Research Article

Comparison of T2-Weighted 3D-Space and T2-Weighted 2D-TSE Sequences in Lumbar Spine MR Imaging

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Abstract

Background: Spine-related issues like low back pain have sub-stantially increased in the past few decades across all age categories, with a variety of etiologic reasons, of which degenerative illnesses make up the majority.

Objectives: To compare the image quality and diagnostic value of 3D space MRI sequence with 2D TSE MRI sequence in lumbar spine imaging.

Methods: Fifty patients, irrespective of gender having age between 30-70 years, who presented with lower back pain were enrolled for the study. Lumbar spine imaging was done using 2D TSE and 3D space sequences and the subsequent images were evaluated by two senior consultant radiologists for qualitative analysis of visibility and pathologic indices of both sequences. Data was analyzed on SPSS 25.0. Statistical analysis was done using Cohen's kappa (k).

Results: Female participants were 56% of total study population. Mean age of study participants found to be 53.62±10.76 years. Statistically significant difference (p-value =0.000) was noted for visibility score of all the lumbar spine components, when the 3D SPACE and 2D TSE images were compared with 3D-SPACE images found being superior in visibility. Inter- observer agreement for visibility of various regions of lumber spine was nearly perfect (k> 0.8) and substantial (0.6 to 0.8) for 3D-SPACE, while substantial (0.8<k> 0.6) for 2D-TSE. Pathologic indexes had a significant level of inter-observer agreement (k > 0.6). Inter-observer agreement for 3D sequence (k = 0.72) was greater than that for 2D-TSE sequence (k = 0.64).

Conclusion: Images from 3D-SPACE sequences provide superior visibility over 2D-TSE and could be recommended as alternative imaging method for lumbar spine pathologies. Higher inter observer agreement illustrate that it may be included in routine sequences to make the better diagnosis for lumbar spine pathologies correctly.

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Keywords | 3D-SPACE sequence, 2D-TSE sequence, lumbar spine, lower back pain.

Introduction

Spine-related issues like low back pain have sub-stantially increased in the past few decades across all age categories, with a variety of etiologic reasons, of which degenerative illnesses make up the majority.[1] Largely, it is believed that MRI of the lumbosacral spine (LS spine), with its excellent contrast and spatial resolution and lack of ionizing radiation, is the ideal imaging tool for examining low back pain. It is considered as a powerful diagnostic tool to examine the alignment of the spine, find anomalies in the vertebrae or the spinal

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cord, assess any inflammation of the spinal cord or nerves, look for tumors on or near the spinal cord, track the effects of injury or surgery on the spine, and investigate various causes of back pain. Sagittal and axial views of Tl and T2 weighted sequences are frequently used in traditional MRI protocols for the spine.[2,3]

2D TSE sequence has thicker slices and larger interslice gaps (particularly in the axial plane). In axial views of 2D TSE sequences, interslice gaps can result in loss of detail among the slice categories. Therefore, smaller structures like compressed nerve roots which are the most frequent cause of lower back pain, may be missed because of the wider interslice gaps in the 2D TSE sequenced images.[4] Due to the wider inter slice gaps in the 2D-TSE sequence, some of the smaller structures, like nerve root compressions, which can be the main cause of low back pain, may be missed. The voxels in this traditional 2D TSE sequence are not isotropic so multiplanar reconstruction is not practical, as it would impair overall picture quality, necessitate additional measurements, and extend imaging time while increasing the likelihood of motion artifacts.[5] The usefulness of 2D TSE sequences is quite limited in patients with abnormal lumbar spine curvature (lordosis, scoliosis) as it requires imaging in oblique planes in a certain orientation is necessary to see a specific structure that would otherwise be difficult to see. In comparison to the traditional 2D T2 TSE sequence, this 3D T2 SPACE sequence with its multi planar reconstruction has many advantages[6,7,8] Above all, they provide gapless imaging, which ensures that no data is lost in between slices. Second, there is a decrease in partial volume artifacts as a result of the capture of thin continuous slices. Third, by creating multi planar reconstruction, it provides a potential new method of evaluating spinal anatomy and pathology.[9]

Few past studies have conducted around the globe that compared the diagnostic values of both these technologies, however mixed observations have been made in these researches. Spinal imaging is being done using both these MRI modalities in our country. However there has been no study done to compare the diagnostic value of 2DTSE sequential images with 3D space images, for analyzing image quality variables including anatomical structure visibility and lumbar spine pathological index. Better visibility and higher interobserver rating for both visibility and pathological index makes 3D-SPACE the MR sequence of choice in future for analysis of lumbar spine pathologies.

