Diagnostic Efficacy of Posterior Epidural Fat Interposition on Magnetic Resonance T1-Weighted Sequence in the Diagnosis of Spondylolysis

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■ OBJECTIVE: **Supportive radiologic signs may be needed to diagnose spondylolysis (SL) via lumbar magnetic resonance imaging (MRI). In SL, the slight displacement of the corpus forward and lamina posteriorly can cause the interposition of posterior epidural fat (EFI), which is normally segmental. This study aimed to determine the diagnostic value of EFI, an indirect sign of SL, on lumbar mid-sagittal T1-weighted MRI.**

■ METHODS: **The lumbar MRI of 115 randomly selected patients with SL and degenerative disc disease (DDD) was randomized and assessed for the presence or absence of EFI by 2 masked observers. These observers were not permitted to examine the pars region. Interobserver agreement was tested using Cohen's kappa coefficient.**

■ RESULTS: **EFI was positive in 98 (85%) of 115 patients with SL, 14 (12%) in the DDD group, and 6 (5%) with an upper vertebral level adjacent to the SL. The difference was statistically significant ($P < 0.01$). In patients with SL, the EFI positivity rate was highest at lumbar 5 vertebrae (94%) and lowest at lumbar 3 vertebrae (33%). The specificity, sensitivity, positive predictive value, negative predictive value, and accuracy of EFI in diagnosing SL were mean 64%, 97%, 80%, 97%, and 95%, respectively. The highest diagnostic value of EFI was at the lumbar 5 vertebrae level, where intraobserver and interobserver reliability were nearly perfect.**

■ CONCLUSIONS: **EFI is an indirect radiological finding with high reliability in diagnosing SL with mid-sagittal T1-weighted images in lumbar MRI.**

INTRODUCTION

Lumbar posterior epidural fat (EF) tissue is disconnected and segmentally localized.[1,2] This segmentation can be altered and disrupted under various conditions affecting the spinal canal. In spondylolysis (SL), the posterior translation of the lamina or the anterior listhesis of the corpus can cause a slight widening of the spinal canal, leading to the interposition of EF pads. Therefore, EFI may be a significant indirect sign supporting the presence of a pars interarticularis defect in the absence of overt spondylolisthesis, but studies on EFI are limited.[1,2] This study aimed to create radiologic awareness by examining the presence or absence of EFI in mid-sagittal T1-sequence lumbar magnetic resonance (MR) images and determining its rate in groups with SL and degenerative disc disease (DDD).

MATERIALS AND METHODS

The study protocol was approved by the Istanbul Medipol University Non-Interventional Clinical Research Ethics Committee (date: 07.19.2024, no: E-10840098-202.3.02-4327). The study was conducted in accordance with the principles of the Declaration of

Key words
- Epidural fat interposition
- Epidural fat
- Isthmic defect
- Magnetic resonance imaging
- Pars interarticularis
- Spine
- Spondylolysis

Abbreviations and Acronyms
DDD: Degenerative disc disease
EF: Epidural fat
EFI-: Epidural fat interposition negative
EFI: Epidural fat interposition
EFI+: Epidural fat interposition positive
L3: Lumbar 3 vertebrae
L4: Lumbar 4 vertebrae
L5: Lumbar 5 vertebrae
LPM: Lipomatosis
MR: Magnetic resonance
MRI: Magnetic resonance imaging

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Helsinki. The study included lumbar magnetic resonance imaging (MRI) scans of 115 consecutive SL patients and 115 randomly selected DDD patients diagnosed by lumbar radiography, computed tomography, and MRI between January 1, 2014 and November 2020. The study population included patients with less than 2 mm of listhesis, which is considered within normal limits according to most studies.[3-5] To eliminate study bias, a radiologist and a neurosurgeon blinded to clinical data and imaging results independently assessed the presence or absence of posterior EFI and epidural lipomatosis (LPM) on mid-sagittal lumbar MR T1 sequences in both groups twice, 1 week apart. Patients with endogenous or exogenous cortisol effects, a history of spinal surgery, spinal stenosis, or insufficient clinical data and imaging were excluded. EFI signs were recorded in the SL group at the upper lumbar level adjacent to the SL level and in the DDD group. Their specificity, sensitivity, positive predictive value, negative predictive value, and accuracy were determined. Cohen's kappa correlation coefficient was used to assess interobserver and intraobserver agreement.

