Suez Canal University Medical Journal Vol. 27 (5), 2024
Pages 1-8

The Added Value of Short Tau Inversion Recovery Magnetic Resonance Imaging Sequence in Evaluation of Endplate Changes of the Lumbar Spine in Patients with Low Back Pain

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Abstract

Background: **Endplate change classification in low back pain patients is broadly utilized and is the most recognized method for categorizing endplate changes. Short tau inversion recovery (STIR) images have a significant role in better characterizing bone marrow endplate changes.** ***Aim:*** **To assess the added value of short tau inversion recovery magnetic resonance imaging (MRI) sequence in evaluating endplate changes of patients with low back pain.** ***Subjects and Methods:*** **A descriptive cross-sectional study included 100 Patients with low back pain referred to a routine MRI study of the lumbar spine. Sagittal T1W, sagittal and axial T2W, and sagittal STIR sequences were used. Twelve endplates in each patient from D12-S1 levels were evaluated for abnormal signals. Modic change type was recorded.** ***Results:*** **Fifty-seven female and 43 male patients, aged 19 to 72 years, were included. Abnormal STIR signal and abnormal T2W/T1W signal were seen in 8.4% and 9.3% of all endplates, respectively. Forty-five (95.7%) and 54 (33.3%) endplates with Modic type 1 and type 2 changes show abnormal STIR signals, respectively.** ***Conclusion:*** **The STIR sequence has added value and is complementary to T1W and T2W images. When incorporated into the standard non-contrast MRI technique for assessing low back pain, it provides additional information in some individuals.**

Keywords: STIR, endplate changes, low back pain.

Introduction

One of the leading medical and economical universal health problems is low back pain (LBP). According to reports, LBP is prevalent in 31% of people, and the lifetime prevalence ranges from 60% to 80%. LBP is a complex illness involving both physical and psychological aspects as well as alterations in the brain[1,2]. For people with LBP, intervertebral disc (IVD) degeneration is a significant source of pain. Back pain linked with dehydration of IVD, anatomical malformation, or any alternative obvious causes of discomfort and impairment is frequently referred to as "axial back pain" or "discogenic back pain," respectively. Spinal surgery is beneficial for treating various diseases, including spinal malformation, radiating pain due to disc bulge, spinal stenosis, and spondylolisthesis[3,4]. Classification of Modic changes (MCs) signal abnormalities in the vertebral endplates into categories Modic type 1 changes (MC1) (edema

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type), Modic type 2 changes (MC2) (fatty type), and Modic type 3 changes (MC3) (sclerotic type) is established on Magnetic resonance imaging (MRI)T1-weighted (T1W) and T2-weighted (T2W) imaging[5]. Of patients with nonspecific chronic low back pain (CLBP), about 22% (range 12–37%) show MC1 or mixed MC1/MC2[6]. The pathophysiology of MCs is still being studied, and mechano-immunological and infectious mechanisms are implicated either separately or concurrently[7]. Basivertebral nerve ablation (BVNA) was recently approved for treating individuals with vertebrogenic pain associated with MC1 and MC2 endplate edema. This development highlights the significance of recognizing MCs[8]. As a result of increased awareness of the connection between CLBP and vertebral endplate and marrow destruction, manifested as MC1 or MC2 abnormalities on MRI, United States academic institutions now support the BVNA procedure and the diagnostic identification of CLBP patients with MC1 or MC2 abnormalities[9]. The International Classification of Diseases (10th Revision) diagnostic code M54-51 has been established to diagnose vertebrogenic pain based on medical history and MRI[10]. The short tau inversion recovery (STIR) sequence is pertinent for MCs evaluation and sensitive to edema. Although there is no clear correlation between MCs and pain, MC1 may be symptomatic[11-13]. Validating the STIR findings' applicability to symptoms and therapy requires accurate examination, MRI scans are combined to help clinicians and researchers assess MCs. The dependability of assessments using T1W/T2W sequences without fat suppression is generally well documented; however, this is not the case for assessments using fat-suppressed, fluid-sensitive sequences[14,15]. STIR sequences are frequently employed in MRI to assess edematous alterations in the bone marrow, particularly the spine. Despite their ubiquitous use, spinal examinations using STIR or other fluid-sensitive series with fat suppression have inconsistent reliability statistics[5]. More thorough reliability data is required for STIR examinations of the lumbar spine. This study aims to find out if low back pain patients may benefit from using the STIR sequence to assess changes in their lumbar endplates.