Methods

This observational study was done between August 2021 and April 2022 at the Department of Radiology of Combined Military Hospital CMH, Lahore. After getting permission from ethical review committee of CMH, Lahore, patients of age between 30 to 70 years irrespective of gender who presented with low back pain were shortlisted for the study. Sample size was calculated using a web-based sample calculator for reliability studies developed by Arifin WN[10] taking expected kappa (k) as 0.8, precision as 0.15,90 % confidence level and 0.5 as proportion of outcome. Patients with clinical history of spinal trauma or surgery, patients with any malignancy or spinal infection, patients with metallic implants in situ, claustrophobic and pregnant patients were all excluded in the study. After taking written consent, all the selected patients underwent T1W and T2W 2D-Turbo spine-echo (TSE) in sagittal and axial planes; after that, T2- weighted SPACE imaging was performed for evaluating lower back pain on a 1.5 T MRI Scanner (Model-Magnetom SOLA, by SIEMENS HEALTHINEERS manufactured in 2020). 2D and 3D protocols with the same field of view (FOV-360 and base resolution-224) was used to examine the patients. Image analysis was done by the two senior radiologists with at least ten years of teaching experience. To avoid systematic bias, every image was examined in a different order from the visibility of anatomical structures. Five-point confidence scale was used for the quantitative assessment of each sequence, where I for not visible, 2 for poorly visible, 3 for moderately visible, 4 for clearly visible and 5 for exceptional visibility. The structures analyzed included the nerve roots, cerebrospinal fluid (CSF), spinal cord, intervertebral disc and vertebrae. From LI to L5 level of the 2D-TSE and 3D SPACE images, 47 data points were evaluated based on an established criteria for herniation, stenosis, and degenerative changes. The severity scores for the associated pathologic indexes are shown in the Table-1. SPSS version 25.0 was used to perform the statistical calculations. The Mean values for visibility of anatomical structures as per criteria were calculated. The Cohen's kappa correlation coefficient was used to measure the degree of inter observer agreement related to the qualitative in vivo

analysis of pathologic index and anatomical structures. The Inter observer concordance was analyzed as suggested by Viera A.I and Garrett Im.[11]

Results

A total of fifty (n=50) patients were enrolled for the study, of which n=27 (54%) of participants were female with mean age of 53.96±11.27 years and n=23 (46%) was male with mean age of 53.22±10.38 years. Mean cumulative age of study population was 53.62±10.76 years. The 3D T2-weighted SPACE sequence revealed considerably improved visualization (p-value=0.000) of CSF, spinal cord, vertebrae, nerve roots and discs (Table 2), in comparison with 2D T2-weighted TSE sequences. Upon implication of kappa statistics for inter-observer agreement for 3D-SPACE among all the regions, almost

Table 1: *Pathologic Indexes of the Lumbar Spine for Radiologist Interpretation*[17]

