FİZİKSEL TIP VE REHABİLİTASYON BİLİMLERİ DERGİSİ
Journal of Physical Medicine and Rehabilitation Sciences J PMR Sci. 2023;26(3):321-7

ORIGINAL RESEARCH ORİJİNAL ARAŞTIRMA DOI: 10.31609/jpmrs.2023-98257

The Relationship Between Nerve Root Sedimentation Sign and Cerebrospinal Fluid Signal Loss Sign and Treatment Success in Patients Undergoing Lumbar Epidural Injections

Lomber Epidural Enjeksiyon Uygulanan Hastalarda Sinir Kökü Sedimantasyon İşareti ve Beyin Omurilik Sıvısı Sinyal Kaybı Belirtisinin Tedavi Başarısı ile İlişkisi

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ABSTRACT Objective: This study aimed to determine whether nerve root sedimentation sign (NRSS) and cerebrospinal fluid signal loss sign (CFSLS) could predict the short-term outcomes of interlaminar lumbar epidural steroid injections (ILESIs) in the treatment of lumbar spinal stenosis (LSS). **Material and Methods:** In this retrospective study, a total of 73 patients who were diagnosed with LSS and underwent ILESIs were included. Successful pain management was determined as a decrease of ≥50% in visual analogue scale scores 1 month after ILESIs. The patients were divided into successful and unsuccessful treatment groups and the findings of NRSS and CFSLS were compared between the two groups. **Results:** While 62.2% of patients in the successful group had a positive NRSS, 32.1% of patients in the unsuccessful group had a positive NRSS and the difference was statistically significant (p=0.017). The CFSLS was positive for 62.2% of patients in the successful group compared to 57.11% of patients in the unsuccessful group and this difference was not statistically significant (p=0.806). **Conclusion:** One month after ILESI, low back/leg pain decreased more in patients with positive NRSS than in patients with negative NRSS. The NRSS might be a valuable sign in predicting the success of ILESI treatment among patients with LSS.

Keywords: Lumbar spinal stenosis; sedimentation sign; cerebrospinal fluid signal; interlaminar epidural steroid injection

ÖZET Amaç: Sinir kökü sedimantasyon işareti (SKSİ) ve beyin omurilik sıvısı sinyal kaybı işaretinin (BOSSK), lomber spinal stenoz (LSS) tedavisinde interlaminar lumbar epidural steroid enjeksiyonlarının (İLESE) kısa vadeli sonuçlarını tahmin edip edemeyeceğini belirlemek. **Gereç ve Yöntemler:** Bu retrospektif çalışmaya LSS tanısı alan ve İLESE uygulanan toplam 73 hasta dâhil edildi. Başarılı ağrı yönetimi, İLESE'den bir ay sonra vizüel analog skala skorunda ≥%50 azalma olarak belirlendi. Hastalar başarılı ve başarısız olarak iki gruba ayrıldı. SKSİ ve CFSLS iki grup arasında karşılaştırıldı. **Bulgular:** Başarılı gruptaki hastaların %62,2'sinde, başarısız gruptaki hastaların ise %32,1'inde SKSİ pozitifti ve gruplar arasında SKSİ varlığı açısından istatistiksel olarak anlamlı fark vardı (p=0,017). Başarılı gruptaki hastaların %62,2'sinde, başarısız gruptaki hastaların ise %57,11'inde BOSSK pozitifti ve BOSSK pozitifliğine göre gruplar arasında istatistiksel fark yoktu (p=0,806). **Sonuç:** İLESE'den bir ay sonra pozitif SKSİ'li hastalarda negatif SKSİ'li hastalara göre bel/bacak ağrısı daha fazla azaldı. SKSİ, LSS'li hastalarda İLESE tedavisinin kısa süreli başarısını öngörmede değerli bir işaret olabilir.

Anahtar Kelimeler: Lomber spinal stenoz; sedimantasyon işareti; serebrospinal sıvı sinyali; interlaminar epidural steroid enjeksiyonu

Lumbar spinal stenosis (LSS) is the narrowing of the spinal canal via the compression of the neural structures by the surrounding bone and soft tissues.[1] Patients typically present with low back pain (LBP) accompanying leg pain or neurogenic claudication (pain in the hips or legs while walking or standing that improves with sitting or lumbar flexion).[2,3] The first-line treatment of LSS is conservative methods.[4]

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Peer review under responsibility of Journal of Physical Medicine and Rehabilitation Science.