Subjects and Methods

Researchers used a descriptive cross-sectional design at the Diagnostic Radiology Department of Ismailia's MRI unit at Suez Canal University Hospital. The study included one hundred adult patients with low back pain referred from the Neurology Department. Patients of both genders aged more than 18 were included in the study. Criteria for exclusion included those with a history of lumbar spine operation, spondylo-discitis, or malignancy of the spine, as well as those with absolute contraindications to MRI (claustrophobia, cochlear implants, pacemakers, or metallic foreign bodies). Suez Canal University's Faculty of Medicine's research ethics committee approved the project. The approval number was (5238). Before data collection and inquiry, all subjects provided signed informed consent. Each patient was subjected to an extensive neurological history and examination, and a lumbosacral MRI scan was performed using a 1.5 Tesla MR scanner (Philips Medical Systems, Achieva). The researchers were personally responsible for collecting the data. The examination time ranged between 15 and 20 minutes for each patient. Sagittal T1W images (TR = 575, TE = 11), T2W images (TR = 3700, TE = 87), STIR images (TR = 5530, TE = 70), and axial T2W images (TR = 300–3800, TE = 100–120) were all included in the MRI scans. All

sequences were produced with 0.4 mm slice spacing and 4 mm slice thickness. On sagittal images, the field of vision was 30 cm, while on axial images, it was 18 cm[5]. A radiologist with 12 years of expertise evaluated twelve endplates in each patient from T12-S1 levels. For each endplate, we noted whether an abnormal signal appeared on T1W/T2W pictures, STIR, or both sequences. Based on the appearance of T2W and T1W images, the MCs type was noted for each endplate.

Table 1: Demographic and clinical parameters among patients (n = 100)

	No. (%)
Sex	
Male	43(43%)
Female	57(57%)
Age (years)	
Mean ± SD.	48.3 ± 13.1
Median (Min. – Max.)	51(19 – 72)
Clinical presentation	
Low back pain	21(21%)
Motor	1(1%)
Sensory	7(7%)
Motor + sensory	1(1%)
Low back pain + Motor	9(9%)
Low back pain + Sensory	38(38%)
Low back pain + Motor + Sensory	21(21%)
Low back pain + Sphincter	2(2%)
Laterality	
No laterality	15(15%)
Right	17(17%)
Left	15(15%)
Bilateral	53(53%)

SD: Standard deviation

Statistical analysis

To examine the data input into the computer, we used IBM SPSS software package version 20.0. ("Redwood City, New York: IBM Corporation, 2016"). For categorical data, percentages and numbers were employed. Numbers were expressed quantitatively using minimum and maximum values, means, standard deviations, and medians. Chi-square test (Monte Carlo). For Comparisons between groups. The significance of the results obtained was judged at the 5% level.

Results

Fifty-seven female and 43 male patients, ages nineteen to seventy-two, with a mean ± SD (48.3 ± 13.1) (Table 1). The mean age for males and females is 49.5 ± 13.7 and 47.5 ± 12.8, respectively (Table 2). Most clinical indications for lumbar spine MRI were low back pain, low back pain with sensory symptoms and low back pain with motor and sensory symptoms, representing 21 (21%), 38(38%) and 21(21%) patients, respectively. Most of the symptoms were bilateral, representing 53(53%) patients (Table 1). Five/1200 (0.4%) and 111/1200 (9.3%) of the endplates showed abnormal signals only on STIR images and abnormal signals only on T1W/T2W images, respectively. 101/1200 (8.4%) of all endplates showed abnormal STIR and T1/T2 signals. MC1, MC2 and MC3 were seen in 47(3.9%), 162(13.5%), and 2(0.2%) endplates, respectively (Table 3).

