ANALYSIS OF VARIATION IN TIME OF REPETITION (TR) VALUE ON THE MEAN T2 MAP VALUE OF SAGITTAL LUMBAR INTERVERTEBRAL DISCS WITH 3.0T MRI: Study on Discus Degenerative Diseases

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Abstract — **T2 Mapping sequence MRI imaging is one of the MRI examination sequences developed to assess the musculoskeletal architecture including the intervertebral disc. The parameter that affects the T2 Mapping sequence is the Time of Repetition (TR). T2 Mapping sequence is still in the research stage with various TR values. This study aims to determine the effect of variations in the TR value on the T2 Map value of the intervertebral disc on Grade I - IV on the Modified Pfirrmann scale and the optimal TR on the T2 Mapping sequence. Sagittal T2WI and T2 Mapping TRs of 1000, 2000, 3000, 4000, and 5000 ms were performed on 21 volunteers (aged 23 – 33 years) with 490 lumbar intervertebral discs. The samples were categorized based on the modified Pfirrmann grade I – IV scale. Data analysis looked at the effect of variations in TR values on the mean T2 Map and optimal TR values for the lumbar intervertebral disc using the Kruskal-Wallis test. The variation of the TR value on the mean of T2 Map value of the intervertebral disc showed a significant effect (all $p<0.05$). The greater the TR value, the more scanning time and the mean of the T2 map value, the less appropriate the Pfirrmann modified scale grading category. The Kruskal-Wallis Mean Rank shows that TR 2000 ms is the optimal TR in assessing the degree of degeneration qualitatively on the T2 Mapping sequence with a scanning time of 3 minutes 28 seconds. Sequence T2 mapping with TR 2000 ms value is good for assessing intervertebral disc degeneration qualitatively with relatively short scanning time.**

Keywords — **T2 Mapping, Sequence**, **Time of Repetition(TR), Intervertebral Disc, Degeneration, T2 Map Value**

I. INTRODUCTION

Magnetic resonance imaging (MRI) is a diagnostic radiological examination technique in the field of medicine that produces images of human body parts using magnetic fields and radiofrequency. MRI is a non-invasive imaging modality that can visualise the morphology, anatomy, and pathology of one of the intervertebral discs[1][2].

The intervertebral disc is a fibrocartilage cushion that has the function of transmitting body weight and providing flexibility to the spine. The intervertebral disc is the largest avascular organ in humans, which requires nutritional intake in the form of oxygen and glucose from blood vessels. As we age, the structure of the vertebrae and the vascularity around them will experience a decrease in function, resulting in clinical pathology, one of which is intervertebral disc degeneration[3].

Early detection of intervertebral disc degeneration is crucial to prevent and/or reduce morbidity. Based on data from the Global Health Data Exchange (GHDx), Low Back Pain (LBP) is the 6th highest cause of disability in the world, with a disability-adjusted-life-years (DALYs) value of 64.9 million or 2.6%[4]. A meta-analysis study in 2018 stated that 5.5% of all Low Back Pain (LBP) cases in the world per year[5]. Based on research by Kumbea, et al (2021), the exact number of low back pain sufferers in Indonesia is unknown, but it is estimated that between 7.6% and 37% are caused by intervertebral disc degeneration[6].

The degree of intervertebral disc degeneration is very important to know in determining the type of management that will be given to the patient. Patients with mild degrees of degeneration require molecular therapy aimed at restoring disc morphology and function[7]. Assessment of the degree of intervertebral disc degeneration generally uses a scoring system based on the modified Pfirrmann scale[8].

The Pfirrmann modified scale system is a commonly used grading system for the degree of intervertebral disc degeneration (IDD)[8][9] in this grading system, IDD is assessed using the MRI modality and categorised into 8 grades on the Pfirrmann modified scale[8]. The grading is based on intervertebral disc signal intensity, intervertebral disc structure, the boundary between the nucleus pulposus and the annulus fibrosus, and intervertebral disc height[8][10].

Imaging to detect the IDD process caused by low back pain is to perform Lumbar MRI. The commonly used Lumbar MRI sequence is the sagittal section T2-

Weighted Image (T2-WI) sequence. IDD assessment based on the pfirrmann modified scale with sagittal T2-WI images often leads to inaccuracies in categorising disc degeneration[11]. With the development of technology in the medical field, one of the sequences on MRI that is starting to be developed for early detection of degeneration, especially intervertebral discs, is the T2 Mapping sequence, which provides quantitative and more accurate results[7].