Received: 31 May 2023 ***Received in revised form:*** 16 Jun 2023 ***Accepted:*** 25 Jun 2023 ***Available online:*** 07 Jul 2023

Indications for surgical treatment in patients unresponsive to conservative treatments are still unclear.[5-7] In addition to the benefits of surgical treatments, alternative methods in the treatment of LSS are also becoming increasingly popular due to reasons such as the risk of failed back surgery syndrome, possible complications, and adverse effects on the quality of life of the patients. Epidural injections are one of the most frequently applied alternative treatment methods for these patients before surgery.[8]

The absence of LSS symptoms at rest complicates the diagnosis. Furthermore, there is no consensus regarding the diagnostic criteria for LSS. Cross-sectional area measurement, the most commonly used imaging criterion for LSS, can lead to under- or overdiagnosis and is poorly correlated with patient symptoms.[9,10] For this reason, additional diagnostic signs for LSS have been investigated in recent years. In 2010, Barz et al. reported that the nerve root sedimentation sign (NRSS) has high sensitivity and specificity in the diagnosis of LSS.[11] Normally, nerve roots are located in the dorsal region of the lumbar spinal canal in supine magnetic resonance imaging (MRI) due to gravity, and this finding is defined as negative NRSS. If the nerve roots are compressed and located in the ventral region of the lumbar spinal canal, it is defined as positive NRSS. Studies investigating the effects of the presence or absence of the NRSS on surgical treatment have reported that patients with positive NRSS have better clinical outcomes than patients with negative NRSS.[12,13] In 2021, Hızal et al. identified the cerebrospinal fluid signal loss sign (CFSLS) in MRI for the diagnosis of LSS.[14] They reported that the CFSLS is an effective finding in distinguishing LSS from LBP.

The success rates of epidural steroid injections vary from 20% to 100% with an average success rate of 67%.[15] These conflicting results show that there are several factors affecting the success of the injections. Identifying patients likely to benefit from interlaminar lumbar epidural steroid injections (ILESIs) is essential for appropriate treatment selection and predictions of the success of treatment, and it may also reduce the complications associated with unnecessary interventions.

To the best of our knowledge, there is no previous study investigating the relationships between the NRSS and CFSLS and ILESI outcomes in patients with LSS. The aim of this study was to identify whether the NRSS or CFSLS could predict short-term outcomes of ILESI administration in the treatment of LSS.

MATERIAL AND METHODS

The medical records of patients with back and/or leg pain not responding to conservative treatments who underwent ILESIs between October 2022 and December 2022 were retrospectively reviewed. Diagnoses were based on clinical findings, physical examinations, and MRI scans. Ethics committee approval was obtained from Ankara City Hospital Ethics Committee No. 1 (date: March 22, 2023, no: E1-23-3390). The study was conducted in accordance with the guidelines of the Declaration of Helsinki.

The inclusion criteria included being aged 18 or older, having LSS-related back and/or leg pain for more than 3 months, and being unresponsive to conservative treatments. Exclusion criteria included having a protruded, extruded, or sequestered disc, advanced spondylolisthesis, previous spinal surgery history, history of lumbar spinal interventions in the last 6 months (transforaminal epidural steroid injection, facet injections, etc.), and missing follow-up visits.

ILESI TECHNIQUE

Injections were performed in an operating room under aseptic conditions and under the guidance of C-arm fluoroscopy. Each patient was monitored and the vital signs of blood pressure, heart rate, and SpO_2 were observed throughout the entire procedure. The patient was placed in a prone position and the abdomen was supported with a pillow. Anteroposterior fluoroscopic images were obtained to determine the level of the interlaminar space. After local infiltration with 2% lidocaine, an 18-gauge Tuohy needle was inserted at the level of LSS and advanced from the posterior to the anterior. The needle was inserted into the epidural space using the loss-of-resistance technique. After negative aspiration for cerebrospinal

fluid and blood, 2 mL of non-ionic contrast was injected to confirm the epidural space. After confirming the appropriate contrast spread with anterior-posterior and lateral fluoroscopic (biplanar) views, a mixture of 2 mL of 2% lidocaine, 16 mg of dexamethasone, and 4 mL of saline was injected into the epidural space (Figure 1). All injections were performed by the same pain management specialist.

