a score of 1: poor (unclear anatomy, unclear boundaries and cannot be analyzed), score 2: sufficient (anatomy clear enough, boundaries clear enough and can be analyzed), and score 3: good (precise anatomy, clear boundaries with sharp and easy to analyze structural lines)[13,19]. Each of the visual grading results of the MRI wrist joint image T2 TSE FS SPAIR coronal slices sequence at ID variations of 70 ms, 85 ms, and 100 ms, then distributed to each anatomy.

Statistical Analysis

Statistical analysis using SPSS begins with the suitability test of opinion (interobserver agreement test) using the Cohen's Kappa test (K<0.20 bad agreement; 0.21-0.40 fair agreement; 0.41-0.60 moderate agreement; 0.61 -0.80 good agreement; and 0.81-1.00 perfect agreement)[21,22]. Then continued the Friedman test both as a whole and per anatomical criteria to identify differences in information on MRI wrist joint T2 TSE FS SPAIR coronal slices with a variation of ID 70 ms, 85 ms. and 100 ms, while to get the

most optimal image using the mean rank from the Friedman test results.

RESULTS

Assessment of difference information image on the MRI wrist joint T2 TSE FS SPAIR coronal slices sequence between ID variation value of 70 ms, 85 ms, and 100 ms qualitatively carried out by visual grading by an observer (radiologists) can be seen in Table 2 and Figure 1. Assessment of the MRI wrist joint T2 TSE FS SPAIR coronal slices sequence image information with variations in the ID value was carried out using the Friedman test; the statistical tests' results are as in Table 3.

Table 2 shows that the results of the visual grading observer for the MRI wrist joint image T2 TSE FS SPAIR coronal slices sequence at the ID variation of 85 ms in the anatomy of muscle, liquid, bone marrow, joint space, ligament, and cartilage appear to get a score of 2 (sufficient) and 3 (good) which are dominant compared to images with a variation of ID 70 ms and 100 ms. This means that image information with ID 85 ms is qualitatively said to be good with a clear anatomical display, clear boundaries with sharp structural lines, and easy to analyze on the MRI wrist joint image T2 TSE FS SPAIR coronal slices sequence.

In table 3, the Friedman test results show that the p-value for bone marrow, muscle, and ligament anatomy <0.05 or in other words, there are differences in image information from the three ID variations. However, it was different from the anatomy of cartilage, joint space, and liquid. The p>0.05 means no image information between ID 70 ms, 85 ms, and 100 ms in the image for cartilage anatomy, joint space, and liquid. Meanwhile, for the whole anatomy in the image, all the ID variations have a p-value below 0.05. This means a difference in image information between ID 70 ms, 85 ms, and 100 ms on the MRI wrist joint image T2 TSE FS SPAIR coronal slices sequence.

Table 3 also shows the mean rank on the MRI image TS TSE FS SPAIR sequence to find out the most optimal image information by varying the value of the ID parameter both as a whole and per anatomical criteria. Overall, the Friedman test's mean rank on the image shows that the ID value of 85 ms has the highest mean rank compared to the ID of 100 ms and 75 ms. Meanwhile, based on the results of the mean rank of the Friedman test specifically per anatomical criteria on the anatomy of cartilage, bone marrow, ligament, muscle, joint space, and liquid, it also shows that ID 85 ms has the highest mean rank compared to ID 70 ms and 100 ms. This means that the highest mean rank value at ID 85 ms both overall and per anatomical criteria shows that this ID has the most optimal image information when applying the SPAIR fat suppression technique to the MRI wrist joint image T2 TSE coronal slices sequence.

Table 2. Distribution assessment score (%) of MRI wrist joint T2 TSE FS SPAIR coronal slices sequence between ID variation value of 70 ms, 85 ms, and 100 ms.

	Anatomical Criteria																	
	Muscle			Liquid			Bone Marrow			Joint Space			Ligament			Cartilage		
Score	ID 70 ms	ID 85 ms	ID 100 ms	ID 70 ms	ID 85 ms	ID 100 ms	ID 70 ms	ID 85 ms	ID 100 ms	ID 70 ms	ID 85 ms	ID 100 ms	ID 70 ms	ID 85 ms	ID 100 ms	ID 70 ms	ID 85 ms	ID 100 ms
1	50	25	25	0	0	0	68.7	12.5	12.5	0	0	0	31.3	6.3	68.7	25	6.3	6.3
2	50	75	75	56.2	37.5	42.8	31.3	75	81.2	68.7	43.8	50	68.7	81.2	18.8	68.7	81.2	6.3
3	0	0	0	42.8	62.5	56.2	0	12.5	6.3	31.3	56.2	50	0	12.5	12.5	6.3	12.5	87.4