RESULTS

Of the 115 patients with SL, 60 were female and 55 were male (age range: 18–75 years; mean: 43 years), while in the DDD group (age range: 18–79 years; mean: 45 years), 54 were female and 61 were male. Of the 115 patients with SL, 111 had bilateral pars interarticularis defects and 4 had unilateral pars defects. SL was at the lumbar 5 vertebrae (L5) level in 90 patients with bilateral SL, at the lumbar 4 vertebrae (L4) level in 15 patients, and at the lumbar 3 vertebrae (L3) level in 6 patients. Unilateral SL was at the L5 level (2 right and 2 left). In the SL group, EFI was positive in 85 of the 90 patients at the L5 level (Figure 1). In patients with L5 SL, EFI at the upper level adjacent to the SL was detected in 6 patients. EFIwas not detected at the upper level adjacent to the L4 and L3 levels. In the 115-patient DDD group, EFI was positive at the L5 level in 13 patients. Of the 115 SL patients, 98 were EFI-positive and 17 were EFI-negative. The DDD patient group comprised 14 EFI-positive patients and 101 EFI-negative patients (Figure 2). In patients with SL, the EFI negativity rate was higher at L3 and L4 levels than at L5. EFI was positive in 3 of the 4 patients with

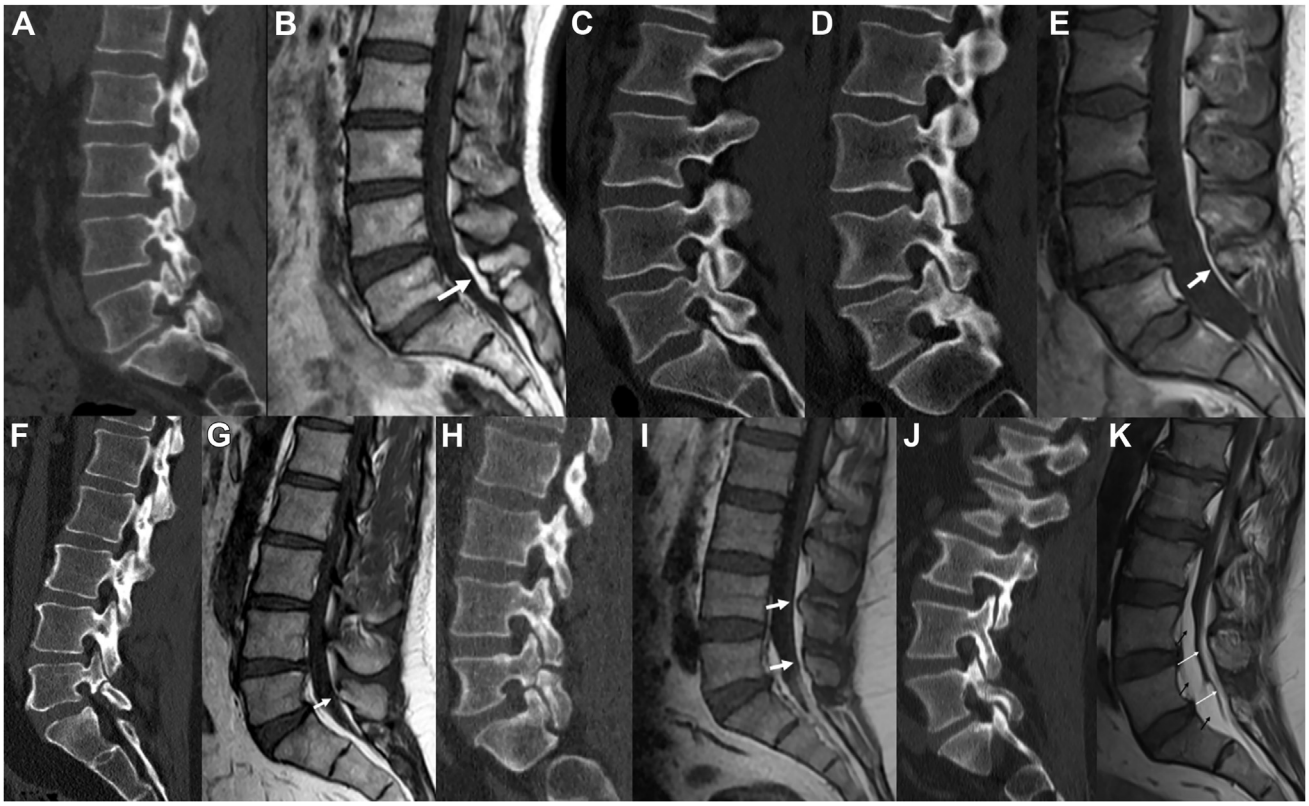

Figure 1. (**A**) The 10th patient with bilateral spondylolysis (SL) had a pars defect on lumbar CT and (**B**) EFI positivity on lumbar T1-W MRI (arrow). (**C**) The 20th patient with unilateral SL had intact pars on CT, (**D**) a pars defect on the left, and (**E**) EFI positivity on lumbar T1-W MRI (arrow). (**F**) The 30th patient with bilateral SL had a pars defect on lumbar CT and (**G**) EFI negativity on