Table 2: Mean age of male and female separately (n= 100)

	Male	Female
Age		
Mean ± SD.	49.5 ± 13.7	47.5 ± 12.8
Median (Min. – Max.)	51(19 – 72)	50(19 – 71)

SD: Standard deviation

Table 3: Vertebral endplate abnormal signal and Modic changes among patients (n = 1200)	
	No. (%)
Abnormal signal	**217(18.1%)**
Abnormal STIR	5(0.4%)
Abnormal T1/T2	111(9.3%)
Abnormal STIR + T1/T2	101(8.4%)
Modic changes	**211(17.6%)**
Type 1	47(3.9%)
Type 2	162(13.5%)
Type 3	2(0.2%)

SD: Standard deviation, STIR: short tau inversion recovery, T1: T1 weighted image, T2: T2 weighted image

A statistically significant relation (p-value <0.001) existed between the abnormal signal and MCs. Forty-five (95.7%) and 54 (33.3%) endplates with MC1 and MC2, respectively, show abnormal STIR signals (Table 4). The inferior endplate of L4 was the most affected, with abnormal STIR signals representing 10% of patients. The inferior endplate of L4, superior endplate of L5, inferior endplate of L5 and superior endplate of S1 were the most affected endplates with abnormal T1/T2 signals representing 18%, 20%, 18% and 19% of patients. The inferior endplate of L5 and superior endplate of S1 were the most affected endplates, with both abnormal STIR and abnormal T1/T2 signal representing 25% and 20% of patients (Table 5). Modic type 1 changes were more evident at the inferior endplate of L5 and the superior endplate of S1, representing 11% and 10% of patients, respectively. Modic type 2 changes were more evident at the inferior endplate of L4 23(23%), superior endplate of L5 24 (24%), inferior endplate of L5 32 (32%), and superior endplate of S1 29 (29%), representing 23%, 24%, 32%, and 29% of patients, respectively (Table 5).

Discussion

Low back pain ranks high among the most significant health problems as a social and economic burden. This research aims to determine if the STIR sequence is useful for evaluating lumbar spine endplate changes in LBP patients. The mean age of patients was 48.3 years, ranging from 19 to 72; 57 (57%) females made up the sample. The mean age was 45.3 (61 women) in the study by Vigeland et al.[16].

Table 4: Relation between abnormal signal and Modic changes (n = 1200) (% from raw)							
Modic changes	**N**	**Abnormal signal**				**X^2**	**^{MC}p**
		Normal (n= 983)	**Abnormal STIR (n= 5)**	**Abnormal T1/T2 (n= 111)**	**Abnormal STIR + T1/T2 (n= 101)**		
Normal	**989**	983 (99.4%)	5 (0.5%)	1 (0.1%)	0 (0%)	1157.919*	<0.001*
Type 1	**47**	0 (0%)	0 (0%)	2 (4.3%)	45 (95.7%)		
Type 2	**182**	0 (0%)	0 (0%)	108 (66.7%)	54 (33.3%)		
Type 3	**2**	0 (0%)	0 (0%)	0 (0%)	2 (100%)		

*χ^2: Chi-square test, MC: Monte Carlo, STIR: short tau inversion recovery, T1: T1 weighted image, T2: T2 weighted image, p: p-value for comparison between the studied categories, *: Statistically significant at p ≤ 0.05.*

In agreement with Bråten et al.[17], patients with MC1 had an average age of 45.3 years. In contrast, patients with MC2, who were primarily female, had an average age of

44.4 years. The data show that low back pain often affects more women than men and that the average age at which it first appears is 45 years old. In this study, 5/1200(0.4%) of the endplates showed abnormal signals only on the STIR sequence. 111/1200 (9.3%) of the endplates showed abnormal signal only T1W/T2W sequences. 101/1200 (8.4%) of all endplates demonstrated abnormal STIR and T1/T2 signals. Meanwhile, in Vettiyil et al.[5], an abnormal STIR signal was visible in 132/600 (22%) of the endplates. In 125/600 (21%) of the endplates, abnormal T1W/T2W signal was seen. 28/600 (4.7%) of the endplates showed abnormal signals only on the STIR sequence. 31/600 (5.2%) of the endplates showed abnormal signals only on T1W/T2W sequences.