Exp: Score 1: less (unclear anatomy, no limit explicit and unanalyzed); Score 2: sufficient (anatomy clear enough, boundary clear and analyzable); Score 3: good (precise anatomy, clear boundaries with sharp structural lines and easy to analyze); ID: inversion delay; ms: millisecond

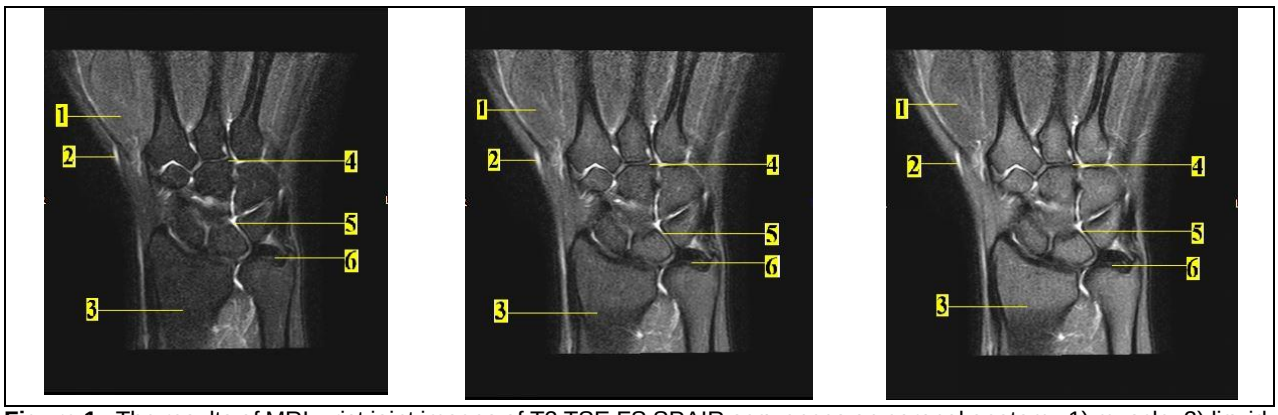

Figure 1. The results of MRI wrist joint images of T2 TSE FS SPAIR sequences on coronal anatomy 1) muscle, 2) liquid, 3) bone marrow, 4) joint space, 5) ligament and 6) cartilage, A) Variation of ID in 70ms value seems too suppressing the

signal fat (over suppress), B) Variation of ID in 85 ms shows optimal anatomical fat suppression with clear boundaries and clear structures so that it is easy to analyze, C) Variations of ID in 100 ms appear late in suppressing fat signals causing anatomical signals to recover when image acquisition quickly.

Table 3. Friedman test results for per anatomical criteria on the MRI wrist joint image T2 TSE FS SPAIR coronal slices sequence with variations in the ID value of 70 ms, 85 ms, and 100 ms.

Organ	ID value	*Mean rank*	Each Anatomical Criteria	Overall
Muscle	70 ms	1.78	0.039	<0.001
	85 ms	2.16		
	100 ms	2.06		
Liquid	70 ms	1.84	0.097	
	85 ms	2.13		
	100 ms	2.03		
Bone marrow	70 ms	1.38	<0.001	
	85 ms	2.34		
	100 ms	2.28		
Joint space	70 ms	1.75	0.069	
	85 ms	2.13		
	100 ms	2.13		
Ligament	70 ms	1.69	0.018	
	85 ms	2.25		
	100 ms	2.06		
Cartilage	70 ms	1.75	0.069	
	85 ms	2.13		
	100 ms	2.13		

DISCUSSION

Selection of the correct ID value can provide image information with optimal fat suppression level control. The ID parameter dramatically affects the amount of fat signal to be suppressed. In choosing the ID parameter value in applying the SPAIR fat suppression hybrid technique, it must be adjusted in such a way by the user. The longer the ID is used, the more time the fat will recover (recovery), and thus more signals from the fat will be seen. Besides that, the excessive level of fat compression also results in less than optimal image information. The variation in the selection of ID variations will undoubtedly be very influential and cause differences in information on the resulting image.