Pathologic Index	Severity		Description
Sagittal Views	**T2 TSE**	**3D Space**	
Hydration of Disc	Lumbar 1-2 Lumbar 2-3 Lumbar 3-4 Lumbar 4-5 Lumbar 5-Sacral 1		Normal: Zero Mildly reduced: One Dark disc: Two
Disc height	Lumbar 1= Lumbar 2= Lumbar 3= Lumbar 4= Lumbar 5=		Normal: Zero Partially reduced ‹ 50%: One Markedly reduced › 50% : Two
Herniation of disc	Lumbar 1= Lumbar 2= Lumbar 3= Lumbar 4= Lumbar 5=		Absent: 0 Present but with no spinal canal compression: One Present with mild spinal canal compression (‹50%): Two Present with marked spinal canal compression (›50%): Three
Transitional vertebrae			No: Zero Yes: One
Changes at endplate	Lumbar 1= Lumbar 2= Lumbar 3= Lumbar 4= Lumbar 5=		Normal: Zero Present: One
Spondylolisthesis	Lumbar 1= Lumbar 2= Lumbar 3= Lumbar 4= Lumbar 5=		Normal: Zero Anterolisthesis: One Retrolisthesis: Two
Signal changes of Spinal cord			Normal: Zero Present: One
Axial Views			
Central Stenosis	Lumbar 1= Lumbar 2= Lumbar 3= Lumbar 4= Lumbar 5=		Normal: Zero Mild: One Moderate: Two Severe: Three
Herniation of disc	**Lumbar 1=** Lumbar 2= Lumbar 3= Lumbar 4= Lumbar 5=		Absent: Zero Present, but with no spinal canal compression: One Present with mild spinal canalcompression (‹50%): Two Present with marked spinal canal compression (›50%): Three
Facet joint arthropathy	Lumbar 1= Lumbar 2= Lumbar 3= Lumbar 4= Lumbar 5=		Absent: Zero Present: One

Table 2: *Mean Visibility for 2D TSE and 3D Space Sequences for Various Segments of Lumbar Spine*

Segment of lumbar spine	MRI Sequences	Mean visibility score	Standard deviation	*p*-value
CSF	2D-TSE	3.06	0.98	0.000
	3D-SPACE	4.08	0.85	
Spinal cord	2D-TSE	3.32	0.98	0.000
	3D-SPACE	4.18	0.77	
Vertebrae	2D-TSE	3.80	1.07	0.000
	3D-SPACE	4.48	0.65	
Disc	2D-TSE	3.90	0.93	0.000
	3D-SPACE	4.44	0.64	
Nerve root	2D-TSE	3.58	1.18	0.000
	3D-SPACE	4.14	0.97	

Table 3: *Inter Observer Agreement for Visibility of Lumbar Spine Segments for 2D TSE and 3D Space Sequences*

Segment of lumbar spine	MRI Sequences	Inter-observer agreement (*k*)
CSF	2D-TSE	0.69
	3D-SPACE	0.82
Spinal cord	2D-TSE	0.70
	3D-SPACE	0.72
Vertebrae	2D-TSE	0.75
	3D-SPACE	0.82
Disc	2D-TSE	0.80
	3D-SPACE	0.79
Nerve root	2D-TSE	0.79
	3D-SPACE	0.85

perfect agreement was noted for CSF, vertebrae and nerve root. On the other hand, 2D-TSE inter observer concordance was noted substantial for all the lumbar spine components. Also, there was substantial agreement in rest of the regions for 3D- SPACE (Table 3). We further noticed that inter-observer agreement for scoring the pathologic index was considerable for 2D- TSE (k=0.64) and 3D-SPACE(k0.72), with higher k value for latter.

Figure- 1: *Comparing Axial and Sagital Images of T2-TSE and T2- Space MR Sequences*

Discussion

Classically, 2DTIW1 and T2W1 sequences which provided uni-planar visualization of osseous structures and soft tissues have been used in spinal MR imaging.

The 3D sampling perfection with application-optimized contrasts using different flip angle evolution (SPACE) sequence is a turbo spin-echo T2 weighted 3D sequence that uses variable flip angles for refocusing rather than the standard 180 degree refocusing plane. The 3D SPACE sequence with its multi planar reconstruction after a single-plane acquisition has now become clinically feasible as it has provided many advantages over the conventional 2D TSE sequence in evaluation of spinal anatomy and pathology[12] (Figure-1). The absence of crosstalk across sections, a high signal to noise ratio (SNR) along with good spatial resolution are advantages of 3D techniques.[13]