Table 5: Vertebral endplate abnormal signal and Modic changes (n = 100) (% from total)

	Inf D12	Sup L1	Inf L1	Sup L2	Inf L2	Sup L3	Inf L3	Sup L4	Inf L4	Sup L5	Inf L5	Sup S1
Abnormal signal												
Normal	96(96%)	95(95%)	95(95%)	94(94%)	87(87%)	85(85%)	86(86%)	85(85%)	71(71%)	73(73%)	55(55%)	61(61%)
Abnormal STIR	0(0%)	0(0%)	0(0%)	2(2%)	0(0%)	0(0%)	0(0%)	10(10%)	1(1%)	1(1%)	2(2%)	0(0%)
Abnormal T1/T2	0(0%)	0(0%)	2(2%)	0(0%)	5(5%)	8(8%)	10(10%)	9(9%)	18(18%)	20(20%)	18(18%)	19(19%)
Abnormal STIR + T1/T2	4(4%)	5(5%)	3(3%)	4(4%)	8(8%)	7(7%)	4(4%)	5(5%)	10(10%)	6(6%)	25(25%)	20(20%)
Modic changes												
Normal	96(96%)	95(95%)	95(95%)	94(94%)	87(87%)	85(85%)	87(87%)	86(86%)	72(72%)	74(74%)	57(57%)	61(61%)
Type 1	3(3%)	4(4%)	2(2%)	1(1%)	5(5%)	3(3%)	2(2%)	1(1%)	4(4%)	1(1%)	11(11%)	10(10%)
Type 2	1(1%)	1(1%)	3(3%)	5(5%)	8(8%)	12(12%)	11(11%)	13(13%)	23(23%)	24(24%)	32(32%)	29(29%)
Type 3	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	0(0%)	1(1%)	1(1%)	0(0%)	0(0%)

STIR: short tau inversion recovery, **T1:** T1 weighted image, **T2:** T2 weighted image, **Sup:** superior, **Inf:** inferior, **D:** dorsal, **L:** lumbar.

Modic type 1 change was found in 47(3.9%) endplates, MC2 was found in 162(13.5%) endplates, and MC3 was seen in 2(0.2%) endplates. While in Vettiyil et al.[5], MC1, MC2, and MC3 were seen in 30/600 (5%), 83/600 (14%), and 12/600 (2%) endplates, respectively. This was in discordance with Bråten et al.[17]. Modic type 1 and 2 changes were seen in 118 (65.5%) and 62 (34.5%) patients, respectively. In this study, an Abnormal STIR signal was seen in 45 (95.7%), 54 (33.3%), and 2(100%) of the endplates that showed MC1, MC2, and MC3, respectively. In Vettiyil et al.[5], abnormal STIR signal was seen in 25/30 (83.3%), 60/83 (72.3%), and (11/12) 91.7% of endplates that showed MC1, MC2 and MC3 respectively. Abnormal STIR signals in MC2 and MC3 prove that bone marrow edema can occur in later stages of the disease (acute on top of chronic changes). Modic type 1 changes were more evident at the L5/S1 level, while MC2 was more evident at the L4/L5 and L5/S1 levels. This is in concordance with Bråten et al.[17]. Modic type I and type II changes were more evident at the L4/L5 and L5/S1 levels, representing 77(42.7%) and 132 (73.3%), respectively. This study showed that a subset of patients only exhibits abnormal endplate signals on T1W/T2W imaging, whereas another subgroup exhibits abnormal signals on STIR images. We further show that STIR hyperintense signals are visible in MC2 and MC3, in addition to the expected hyperintense appearance of endplates on STIR images corresponding to MC1. On T1W/T2W pictures, some endplates with MC1 do not show a hyperintense STIR signal. The variations in the endplate appearance between STIR and

T1W/T2W weighted pictures could be several reasons. Fat saturation may lead to improved edema and hyperemia delineation in certain instances. In other circumstances, abnormal signals only seen on T1W/T2W weighted pictures may be explained by the increased signal-to-noise ratio of conventional T1W and T2W sequences.