The difference in MRI wrist joint image information T2 TSE FS SPAIR coronal slices sequence was significant between ID 70 ms, 85 ms, and 100 ms with a $p<0.05$ for bone marrow anatomy ($p <0.001$), muscle ($p=0.039$), and ligament ($p=0.018$) due to the combination of optimal fat and water contrast images that can image the ligament layer, allowing the radiologist to accurately measure the thickness of the ligament and avoid excessive thickening of the ligament due to the number of dark ligament signals and fat dark signals[23]. Besides, in evaluating the effectiveness of fat suppression, it can be seen in the image of bone marrow and soft tissue (muscle) because effective fat compression in this anatomic area is significant to accurately assess bone edema and synovitis in early inflammatory disease of the hand[24]. In general, the selection of techniques and parameters in applying fat compression depends on the body part being imaged. Also, fat compression can improve the appearance of bone marrow and evaluate the fat in the soft tissue (muscle) mass[15]. The selected ID value strongly influences differences in anatomical information for the anatomical criteria of bone marrow, muscle, and ligament. This was because, in the SPAIR technique, the ID parameter was adjusted according to the sequence and the tissue being examined[18], where the level of tissue fat compression can be controlled, resulting in differences in image information, especially on the anatomical criteria of the bone marrow, muscle, and ligament.

On the other hand, for cartilage anatomy ($p=0.069$), joint space ($p=0.069$), and liquid ($p=0.097$), from the Friedman test results, there is no significant difference in image information $p>0.05$. Due to the absence of significant fat anatomy, SPAIR fat suppression technique with ID variation does not affect the image information in the anatomy. The joint space's anatomical appearance still looks good, even though the ID was varied so that it does not significantly affect the current image information. Meanwhile, cartilage anatomy is difficult to assess than bone marrow; the thin, soft tissue and hetero-genes of the hand cause the ID variation in applying the fat compression technique to the cartilage anatomy to be less than optimal and does not affect the resulting image information[25].

The most optimal image information on the MRI wrist joint image T2 TSE coronal slices sequence is shown from this study's results where the ID value of 85 ms has the highest

mean rank compared to the ID of 100 ms and 75 ms. This study's results are in line with Hornsi's study, namely applying an ID of 85 ms, only it was applied to the Proton Density weighted MR knee joint image. According to Hornsi's study, applying the SPAIR technique with an ID of 85 ms was optimal for suppressing bone marrow and muscular fat[19]. On the other hand, Indrati's study applying an ID of 70 ms. The results of Indrati's study with the application of ID 70 ms in the SPAIR wrist joint technique found that image information was less than optimal, so further research is needed regarding the most optimal ID value for wrist joint imaging[13].

The image information on the MRI wrist joint of the T2 TSE FS SPAIR coronal slices sequence with an ID of 85 ms causes the ID to control the level of fat suppression which is set by the user which must be set for each sequence[18] which means that when the ID is set within 85 ms, the delay time for fat compression causes magnetization zero on the tissue in the wrist joint in general and the anatomy of the bone marrow, muscle and ligament in particular so that control of the level of fat compression in each of these anatomies runs well and provides optimal image information compared to ID 70 ms and 100 ms. In the SPAIR hybrid grease suppression technique, the ID parameter determines the time between the SPAIR prepulse and the excitation pulse, thereby controlling for precise zero crossings. This also means that the ID setting controls the amount of fat compressed. In addition, in the SPAIR technique, adiabatic frequency inversion selectively excites and inversely only stresses tissue. The time delay (delay) for the excitation pulse is applied to the ID set. The zero-crossing relaxation T1 of the network signal to be suppressed occurs at the center of the excitation pulse done optimally[18].

This research was limited to one part of the organ, namely the wrist joint. The limitation of this study is that the ID value of 85 ms, which is obtained is the most optimal for MRI wrist joint imaging T2 TSE FS SPAIR coronal slices sequence cannot be used as a reference for the application of ID for the musculoskeletal part in general, further research is needed related to determining the most optimal ID value for organs SPAIR fat suppression technique.

CONCLUSIONS AND RECOMMENDATION

MRI image of the wrist joint T2 TSE FS SPAIR coronal slices sequence the most optimal with an ID variation of 85 ms compared to ID 70 ms and 100 ms. In carrying out MR wrist joint imaging of the T2 TSE FS SPAIR coronal slices sequence, radiographers should use an ID of 85 ms. We recommend that in future studies, to be able to compare MRI image information with various IDs and determine the optimal ID value on MRI examination with the SPAIR fat suppression technique for other organs.

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