T2 Mapping is a magnetic resonance imaging technique used to calculate the T2 time of a specific tissue and display it on a parametric map. T2 Mapping sequences are one of the MRI examination sequences that are currently widely developed to assess cell macromolecular architecture, inter-matrix interactions, water molecular motion and integrity of collagen and proteoglycans because they have high sensitivity, so they can provide a quantitative assessment of the structure of the tissue to be examined[12]. T2 mapping examination methods differ in each health centre and provide significant differences in T2 values. The difference in T2 mapping values depends on the sequences used for image acquisition at each institution[13]. Therefore, it is necessary to normalise the calculation of T2 mapping values in the same patient, which is called the calculation of the average T2 map [14]. Imaging studies with T2 mapping sequences for the evaluation of lumbar intervetebral discs in sagittal sections currently have long scan times. A long scan time in one sequence will cause arterfacts due to the patient's movement when in pain while lying down[7]. There are several parameters that reduce the scan time of imaging with T2 Mapping sequences including Time of Repetition (TR)[15].

Time of Repetition (TR) is the repetition time between one pulse sequence and the next[15]. T2 Mapping image capture generally uses the multiecho spin-echo (ME-SE) technique which uses a single TR and 3 - 8 Time of Echo (TE) parameters[16].

In recent years, there has been research related to T2 Mapping of intervertebral discs, and has a variety of TR values. The TR values used vary such as TR 1000 ms by Izaya Ogon et al in 2014[17], TR 1200 ms by Alina Messner in 2015[18] and Marcus Raudner et al in 2020[7], TR 2500 ms was used by Feifei Zeng et al in 2018[19], TR 3000 ms Federico Bruno et al in 2019[12] and TR 5000 ms by Anna-Katharian Kolf et al in 2019[20]. Based on the background, the researcher is interested in conducting an analysis of variations in Time of Repetition (TR) values on the mean T2 map value of sagittal lumbar intervertebral discs with 3.0T MRI: study on disc degeneration disease. This is because the research above still has a long scan time in the range of 07 minutes 55 seconds[7] to 14 minutes 37 seconds[12][20].

II. MATERIALS AND METHODS

A. Patient data collection

The subjects of the study were volunteers who would be subjected to Lumbar MRI examination of T2 sequences and T2 Mapping Sagittal Pieces with TRs of 1000, 2000, 3000, 4000, and 5000 ms performed on 21 volunteers (aged 23 - 33 years) the sample acquisition was 490 lumbar intervertebral discs. The samples were categorised based on the modified Pfirrmann grade I - IV scale. Preliminary research was conducted from June 2021 to September 2021, while data collection was conducted from April 2022 to June 2022. Sample determination was carried out by random allocation with inclusion criteria: Volunteers with complaints of low back pain, Volunteers have no history of spinal surgery, especially lumbar. Exclusion criteria: Volunteers are not pregnant, Non-cooperative patients.

B. Study Design

The study is a quasi-experimental research with a simple experimental design (Post-test Only Control Group) which aims to determine the effect of changes in TR value variations on intervertebral disc T2 Map values at Grade I to IV Modified Pfirrmann scale[21] and optimal TR on T2 Mapping sequences. Data analysis looked at the effect of varying TR values on mean T2 Map and optimal TR values for lumbar intervertebral discs using the Kruskal-Wallis test.

C. Magnetic resonance imaging (MRI)

All MRI examinations were performed using a Philips MR Ingenia 3.0T. Morphological assessment was performed using sagittal, axial, and coronal T2-Weighted Image (T2-WI) images, as well as sagittal T1-Weighted Image (T1-WI).

T2 Mapping sequences were performed in axial and sagittal plane views, with TRs of 1000, 2000, 3000, 4000, and 5000 ms, as well as echo train length of 6, with TEs of 20, 40, 60, 80, 100, and 120 ms. All sequence parameters are presented in Table 1.

Mean T2 Map values were calculated on-site using MR Cartilage Assessment (Philips Intellispace Portal for MRI). All patients had a lower leg brace (maximum height 15 cm) placed accordingly during the examination.