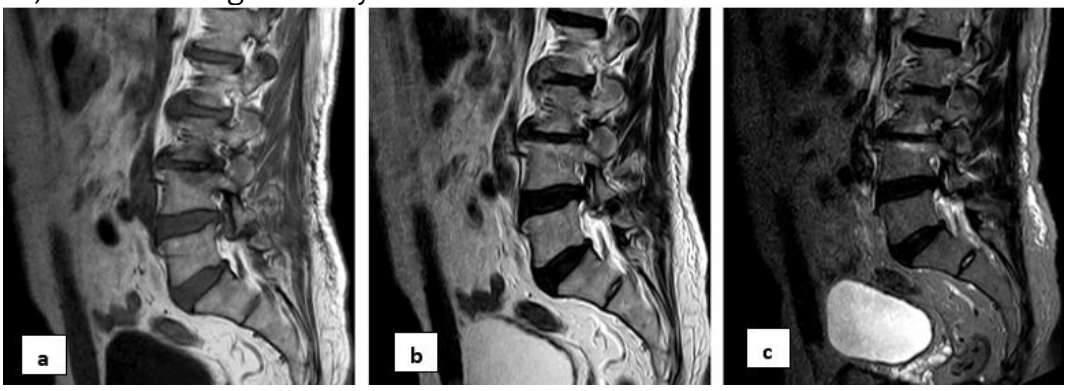

Figure 1: MRI of lumbosacral spine in a 65-year-old man complaining of low back pain with bilateral sciatica. Sagittal T1WI, T2WI, and STIR images show Modic endplate changes type 1 at L3-L4 level seen as hypointense endplates at T1WI (a) and hyperintense endplates at T2WI and STIR images (b and c).

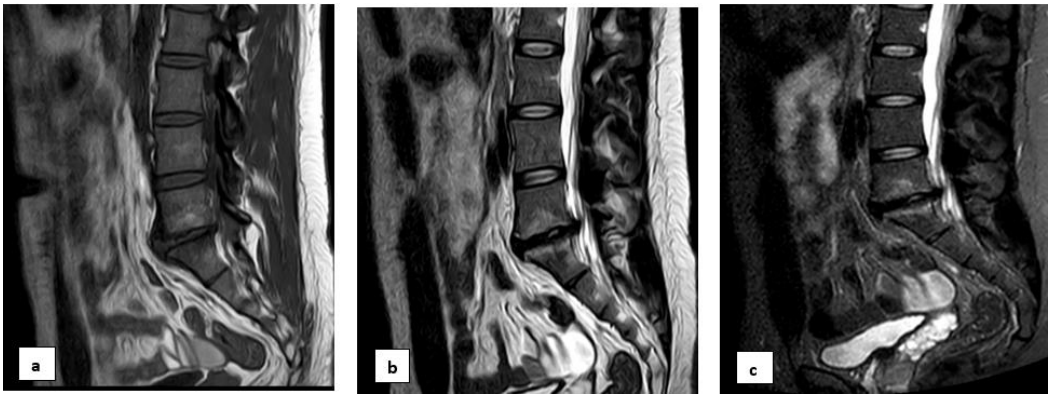

Figure 2: MRI of lumbosacral spine in a 33-year-old man complaining of low back pain with numbness of the right lower limb. Sagittal T1WI, T2WI, and STIR images show Modic endplate changes type 2 at L5-S1 level seen as hyperintense endplates at T1WI, T2WI, and STIR images (a, b and c). Note that the high signal in the STIR image indicates that bone marrow edema can occur on top of chronic changes.

Also, this study showed that any endplate may have multiple stages of MCs at any given moment. Even while some of them are found in the same physical spot on the endplate, an STIR signal abnormality may occasionally be seen in a different place than the Modic changes on T1W/T2W pictures.

Conclusion

The STIR sequence has added value and is complementary to T1W and T2W images. When incorporated into the standard non-contrast MRI technique for assessing low back pain, it provides additional information in some individuals.

Limitations

One limitation is the lack of several observers. Another limitation is that there was no association between the endplate changes observed on microscopy and the histological analyses.