RADIOLOGICAL ASSESSMENT

Pre-injection MRIs of the patients were obtained from the institution's picture archiving and communication system. All measurements were made at L1-2, L2-3, L3-4, and L4-5 levels. Since the S1 and S2 nerve roots exit the dural sac in the ventral position, the L5-S1 level was not evaluated. T2-weighted axial images of the patients were examined for the presence of the NRSS. At each level, the dural sac was divided by a line transversely into the anterior and posterior halves. Except for the exiting nerve roots, the placement of nerve roots on the dorsal half of the dural sac due to gravity was defined as negative NRSS, while the accumulation of nerve roots in the central or anterior half of the dural sac was defined as positive NRSS (Figure 2). The other finding of interest, the CFSLS, was evaluated on sagittal T2W images. In bilateral parasagittal sections, the T2 hyperintense CFSLS was evaluated in terms of being present anteriorly, posteriorly, and/or between cauda equina fibers and a score of 1 was given for each location. Points were summed for each location and side. Thus, CFSLS scores ranging from 0 to 6 (right parasagittal: 0-3, left parasagittal: 0-3) could be obtained for each level. At any level, a CFSL score lower than or equal to 3 was defined as positive CFSLS and a CFSL score greater than 3 was defined as negative CFSLS (Figure 3). LSS severity was categorized as no stenosis, mild (slight obliteration of the anterior CF space and all cauda equina able to be clearly separated from each other), moderate (moderate obliteration of the anterior CF space and some cauda equina aggregation), or severe (severe obliteration of the anterior CF space, marked compression

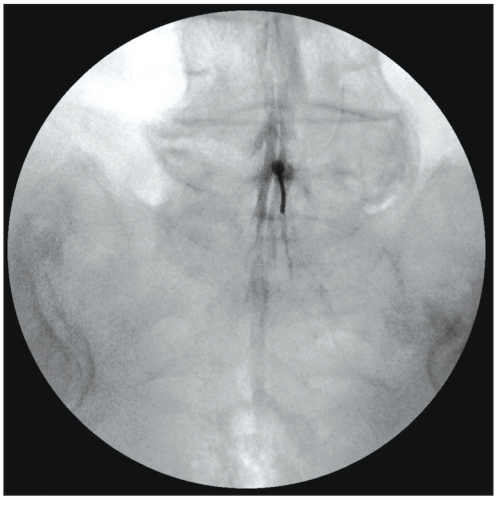

FIGURE 1: Contrast spread into the epidural space of fluoroscopic-guided interlaminar epidural injection.

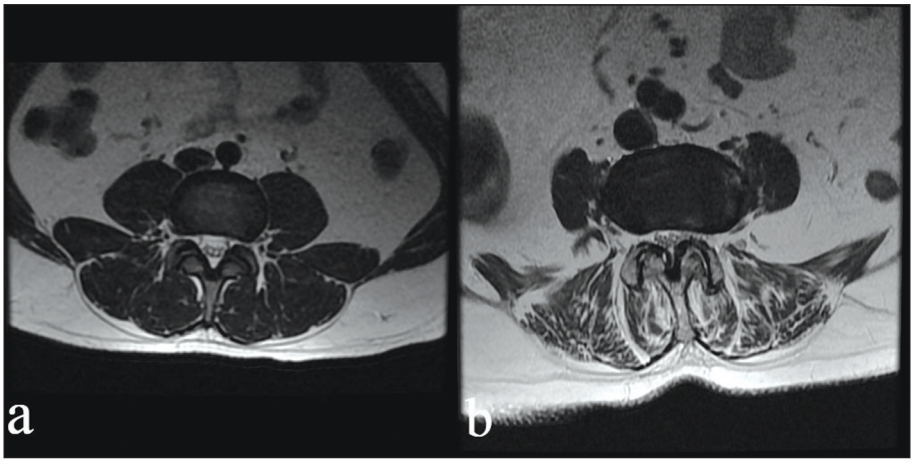

FIGURE 2: Axial T2-weighted MRIs with a negative NRSS **(a)** and a positive NRSS **(b)**.
MRI: Magnetic resonance image; NRSS: Nerve root sedimentation sign.