lumbar T1-W MRI. (**H**) The 40th patient with bilateral SL had a pars defect on lumbar CT and (**I**) EFI positivity at and above the defect level on lumbar T1-W MRI. (**J**) The 50th patient with bilateral SL had a pars defect on lumbar CT, EFI positivity at L5 and L4 levels on lumbar T1-W MRI (white arrows), (**K**) and lumbar epidural lipomatosis extending from L5 to L4 (black arrows).

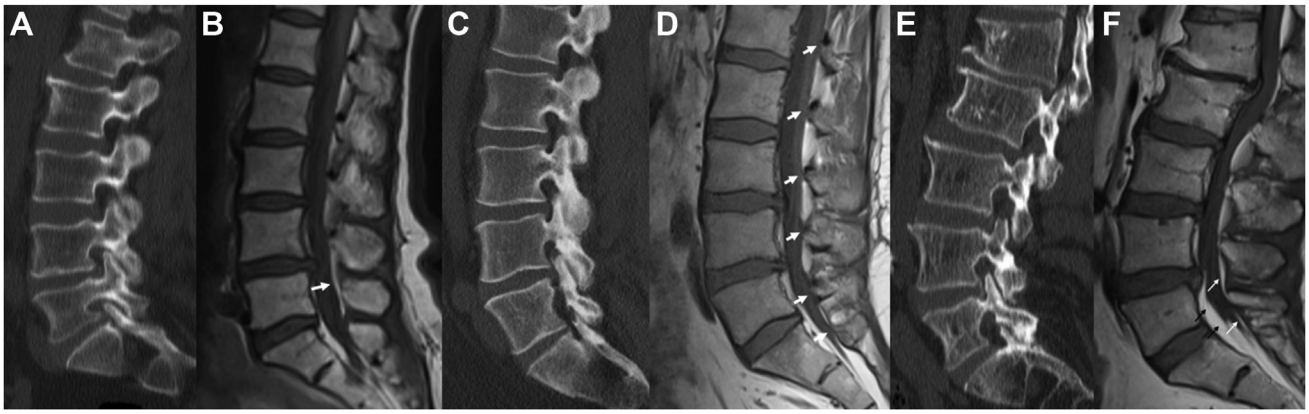

Figure 2. (**A**) The 25th patient with DDD had intact pars at L5 on lumbar CT and (**B**) positive EFI on lumbar T1-W MRI (arrow). (**C**) The 55th patient with DDD had intact pars at L5 on lumbar CT, normal epidural fat tissues, and (**D**) negative EFI on lumbar T1-W MRI (arrow). (**E**) The 105th patient with DDD had intact pars at L5 on lumbar CT, EFI negative on lumbar T1-W MRI (white arrow), and (**F**) positive epidural lipomatosis (black arrows).

unilateral SL. Two epidural lipomatoses were EFI-positive in the SL group, and 2 epidural lipomatoses were EFI-negative in the DDD group (Table 1). The diagnostic value of EFI in SL was compared between the SL group and the DDD group and between the SL group and the upper level adjacent to the SL, respectively. Sensitivity was 64%–64% (mean: 64), specificity was 96%–98% (97), and the positive predictive value was 77%–82% (80) in SL group. The negative predictive value was 96%–97% (97), and accuracy was 95%–94% (95) (Table 2). The diagnostic value of EFI was highest at L5, followed by L4 and L3. In all groups, Cohen's kappa values ranged from intraobserver 0.7861 to 0.931 and from interobserver 0.827 to 0.97, showing almost perfect agreement (Table 3).