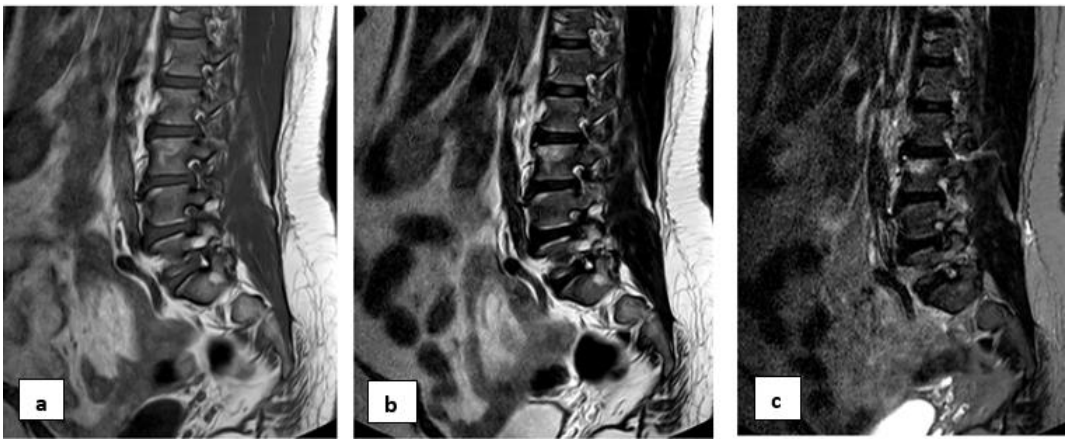

Figure 3: MRI of lumbosacral spine in a 52-year-old woman complaining of low back pain with weakness of both lower limbs. The superior endplate of the L3 vertebral body shows a hyperintense signal in sagittal T1WI, T2WI, and STIR images (a, b, and c) representing Modic endplate changes type 2. Note that the high signal in the STIR image indicates that bone marrow edema can occur on top of chronic changes.

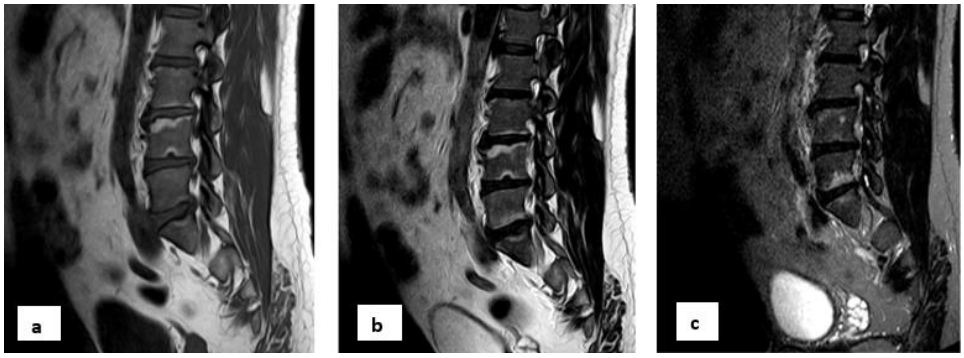

Figure 4: MRI of lumbosacral spine in a 39-year-old man complaining of low back pain with right sciatica. The superior endplate of L4, the inferior endplate of L5, and the superior endplate of S1vertebral bodies show hyperintense signal in sagittal T1WI, T2WI, and STIR images (a, b, and c) representing Modic endplate changes type 2. Note that the high signal in the STIR image indicates that bone marrow edema can occur on top of chronic changes. A Schmorl's node is seen at the inferior endplate of L4.

Abbreviations

BVNA: basivertebral nerve ablation, CLBP: chronic low back pain, IVD: intervertebral disc. LBP: low back pain. MC: Modic changes. MC1: Modic type 1 changes, MC2: Modic type 2 changes, MC3: Modic type 3 changes, MRI: Magnetic resonance imaging, TE: time to echo, TR: repetition time, T1WI: T1 weighted imaging, T2WI: T2 weighted imaging, STIR: Short tau inversion recovery.

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