Iraqi JMS

Published by College of Medicine, Al-Nahrain University
P-ISSN 1681-6579
E-ISSN 2224-4719
Email: iraqijms@colmed.nahrainuniv.edu.iq
http://www.colmed-alnahrain.edu.iq
http://www.iraqijms.net/
Iraqi JMS 2025; Vol. 23(1)

# Comparative Diagnostic Efficacy of 3D vs 2D T2-Weighted MRI in Assessing Lumbar Spine Pathologies

**Noor W. Awad**[1] *MSc*, **Rasha S. Ahmed**[2] *PhD*, **Muna A. Zghair**[3] *PhD*

[1]Dept. of Medical Instrumentation Techniques Engineering, College of Technnical Engineering, Al-maarif University, Anbar, Ramadi, [2]Dept. of Physiology, College of Medicine, Al-Nahrain University, Baghdad, Iraq, [3]Dept. of Surgery and Radiology, College of Medicine, Mustansiriyah University, Baghdad, Iraq

## Abstract

**Background** Magnetic resonance imaging (MRI) detects soft tissue pathologies and lumbar disc illnesses such as bulging, herniation, spinal stenosis, and vertebral abnormalities. Three-dimensional (3D) isotropic MRI provides several benefits over two-dimensional (2D) turbo spin-echo sequences for musculoskeletal imaging.

**Objective** To compare the image quality of 2D T2-weighted turbo spin-echo (2D T2W TSE) sequences to 3D T2-weighted turbo spin-echo (3D T2W TSE) sequences and estimate how physical parameters of patients, including age and sex, may impact the outcome of medical imaging.

**Methods** Seventy patients with lumbar spine problems (mean age below 50) were examined. MRI scans were obtained with 2D T2W TSE and 3D T2W TSE sequences. Parameters assessed included image contrast, signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR), and signal intensity, calculated using a region-of-interest tool.

**Results** The findings demonstrated that 2D T2W TSE images exhibited significantly higher mean (230.59±64.4) signal intensity values, and greater signal intensity variability (2.92±0.61) than 3D T2W TSE images. Conversely, 3D T2W TSE images outperformed their 2D counterparts in signal-to-noise ratio (82.93±31.51) and contrast-to-noise ratio (40.55±14.95). A strong negative correlation was observed between age and both the mean signal intensity and SNR in 2D T2W TSE images. No significant association was found between age and any characteristics of 3D T2W TSE images. Furthermore, sex showed no significant correlation with any features of 2D or 3D T2W TSE images.

**Conclusion** The research found increased signal intensity in 2D T2W TSE images and higher SNR and CNR in 3D T2W TSE images. These data imply that age may affect signal intensity measures from 2D T2W images, lowering image quality in older individuals. The lack of a significant link between age and 3D T2W TSE parameters shows that age-related changes may not impact 3D T2W TSE images.

**Keywords** Magnetic resonance imaging, lumbar spine, 2D sequence, 3D sequence, image quality.

**Citation** Awad NW, Ahmed RS, Zghair MA. Comparative diagnostic efficacy of 3D vs 2D T2-weighted MRI in assessing lumbar spine pathologies. Iraqi JMS. 2025; 23(1): 147-154. doi: 10.22578/IJMS.23.1.17

**List of abbreviations:** 2D T2W TSE = Two-dimensional T2-weighted turbo spin-echo, 3D T2W TSE = Three-dimensional T2-weighted turbo spin-echo, CNR = Contrast-to-noise ratio, ROI = Region of interest, SNR = Signal-to-noise ratio, T1 = Longitudinal relaxation, T2 = Transverse relaxation, TE = Echo time, TR = Repetition rime

## Introduction

An increase in the total medical burden of the illness is being caused in part by the prevalence of low back pain (LBP), which is the main cause of years lost due to

disability on a worldwide scale [1]. Lumbar disc herniation (LDH), lumbar central canal stenosis (LCCS), and lumbar nerve roots compression (LNRC) are the most prevalent causes of LBP, which are also the major reasons why patients seek medical therapy for their symptoms [1,2].