Table 1. MR Sequence Parameters (Philips MR Ingenia 3.0T)

	T1-WI mDixon_TSE		T2-WI Sag	T2-WI FatSat Sag	T2-WI Cor	T1-WI Ax	T2-WI Ax	T2 ME-SE (T2 Map Discus gram) Sag				
	T1-WI Sag	T1-WI Fatsat Sag										
***Time of Repetition* (ms)**	Range 550-600		2000	2000	2000	Range 500-650	Range 2000-5000	1000	2000	3000	4000	5000
***Time of Echo* (ms)**	9		60	60	60	9	120	20, 40, 60, 80, 100, 120				
***Field of View* (mm)**	160 x 260		160 x 260	160 x 260	160 x 260	160 x 160	160 x 160	160 x 260				
***Voxel Size* (mm)**	0,95 x 1,14		0.75 x 0.7	0.75 x 0.7	0.75 x 0.7	0,8 x 0,8	0,7 x 0,9	1 x 1				
***Slice Thickness* (mm)**	5		5	5	3	3	3	5				
***Interslice Gap* (mm)**	0,5		0,5	0,5	0,3	0,3	0,3	0,5				
Number of Slice	21	21	15	15	15	5 x 5	5 x 5	11	11	11	11	11
Scan Time	04.59		04.54	06.32	04.54	04.24	02.53	01.44	03.28	04.30	06.40	07.50

III. RESULTS

A. Sample Characteristics

Data collection was carried out from April to June 2022 at the Radiology Cluster of the Kencana Integrated Service Installation, Dr Cipto Mangunkusumo National Hospital Jakarta. The number of volunteers was 21 people with the characteristics presented in Table 2 and Table 3

Table 2. Sample Characteristics

Sample Characteristics	**Male**	**Female**
	Mean ± SD	**Mean ± SD**
Age	29 ± 4 years	28 ± 5 years
Weight	71.5 ± 8.5 Kg	60 ± 20 Kg

Table 1 shows that the age and weight characteristics of volunteers are relatively similar and there are no significant differences in the characteristics of the sample. The total number of samples that met the inclusion criteria was 21 people.

The average age of male subjects was 29 years with a range of 24 - 33 years with an average body weight of 71.5 kg with a range of 63 - 80 kg, while the average age of women was 28 years with a range of 23 - 33 years with an average body weight of 60 kg with a range of 40 - 80 kg, and a total of 490 Lumbar Vertebrae Discs were sampled.

Table 3. Sample Patient by Gender

Sample by Gender	**Number of Patient (n)**	**Percentage (%)**
Male	4	19,05%
Female	17	80,95%
Total Sampling	21	100%

Table 3 shows a description of the gender characteristics of the sample, where the number of female samples is greater than male. There were 17 women (80.95%) and 4 men (19.05%).

All volunteers performed MRI of the Lumbar Vertebrae T2-WI Sagittal Sequence as shown in Figure 1, this is to see the condition of the spine, especially the Lumbar Spine before the study. If it meets the inclusion criteria, the next process is carried out, namely MRI of the Lumbar Vertebrae with the T2 ME-SE sequence (T2 Map Discus gram) Sagittal following the Sagittal T2-WI which has been done five times with a variation in TRs value (1000, 2000, 3000, 4000, and 5000ms) in each repetition of the sequence, no respondents resigned, all continued until the examination was completed. Figure 1 shows samples of MRI images of Lumbar Vertebrae T2-WI Sagittal Sequence and MRI of Lumbar Vertebrae T2 ME-SE (T2 Map Discus gram) Sagittal Sequence.

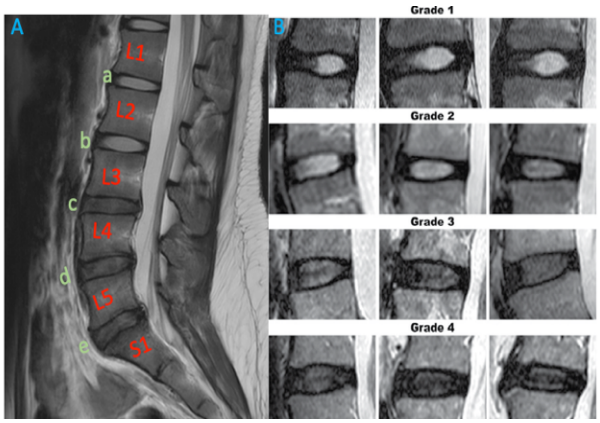

Figure 1. MRI images of lumbar vertebrae Sagittal T2-WI sequences (A), Grade I (b); Grade II (a); Grade III (c); Grade IV (d) and (e), Modified Pfirrmann Scale Grade 1 to IV(B)[8]

B. Kruskal-Wallis t-test assessing the effect of varying TR values on mean T2 Map on Sagittal MRI of Lumbar Intervertebral Disc.