DISCUSSION

The main component of the spinal epidural space is adipose tissue.[6,7] EF fills the spinal canal in a metameric manner and protects the structures in the spinal canal against impact, deceleration, and rotational movements applied to the vertebral column.[2,8,9] The EF is most plentiful in the lumbar region and is more prominent in the posterior epidural space than in the anterior epidural space.[7,10] EF pads have a semiliquid structure but are not viscous. However, their density is lower than that of subcutaneous fat.[9,11] The volume of the posterior EF pads increases from L1 to L5. The mean height of the EF pads is 21 mm (range: 16–25 mm), and the width can increase craniocaudally from 6 to 13 mm^2. The size of the EF pads is unrelated to gender or obesity.[12,13] However, in the presence of certain pathological conditions, the arrangement and size of fat may change.[2,9] In SL, due to pars defects, the lamina is separated from the pedicle and is often displaced slightly posteriorly.[14,15] The corpus is either hypoplastic or slightly anteriorly displaced.[16,17] In these new areas, where the laminae are displaced posteriorly and the corpus anteriorly, EF pads fill and form interposition.

The presence of EFI can be an indirect finding for diagnosing SL using T1 sequence MR, which shows anatomy better. Adipose tissue has high signal characteristics on T1A images, while fluids have low signal characteristics. Adipose and fluid tissue are visible on T2-weighted images and similarly possess high signal characteristics. Fat and fluid are hyperintense in T2-weighted images, making it difficult to differentiate the EFI easily.[18,19] If the EFI rate is high, EFI can sometimes be detected in T2 if listhesis is slightly present. Therefore, EFI can be more easily and quickly recognized in T1-weighted images than in T2-weighted images.

There are some limitations to the detection of pars interarticularis defects with MR.[8,20,21] Since routine lumbar MRI is based on disc levels, the main direction of the pars interarticularis is oblique compared to sagittal and transverse images. Sclerosis of the pars interarticularis, facet osteoarthritis, and partial volume averaging of the pars with the surrounding soft tissue complicate the diagnosis of SL on MR.[15,22] Incomplete pars defects accompanied by sclerosis or the absence of concomitant spondylolisthesis may also pose a diagnostic problem for MRI.[23] Therefore, additional signs, such as the "step-off" sign, the "wide canal" sign, the T2 cortical bone signal on MR, EFI, and fluid in the facet joints, are considered for SL diagnosis with MRI.[22]

In the healthy pars, fat bone marrow shows persistent brightness on T1-weighted images. This brightness is present in only 30%–66% of intact pars interarticularis. Acute bone marrow edema in SL can be detected with fat-suppressed T2-weighted MR images.[24] Thin-section T1-weighted and T2-weighted MRI or intravenous contrast-enhanced MRI can detect pars defects at a higher rate.[25] Due to the limitations of MR in evaluating bony structures, a definitive diagnosis or exclusion of a pars defect is not always possible. In cases of SL without advanced displacement, the increase in the anteroposterior diameter of the spinal canal may be slight, and the ratio between the diameter of the spinal canal at L5 and the diameter of the spinal canal at L1 may need to be calculated. It has been reported that

Table 1. Epidural Fat Interposition and Incidence of Lipomatoses by Level in the Spondylolysis Group, in the Upper Segment Adjacent to the Spondylolysis Level, and in the Degenerative Disc Disease Group

	Incidences of EFI and Lipomatosis in the Spondylolysis Group				EFI and Lipomatosis Incidences at the Upper Level, Adjacent to the Spondylolysis Level				Incidences of EFI and Lipomatosis in DDD Group (Mean)			
	EFI +	EFI -	LPM + EFI+	LPM + EFI -	EFI +	EFI -	LPM + EFI+	LPM + EFI -	EFI +	EFI -	LPM + EFI+	LPM + EFI -
L5	83	5	2	-	6	109			13	100	-	2
L4	8	7	-	-	-	115	-	-	1	114	-	-
L3	2	4	-	-	-	115	-	-	-	115	-	-
L5 unilateral	3	1	-	-	6	109			-	115	-	-

EFI, epidural fat interposition; LPM, lipomatosis.