Magnetic resonance imaging (MRI) of the lumbar spine is an essential diagnostic technique that assists in selecting the most appropriate course of treatment for low back pain [3]. Both non-operative and surgical techniques are considered to be potential therapeutic options. Standard T1W and T2W sequences are utilized in the majority of radiology departments in order to evaluate herniated discs, the spinal canal, and the neural foramina. This is done in order to provide accurate diagnostic information [4].

In the past several years, three-dimensional (3D) isotropic magnetic resonance (MR) sequences have become an increasingly popular alternative to two-dimensional (2D) turbo spin-echo (TSE) sequences in musculoskeletal imaging. This change was made as a substitute for 2D sequences. This is because the latter comes with a number of benefits that are built into it by their very nature. The enhanced through-plane spatial resolution of 3D sequences produces thin continuous slices, which helps to avoid the partial-volume artifacts [5].

In the examination of degenerative diseases of the lumbar spine, preliminary clinical experience with MRI has shown promising results. This is especially the case in the event that an efficient pulse-sequence method is utilized. To give the radiologist the capacity to identify diseased tissue and differentiate between various types of normal tissue based on changes in MRI contrast, MRI technician must select the right pulse sequences. The MRI scanner has made this scenario far more likely.

Image quality in MRI is governed by a number of elements, some of which include scan time, voxel size, the contrast between tissues intrinsic to the MRI sequence (i.e., T1, T2), and the strength of the MR signal and noise [6].

Hossein et al. assessed the diagnostic utility and picture quality of T2-weighted 3D isotropic turbo spin-echo (SPACE) sequences in contrast to T2-weighted 2D TSE sequences for the purpose of performing a thorough examination of lumbar spine diseases. They determined parameters of picture quality such as signal-to-noise ratio and contrast-to-noise ratio for a variety of locations of interest using their calculations [7].

Lee et al. compared the performance of a 3D T2W TSE sequence to that of a standard 2D T2W TSE on the lumbar spine in terms of identifying foraminal stenosis, spinal stenosis, and nerve root compression with clinical and surgical correlation was the objective of their research. 3D T2W TSE-SPACE at 3.0T they revealed equal sensitivity compared to 2D TSE for identifying foraminal stenosis, spinal stenosis, and nerve compression with higher inter-observer agreements and symptom correlations. This was the case for all three types of stenosis [8].

To evaluate and compare the diagnostic quality of 3D and 2D T2-W TSE MRI sequences for the lumbar spine and to analyze the effects of age and sex on image quality parameters.

## Methods

### Patients

This study was approved by the Institutional Review Board (IRB) of the College of Medicine at Al-Nahrain University. Data collection was conducted over a four-month period, from January to April 2023, involving a total of seventy patients (27 males and 43 females). The patients' ages ranged from 40 to 70 years, with a mean age of 46.19±10.81 years. MRI of the lumbar spine, specifically the L1-L2, L2-L3, L3-L4, and L4-L5 levels, was performed using two distinct imaging sequences: 2D T2W TSE and 3D T2W TSE. Patients with pacemakers, platinum implants, or metallic components were excluded from participation. Additionally, women of reproductive age who reported a potential pregnancy during their first trimester were not included in this study.

**Examination protocol and sequences**

The examination was conducted using a 1.5 Tesla MRI scanner (Siemens, 2018 model) at Al-Ramadi Teaching Hospital in Al-Anbar, Iraq. The imaging protocol began with a conventional 2D-MRI sequence, including T1W and T2W images acquired in both sagittal and axial planes. Subsequently, additional 3D-SPACE sequences in T2W were obtained in the axial plane using the parameters detailed in Table 1. The acquisition time for the axial and sagittal 2D-TSE sequences totaled 426 seconds, while the 3D axial SPACE sequence required 291 seconds.