Table 4. Kruskal-Wallis test Analysis Results

TR value (ms)	Pfirrmann's Modified Grading Scale	*p-value*
TR 1000	Grade I, II, III, IV	0,000
TR 2000	Grade I, II, III, IV	0,000
TR 3000	Grade I, II, III, IV	0,000
TR 4000	Grade I, II, III, IV	0,000
TR 5000	Grade I, II, III, IV	0,000

The results of the Kruskal-Wallis non-parametric statistical test in Table 4 state that there is an effect of variations in changes in the value of Time of Repetition (TR) on the average value of the T2 Map, with a significance value of $p = 0.000$ ($p < 0.05$) at TRs of 1000, 2000, 3000, 4000, and 5000 ms.

The effect of variations in TR values generally affects scan time, the greater the TR value will increase scan time as stated by A. Tanjung, (2013)[22]. Based on this study, the author has a view on the effect of variations in TR values on the value of the T2 map. TR is a parameter in the T2 Mapping sequence that is varied, while other variables are made similar. Different TR produce different T2 Map values.

C. Mean Rank in determining the optimal TR on T2 Mapping sequences

To find out which TR value is better in producing the optimal mean T2 Map value, the mean rank results of the Kruskal Wallis test can be seen in Table 5.

Table 5. Means Rank results of the Kruskal-Wallis Test

T2 Map Mean Value	Mean Rank of TR Value				
	TR 1000	TR 2000	TR 3000	TR 4000	TR 5000
Grade I	61.92	**66.70**	62.79	62.61	58.73
Grade II	57.41	55.05	56.95	57.37	**60.98**
Grade III	17.00	16.45	**20.09**	16.00	15.82
Grade IV	**13.82**	9.27	9.91	12.91	10.64

Based on table 5, the results show that TR 2000 ms has the highest mean rank value on the T2 Map Grade I Modified Pfirmann Scale value of 66.70, TR 5000 ms has the highest mean rank value on the T2 Map Grade II Modified Pfirmann Scale value of 60.98, TR 3000 ms has the highest mean rank value on the T2 Map Grade III Modified Pfirmann Scale value of 20.09, and TR 1000 ms has the highest mean rank value on the T2 Map Grade IV Modified Pfirmann Scale value of 13.82.

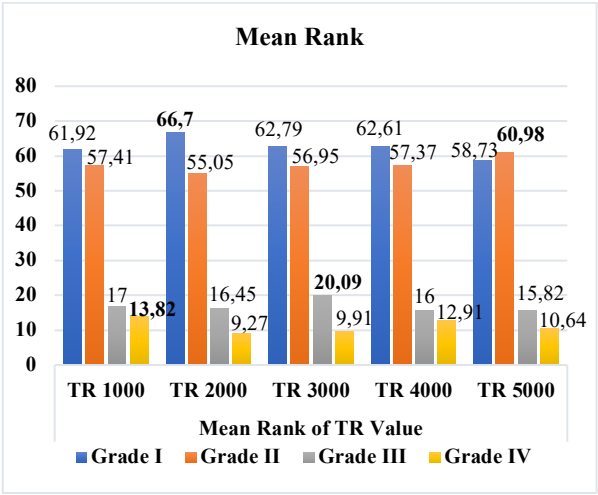

Figure 2. The graph shows that the mean rank of TR 2000 ms is relatively the highest, compared to other TR values and the TR 2000 ms value is a good TR reference value to be used in T2 Mapping sequences in obtaining the mean value of the T2 Map.

Figure 2 shows that the mean rank between the TR values is actually not much different. The mean rank of TR 2000 ms is relatively the highest, compared to other TR values. Figure 2 also shows that the TR 2000 ms value is a good TR reference value for use in T2 Mapping sequences in obtaining the mean T2 Map value.