In the current study, we analyzed the visibility value as well as inter-observer agreement for pathologic index of lumbarspine and visibility MRI protocol using 3D T2-weighted SPACE imaging as compared with a 2D-TSE sequence. As a result of parallel acquisition, the spatial resolution and signal to noise ratio are higher, and the imaging time is low.[14,15] Another diagnostic usefulness of SPACE sequence over TSE is to study the CSF more precisely avoiding the flow artifacts and also has the appropriate tissue differentiation. Moreover, multi planar reformats can be created once the patient has exited the scanner, which saves time and reduces the need for additional exams when pathologic abnormalities are missed. With spinal scoliosis and postoperative anatomical distortion, this can be incredibly useful.[16] The current study illustrated the visibility and pathologic index of lumbar spine components for 3D SPACE and 2D TSE sequences. We qualitatively assessed the visibility of various lumbar spine components (i.e. disc, CSF, vertebrae, spinal cord and nerve root) as well as it was compared by two experienced radiologists and inter observer agreement was determined. For most lumbar spine segments, the results of average visibility and inter observer agreement for both sequences were considerably different with higher visibility for 3D SPACE. Moreover, inter-observer concordance for visibility was substantial and nearly perfect for all components of lumbar spine in case of 3D- SPACE, however, for 2DTSE it was also substantial for all cases. Pathologic indices were also assessed qualitatively, and both inter-method and inter-observer agreement were identified. Compared to 2D-TSE, the inter-observer agreement for the 3D SPACE sequence was greater, that may be because the 3D SPACE sequence has better image quality which makes it simpler to diagnose abnormal indices. Additionally, an imperfect inter observer agreement may be the result of the radiologists reporting style and the qualitative evaluation of pathologic indexes. Our results are comparable with the study conducted by Hossein J et al. and colleagues,[17] in which they reported that inter-observer agreement for visibility of various lumbar spine segment was perfect (k>0.6) and substantial, which is similar to our findings. On the other hand, contrary to our study, they illuminated a substantial and perfect inter-method agreements for all of the pathologic indexes (k 46), which was less than chance in our study. In their study, however, compared to 2D-TSE

sequence (k=0.603), 3D SPACE sequence was higher (k=0.793) but values are lesser than our study findings.

In an intra-individual comparison, Sartoretti E et al, studied singular, unilateral radiculopathy in symptomatic patients who were evaluated with both 2D-TSE and 3D SPACE MRI sequences both.[18] In this study of Saroretti E, two readers classified the grade of lumbar lateral recess stenosis and lumbar foraminal stenosis twice on both image sets using formerly authenticated grading systems. There was high inter-readout agreement for both the imaging and grading systems. There was moderate Inter-sequence agreement for both lumbar lateral recess stenosis and lumbar foraminal stenosis. The above mentioned study provided evidence that 3D-SPACE sequenceoutperforms 2D T2 TSE imaging in visualizing lumbar nerve root compromise.[19] Sayah A et al, also compared the effectiveness of a lumbar MRI protocol using 3D SPACE sequences with a standard MRI protocol for evaluation of lumbar spondylosis. They also found 3D SPACE a highly accurate sequence for all degenerative processes, disc herniation, canal compromise, for lateral recess compromise and for foraminal compromise.[19]

Limited studies have been done internationally that discussed and compared the lumbar spine diagnostic similarity and value for 3D-SPACE and 2D-TSE. So, this study will definitely be a good addition to the data for the future researches not on local level but also for the global implications. However, this study has few limitations, such as it was conducted in a hospital and most of the study population belonged to the same ethnicity and data cannot be generalized. Demographic stratification along with few study parameters such as scan time, patient comfort, test related anxiety is also missed in our study. In order to minimize these limitations, multi-institutional, larger scale studies on the national level should be conducted.

Conclusion

3D-SPACE sequence provides high-quality imaging of lumbar spine segments in terms of visibility and pathologic index, with multi planar reformatting capability. Higher inter-observer agreement regarding diagnostic image quality for 3D SPACE sequence as compared to 2D-TSE, makes it sequence of choice of future for MR evaluation of pathologies of the lumbar spine.

Ethical Approval: The Research review board of Combined Military Hospital Lahore approved the study vide letter No. 326/2021.

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Authors' Contribution:

QA: Conception, design, analysis, interpretation, of data, drafting and critical revision

SFN: Supervised all steps and critical revision of the article

TMM: Conception, design, drafting, critical review

MS: Design, analysis, critical review and drafting

ZB: Conception, drafting and literature review

KK: Design, critical review and drafting

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