**Table 1. Parameters of Two-Dimensional (2D) vs. Three-Dimensional (3D) T2-weighted (T2W) MRI for Lumbar Spine Nerve Root Compression Patients**

| Parameters | 2D T2W | 3D T2W |
|---|---|---|
| Voxel Size | 0.7x0.7x0.8 $mm^3$ | 0.8x0.8x4.0 $mm^3$ |
| Total Scan Time | 0.2021±0.0403 | 0.098±0.0403 |
| Flip Angle | 160° | 150° |
| NEX (Number of Excitations) | 1.40 | 3.00 |
| TE (Echo Time) | 143 ms | 66.33±49.69 ms |
| TR (Repetition Time) | 1500 ms | 2768.66±905.34 ms |

Voxel size refers to the spatial resolution of the images; 2D T2W offers finer resolution in two dimensions, while 3D T2W captures data in a thicker voxel dimension, which may provide additional volume information at the cost of resolution in specific planes.

Total Scan Time indicates how much time each MRI sequence requires for image acquisition.

Flip angle, NEX, TE, and TR are MRI sequence parameters that influence the contrast, quality, and signal intensity of the images. These parameters vary between 2D and 3D sequences, contributing to differences in diagnostic quality and image characteristics.

**Image analysis**

**Signal-to-noise ratio (SNR) and contrast-to-Noise Ratio (CNR) calculation**

For both applied sequences 2D TSE T2W and 3D SPACE T2W used, MR signal intensities were evaluated by selecting the region of interest (ROI), the SNR was recorded from the ROI image window analysis by the following equation [9], as illustrated in figure (1).

$$SNR = \frac{\text{mean signal intensity of the region of interest signal}}{\text{standard deviation of background signal intensity (noise)}} \dots\dots (1)$$

This method is based on the signal statistics in two different ROIs from a single image.

The CNR was also measured by selecting the ROI window according to the following equation [10], as illustrated in figure (2).

$$CNR_{AB} = \frac{C_{AB}}{\sigma_N} = \frac{|S_A - S_B|}{\sigma_N} = |SNR_A - SNR_B| \dots\dots (2)$$

Where σN is the standard deviation of the noise.