IV. Discussion

This study was conducted on volunteers who came to the Radiology department. MRI examination of Lumbar Vertebrae with complaints of lower back pain that has an age range of 18 - 45 years with a total sample of 21 people who meet the inclusion criteria and determination of discs is done by calculating the average value of T2 Map based on the reading results of a Musculoskeletal Consultant Radiologist with more than

10 years experience in the field as a validator and obtained as many as 98 Discs.

The collected samples have characteristics: in male samples with an average age of 29 years with a range between 24 - 33 years, there are 4 people with an average body weight of 71.5 kg with a range between 63 - 80 kg. While the female sample has an average age of 28 years with a range between 23 - 33 years of 17 people with an average body weight of 60 kg with a range between 40 - 80 kg. The total number of lumbar vertebrae discs calculated by the T2 Map was 490 discs. This condition is almost the same as that reported by Peng et al, 2013[23]; Kalleward et al, 2010[24]; and Zhang et al, 2009[25], who said that patients with early degeneration of intervertebral discs accompanied by low back pain often attack people with a young adult age range. Age is reported to be closely related to the process of intervertebral disc degeneration[23][24][25].

A. Effect of variation in Time of Repetition (TR) value changes on the average T2 Map value

The average value of the T2 Map produced allows for uncertainty, there are several values produced in ROI measurements that produce different values with the modified Pfirrmann scale grading scale. The uncertainty of the Pfirrmann Scale has been suggested by Chun Chen, et al (2013)[26] and Federico Bruno, et al (2019)[12]. The Pfirrmann modified scale by Griffith, et al (2007)[8] serves to reduce the level of double perception that occurs on the Pfirrmann scale. The Modified Pfirrmann scale used in this study and the results of the measurements on the T2 Map sequences show that there are several mean values of the T2 Map that have discrepancies. This occurred at TR values above 2000 ms. The average value of the T2 Map that is different in the variation of the TR value shows that there is an influence on the output of the average value of the T2 Map.

B. Optimal Time of Repetition (TR) value

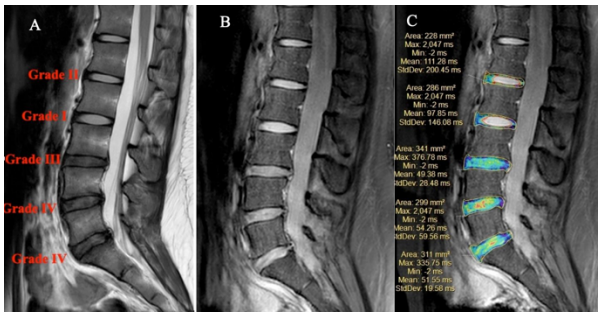

Figure 3. (A) Sagittal T2WI with Pfirrmann Modification Scale, (B) Sagittal T2 Map TR 2000 ms, (C) Sagittal T2 Map TR 2000 ms with T2 Map Value

The mean rank Kruskal-Wallis test shows that the TR value of 2000 ms is the optimal TR value in the T2 Mapping sequence. Figure 3 The T2 Mapping image with TR 2000 ms is better in image quality, sharpness and boundaries between tissues are firmer, making it easier to do Return on Investment (ROI) contouring to get an accurate average T2 Map value and has a scan time for the T2 Map sequence of about 3 minutes 28 seconds.

V. CONCLUSION

1. The study was conducted using a variety of TRs of 1000, 2000, 3000, 4000, and 5000 ms in the T2 Map sequences. The value of each TR on the same disc produces a different mean value of the T2 Map. The mean value of the T2 Map is also different and shows the uncertainty of each grading of the Modified Pfirrmann scale which is the reference grading of disc degeneration. The results showed that there was an effect of Time of Repetition (TR) variation on the mean value of the T2 Map of lumbar MRI of sagittal slices of intervertebral discs with 3 Tesla MRI in evaluating the degree of intervertebral disc degeneration, according to the Kruskal-Wallis test significance value ($p = 0.000$) or ($p < 0.05$). The effect of variations in TR value generally affects scan time, the greater the TR value will increase scan time.
2. In this study, the TR 2000 ms value is well used in T2 mapping in qualitatively assessing intervertebral disc degeneration with a relatively short scan time of 3 minutes 28 seconds, indicating that TR 2000 ms is the optimal TR used in T2 mapping.

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