Table 2. Comparison of the Diagnostic Value of Epidural Fat Interposition With That of the Spondylolysis Group, With the Upper Level Adjacent to the Spondylolysis Level and the Degenerative Disc Disease Group

	The Diagnostic Value of EFI when Comparing the Level of Spondylolysis with the Adjacent Upper Level					The Diagnostic Value of EFI when the Same Lumbar Level is Found in the Spondylolysis and DDD Groups						
	L5	L4	L3	L5 Unilateral	Mean Levels	L5	L4	L3	L5 Unilateral	Mean Levels	Mean of Groups	Mean of L5 in Groups
Sensitivity	94	53	33	75	64	94	53	33	75	64	64	94
Specificity	95	100	100	95	98	89	99	100	95	96	97	92
Positive predictive value	93	100	100	33	82	87	89	100	33	77	80	90
Negative predictive value	96	94	97	99	97	95	94	97	99	96	97	96
Accuracy	95	95	97	94	95	91	94	97	94	94	95	93

EFI, epidural fat interposition; DDD, degenerative disc disease.

Table 3. Cohen's Kappa of Interobserver and Intraobserver Reliability

	SL Group	Upper Level Adjacent to SL Level Group	DDD Group
Intraobserver A*	0.861	0.8658	0.8552
Intraobserver B*	0.931	0.7861	0.8882
Interobserver AB*	0.897	0.827	0.8713

*A and B are the 2 observers in this study.
SL, spondylolysis; DDD, degenerative disc disease.

in 77% of cases of SL, the L5/L1 ratio is 1.6. If there is an increase in the anteroposterior diameter of the spinal canal at the limit of the quantitative value, diagnosis may be difficult.[26] Moreover, separate rates may be required for diagnosing pars defects at other levels and for different age groups. The false positive rate of spinal canal anteroposterior diameter increases with sacral spinal canal width, dural ectasia, and scoliosis; however, measuring the anteroposterior diameter increase of the spinal canal is time-consuming. This increase cannot always be detected quickly visually, while EFI can. Since L5 is the most mobile spinal region, the EFI sign may be explained by the higher incidence of EFI in L5. The lower incidence of EFI in the upper lumbar region may be due to the lower mobility of the upper lumbar levels.

According to the results of 2 studies comparing SL with the DDD group at L5 and our study, the specificity of EFI in SL was 96%, 87%, and 94% (mean: 89); sensitivity was 78%, 89%, and 89% (85); positive predictive value was 95%, 87%, and 87% (90); the negative predictive value was 83%, 89%, and 95% (89); and accuracy was 88%, 88%, and 91% (89), respectively.[1,2]

EFI positivity showed approximately 95% diagnostic accuracy at all levels.

The low diagnostic value of EFI in SL at L3 and L4 may have been due to L5 being the most mobile spinal region. Although other studies have reported that the false positivity of EFI was caused by epidural LPM, in our study, EFI was observed in approximately 12% of the DDD group without LPM. In epidural LPM, an increase in the amount of fat around the dural sac is most commonly seen at the L5-sacral 1 level and may be confused with EFI, thus causing a false-positive result in SL diagnosis. However, in epidural LPM, there is increased fat in the posterior and anterior epidural regions. In EFI, interposition occurs only in the posterior EF. Although increased EF tissue is crucial for differential diagnosis, it does not affect segmentation. Incorporating the examination of EFI as an indirect finding in lumbar MRI into the T1 sequence can significantly aid in diagnosing SL, although it is insufficient on its own. In newly developing SL cases, a negative EFI result may be due to the integrity of the strong ligaments that connect the EF pads to the spinous process. False-positive results may occur due to trauma, occult instability, or congenital factors.

This study's limitations include its retrospective nature and a single-center study with a limited number of patients. Further studies should be conducted to address these limitations. The early detection of SL, especially with MR, may prevent unsuccessful back surgery by recognizing the defect and beginning conservative treatment before the defect reaches the terminal stage.

Considering the recent use and development of artificial intelligence in clinical imaging, the EFI sign can be automatically reported as an incidental finding in diagnosing SL with appropriate image analysis.

CONCLUSION

EFI in the mid-sagittal T1-weighted sequence of lumbar MRI can be used as a simple but valuable indirect radiological finding in SL diagnosis, but it should not be used for definitive diagnosis. Future prospective studies should evaluate whether the EFI sign improves clinical decision-making, since the EFI sign showed adequate intraobserver and interobserver agreement.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Burhan Oral Güdü: Writing — review & editing, Writing — original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Belgin Karan:** Writing — review & editing, Writing — original draft, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Suna Dilbaz:** Writing — review & editing, Writing — original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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