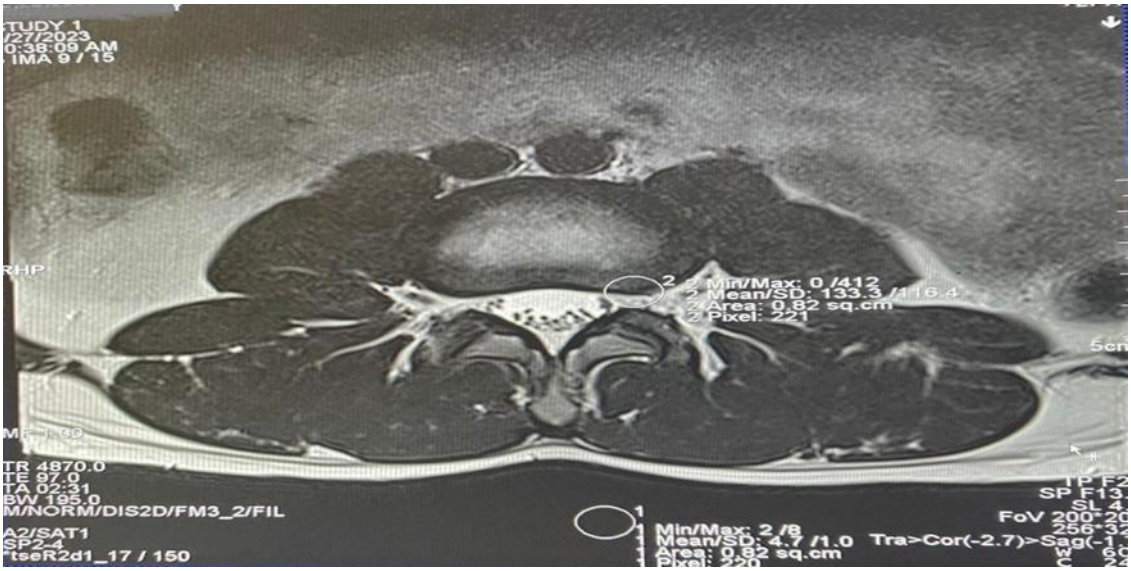


**Figure 1. The ROnoI Statistics on the MR image for a specific area of the lumbar spine to calculate SNR**

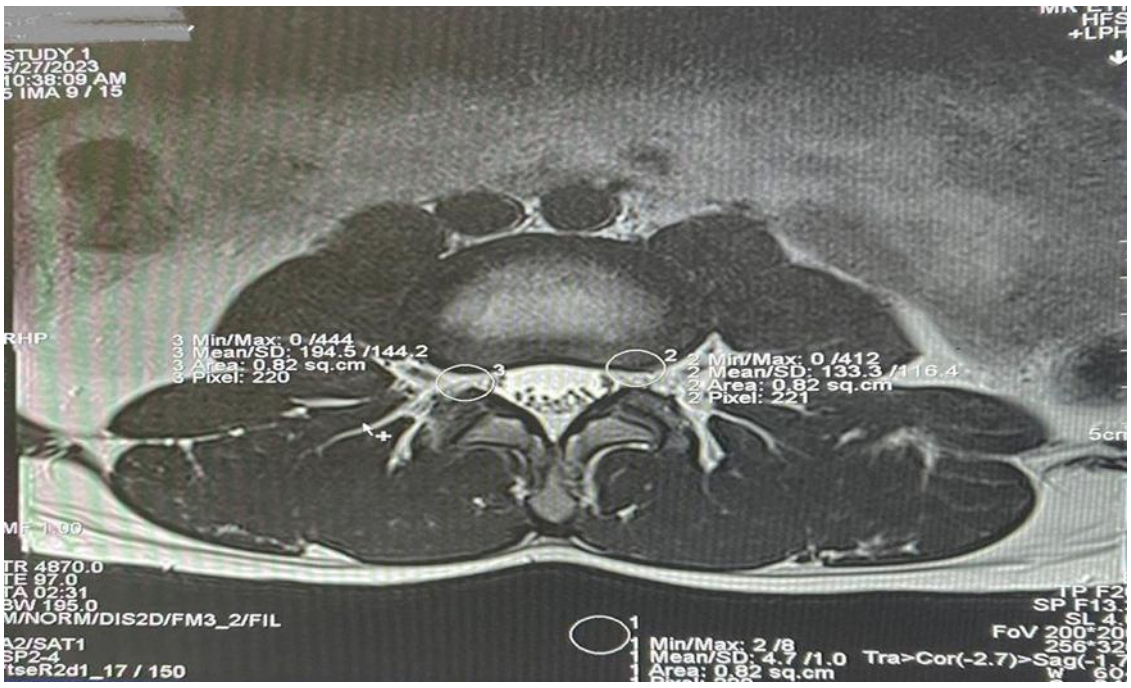


**Figure 2. The ROI Statistics on the MR image for a specific area of the lumbar spine to calculate CNR**

**Statistical Analysis**

The data was analyzed using statistical package for social sciences (SPSS) version 25. The data were presented using percentages, averages, standard deviations, and ranges (minimum-maximum values). The independent samples t-test was used to compare two independent means, while the paired samples t-test was used to compare paired observations or dependent means. A P value of 0.05 or less indicated a significant difference.

## Results

The statistical analysis revealed a significant difference in the parameters of 2D and 3D T2W images, specifically, 3D T2W images demonstrated superior diagnostic performance compared to 2D T2W images, particularly in terms of SNR and CNR.

**Table 2. Parameters of two versus three-dimensional T2W**

| Parameters | 2D T2W | 3D T2W | P value |
|---|---|---|---|
| Mean signal intensity | 230.59±64.40 | 181.70±53.38 | <0.001* |
| Minimum signal intensity | 40.38±10.86 | 2.62±0.31 | <0.001* |
| Maximum signal intensity | 388.59±83.96 | 331.03±62.81 | <0.001* |
| Standard deviation of signal intensity | 2.92±0.61 | 2.26±0.52 | <0.001* |
| SNR | 82.93±31.51 | 83.85±30.31 | 0.821 |
| CNR | 40.55±14.95 | 56.16±16.12 | <0.001* |

* Significant difference at P value ≤0.05

**The relation of age with 2D T2W and 3D T2W**

In order to investigate the impact that a patient's age has on the signal intensity of 2D T2W and 3D T2W, a Pearson correlation test was carried out, as shown in table (3). According to the findings, there is a statistically significant negative correlation between age and both the mean signal intensity and the SNR of 2D T2W. There was no discernible connection between age and any of the other factors in the 3D T2W analysis.

**Table 3. Correlation of age with 2D T2W and 3D T2W**

| Parameters | 2D T2W | | 3D T2W | |
|---|---|---|---|---|
| | r | P value | r | P value |
| Mean signal intensity | -0.365 | 0.004* | -0.219 | 0.093 |
| Minimum signal intensity | -0.003 | 0.988 | 0.047 | 0.724 |
| Maximum signal intensity | -0.209 | 0.111 | -0.244 | 0.060 |
| Standard deviation of signal intensity | 0.159 | 0.224 | -0.060 | 0.654 |
| SNR | -0.339 | 0.008* | -0.158 | 0.231 |
| CNR | -0.200 | 0.126 | -0.137 | 0.300 |

* Significant difference at P value ≤0.05

**The Relation of sex with 2D T2W and 3D T2W**

As can be seen in table (4), a correlation analysis based on the Pearson test was utilized in order to discover whether or not there was a link between sex and the 2D and 3D T2W. There was no statistically significant link found between sex and any of the 2D or 3D T2W approaches that were investigated.

**Table 4. Correlation of sex with 2D T2W and 3D T2W**

| Parameters | 2D T2W | | 3D T2W | |
|---|---|---|---|---|
| | r | P value | r | P value |
| Mean signal intensity | -0.176 | 0.179 | -0.176 | 0.179 |
| Minimum signal intensity | -0.112 | 0.398 | -0.102 | 0.443 |
| Maximum signal intensity | -0.183 | 0.164 | 0.009 | 0.943 |
| Standard deviation of signal intensity | -0.097 | 0.461 | -0.097 | 0.461 |
| SNR | -0.064 | 0.627 | 0.093 | 0.482 |
| CNR | -0.119 | 0.369 | 0.081 | 0.539 |

* Significant difference at P value ≤0.05

## Discussion

MRI is widely used for the evaluation of lumbar intervertebral disc disorders, primarily focusing on the discs themselves. In this study, the 3D T2W TSE sequence demonstrated significant diagnostic potential. These findings are consistent with those reported by Hossein et al. [7], who found that 3D SPACE sequences provide superior image quality and diagnostic performance [11].

To investigate disc herniation, the spinal canal, and the neural foramina, the majority of radiology departments use routine T1W and T2W sequences. The diagnosis of lumbar disc herniation and associated pathologies, such as neural root or thecal sac indentations and neural root oedema, as well as localizing the exact site of the underlying pathology, are both made possible by MRI [4].

The patient population's average age in this study was 46.19 years, with a standard deviation of 10.81 years. Furthermore, it was discovered that the patient sample had much more females than males.

All patients with lumbar spine diagnoses underwent the same scanning protocol, with the same voxel size, total scan time, flip angle, and number of excitations (NEX) parameters. For 2D T2-weighted scans, the parameters remained essentially constant, but for 3D T2-weighted scans, there were differences in the TE, TR, and area parameters.

The findings showed that when comparing 2D T2W images to their 3D T2W equivalents, the mean signal intensity, minimum signal intensity, maximum signal intensity, and the standard deviation of signal intensity were all significantly higher in the 2D T2W images. In contrast, the 3D T2W images had greater SNR and CNR values than the 2D T2W images.

In their work, Hossein et al. [7] compared the 2D TSE and 3D SPACE sequences for lumbar spine MRI protocol in terms of diagnostic value and image quality. They used visibility, agreements among pathological indicators, SNR, CNR, and visibility to assess the image quality of both sequences. The findings demonstrated that, with the exception of the intervertebral disc and vertebrae, where SNR was comparable in both sequences, the 3D SPACE sequence had much greater SNR and CNR in all anatomical structures. Because of the disparity in SNR across these components, the CNR between the spinal cord, CSF, and intervertebral disc was noteworthy. The SNR, CNR, and visibility of some indexes were greater in the 3D T2W SPACE sequence than in the 2D-T2W. The researchers suggested this could be due to the higher image quality of 3D SPACE, which facilitates a more straightforward diagnosis of pathological indexes. The researchers recommended using 3D SPACE sequence for routine lumbar spine MRI protocol based on their findings.

The results showed that the mean signal intensity and SNR values derived from the 2D T2W images were significantly negatively correlated with age. This shows that the mean signal intensity and SNR values of the 2D T2W images decrease with age. Age, on the other hand, did not significantly correlate with any of the parameters determined from the 3D T2W

images. Similar to present findings, Lee et al. [8] reported no significant correlation between sex and image quality in lumbar spine MRI. However, they did not specifically analyze age-related signal variation. Our findings extend this by showing age-related decline in 2D T2W image intensity.

The results showed no conclusive relationship between sex and any of the factors assessed for 2D and 3D T2W images. This shows that the measures of signal intensity made using these imaging modalities were not significantly affected by the patient's sex. The parameters assessed for either 2D or 3D T2W imaging techniques did not significantly correlate with sex, according to the Pearson test correlation analysis. This study found no significant correlation between sex and the signal intensity parameters in both 2D and 3D T2-weighted images, which agrees with previous findings [Kızılgöz et al. [4], Lee et al. [8]]. This indicates that sex does not affect MRI quality for lumbar spine assessment, supporting the use of standardized imaging protocols for all patients.

In conclusion, the study showed that females were more frequently affected than males and that the average age of the patients diagnosed with lumbar spine was slightly under 50 years. The T2-weighted scan parameters used for 2D versus 3D scans were slightly different from the conventional methodology used for this group. The results of the study showed that the parameter values of 2D and 3D T2W images may be distinguished from one another, with 2D T2W images typically having higher values for signal intensity measurements and 3D T2W images having greater SNR and CNR values. Age and the mean signal intensity and SNR of 2D T2W images were inversely associated. The mean signal intensity and SNR of 2D T2W images decrease with age. Age did not correlate with 3D T2W image characteristics. The study showed no conclusive relationship between sex and any of the factors assessed for 2D and 3D T2W images. In light of these findings, the (3D T2W TSE) MRI sequence is the one that should be used rather than the (2D T2W TSE) sequence when attempting to determine the most dysfunction in the lumbar spine. Finally, the primary benefit of 2D T2 over 3D T2 in MRI lies in its faster acquisition time, simpler implementation, and ability to provide diagnostic information in specific clinical contexts. 2D T2 sequences offer quicker imaging, making them ideal for situations requiring rapid assessments, such as emergency cases or when time constraints are present. Additionally, 2D T2 is easier to implement and more widely available, especially in facilities where 3D T2 capabilities may not be accessible. Clinically, 2D T2 is preferred when localized evaluation with high-resolution slices is sufficient, or when there is no need for detailed 3D imaging. While 3D T2 provides superior spatial resolution and comprehensive visualization, particularly for complex conditions, 2D T2 remains a suitable choice when a quick diagnostic assessment is needed or when resources and time are limited.

## Acknowledgement

The authors would like to thank the staff of the MRI Department at Al-Ramadi General Teaching Hospital for their cooperation and support throughout this study.

## Author contribution

Awad: performed data collection, image analysis, and wrote the article. Dr. Ahmed: supervised the study design, provided scientific guidance, and critically revised the manuscript. Dr. Abdulghani: contributed to the clinical assessment and interpretation of clinical findings.

## Conflict of interest

The authors declare no conflict of interest.

## Funding

This research received no external funding.

## References

1. Knezevic NN, Candido KD, Vlaeyen JWS, et al. Low back pain. Lancet. 2021; 398(10294): 78-92. doi: 10.1016/S0140-6736(21)00733-9.
2. Rydevik B, Brown MD, Lundborg G. Pathoanatomy and pathophysiology of nerve root compression. Spine (Phila Pa 1976). 1984; 9(1): 7-15. doi: 10.1097/00007632-198401000-00004.

3. Qaseem A, Wilt TJ, McLean RM, et al. Noninvasive Treatments for Acute, Subacute, and Chronic Low Back Pain: A Clinical Practice Guideline from the American College of Physicians. Ann Intern Med. 2017; 166(7): 514-530. doi: 10.7326/M16-2367.
4. Kızılgöz V, Sivrioğlu AK, Aydın H, et al. Three-dimensional turbo spin-echo sequence versus conventional two-dimensional turbo spin-echo sequences in the evaluation of lumbar intervertebral discs. Eur Res. J. 2018; 4(4): 366-73. doi: 10.18621/eurj.354357.
5. Naraghi A, White LM. Three-dimensional MRI of the musculoskeletal system. AJR Am J Roentgenol. 2012; 199(3): W283-93. doi: 10.2214/AJR.12.9099.
6. Hendrick RE. Breast MRI: Fundamentals and technical aspects. New York, NY: Springer; 2008. p. 93-111. doi: https://doi.org/10.1007/978-0-387-73507-8_7.
7. Hossein J, Fariborz F, Mehrnaz R, et al. Evaluation of diagnostic value and T2-weighted three-dimensional isotropic turbo spin-echo (3D-SPACE) image quality in comparison with T2-weighted two-dimensional turbo spin-echo (2D-TSE) sequences in lumbar spine MR imaging. Eur J Radiol Open. 2018; 6: 36-41. doi: 10.1016/j.ejro.2018.12.003.
8. Lee S, Jee WH, Jung JY, et al. MRI of the lumbar spine: comparison of 3D isotropic turbo spin-echo SPACE sequence versus conventional 2D sequences at 3.0 T. Acta Radiol. 2015; 56(2): 174-81. doi: 10.1177/0284185114524196.
9. Reeder SB. Measurement of signal-to-noise ratio and parallel imaging. In: Schoenberg SO, Dietrich O, Reiser MF. (eds) Parallel imaging in clinical MR applications. Medical Radiology. Berlin, Heidelberg: Springer 2007. doi: https://doi.org/10.1007/978-3-540-68879-2_4.
10. Alvares RDA, Szulc DA, Cheng HL. A scale to measure MRI contrast agent sensitivity. Sci Rep. 2017; 7(1): 15493. doi: 10.1038/s41598-017-15732-8.
11. Neubert A, Fripp J, Engstrom C, et al. Three-dimensional morphological and signal intensity features for detection of intervertebral disc degeneration from magnetic resonance images. J Am Med Inform Assoc. 2013; 20(6): 1082-90. doi: 10.1136/amiajnl-2012-001547.


**Correspondence to Noor W. Awad**
**E-mail: noorw2388@gmail.com**
**Received Jul. 17th 2023**
**Accepted Sep. 11th 2023**