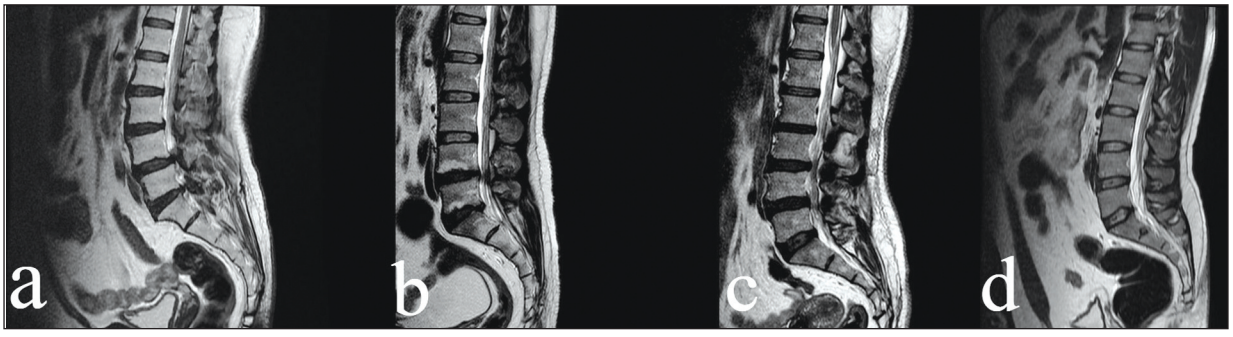

FIGURE 3: Sagittal T2-weighted MRIs, CFSLS score is 0 at L4-5 level **(a)** CFSLS score is 1 at L4-5 level **(b)**, CFSLS score is 2 at L4-5 level **(c)** and CFSLS score is 3 at L4-5 level **(d)**.
MRI: Magnetic resonance image; CFSLS: Cerebrospinal fluid signal loss sign.

of the dural sac, and the entire cauda equina appearing as one bundle).

CLINICAL ASSESSMENT

Age, sex, injection levels, and visual analogue scale (VAS) scores before and after ILESIs (1st month) were collected from patients' medical records. Pain was assessed with VAS scores (0: no pain; 10: worst imaginable pain). Therapeutic success was defined as a ≥50% reduction in the VAS score for the patient's low back and/or leg pain at 1 month.

The patients were divided into two groups according to treatment being successful or unsuccessful. The presence of the NRSS, the presence of the CFSLS, and LSS severity were compared between the two groups.

STATISTICAL ANALYSIS

Data were analyzed with IBM SPSS Statistics 25.0 (IBM Corp., USA). The Kolmogorov-Smirnov test was used to determine whether variables were normally distributed. Categorical data were expressed as numbers and percentages (%). Numerical variables with normal distribution were shown as mean±standard deviation (SD), and non-parametric numerical variables were shown as median and interquartile range (IQR: 25th-75th percentile). The chi-square test and Fisher exact test or likelihood ratio was used according to the percentages of expected counts to compare categorical variables between two groups. The Mann-Whitney U test was used to compare numerical variables without parametric distribution between groups. Values of $p<0.05$ were accepted as statistically significant.

RESULTS

The age, sex, and clinical findings of the patients are shown in Table 1.

While 62.2% of patients with significant improvement had a positive NRSS, 32.1% of patients without significant improvement had a positive NRSS and the difference was statistically significant ($p=0.017$). The CFSLS was positive in 62.2% of patients with significant improvement compared to 57.11% of patients without significant improvement and this difference was not statistically significant ($p=0.806$) (Table 2).

No significant difference was found between the groups in terms of age ($p=0.456$) or sex ($p=0.922$) when the groups with positive and negative NRSS findings were compared. On the other hand, when the groups with positive and negative CFSLS findings were compared, age was significantly higher in the group with positive CFSLS ($p<0.01$), while there was no significant difference between the groups in terms of sex ($p=0.808$). There was no difference between successful and unsuccessful treatment groups regarding age ($p=0.547$), sex ($p=0.328$), or severity of spinal stenosis ($p=0.166$).

DISCUSSION

This study has attempted to use the NRSS and CFSLS to predict the treatment success of ILESIs in patients with LSS. It was found that the NRSS had an effect on treatment success in patients with LSS who underwent ILESIs, while the CFSLS had no ef-

TABLE 1: Demographic features and clinical data of the patients.

		n (%)	Median (IQR: 25th-75th)
Age			64.0 (49.0-72.5)
Sex	Female	43 (58.9)	
	Male	30 (41.1)	
Significant improvement		45 (61.6)	
NRSS positivity		37 (50.7)	
Level of NRSS	L1-2	1 (1.4)	
	L2-3, L3-4	3 (4.1)	
	L3-4	3 (4.1)	
	L4-5	18 (24.7)	
	L3-4, L4-5	13 (17.8)	
CFSLS positivity		29 (39.7)	
CFSLS score	0	10 (13.7)	
	1	4 (5.5)	
	2	14 (19.2)	
	3	16 (21.9)	
	4	10 (13.7)	
	5	8 (11.0)	
	6	11 (15.1)	
Level of CFSLS	L1-2	2 (2.7)	
	L2-3	2 (2.7)	
	L3-4	12 (16.4)	
	L2-3, L3-4	2 (2.7)	
	L3-4, L4-5	8 (11.0)	
Severity of spinal stenosis	Mild	48 (65.8)	
	Moderate	15 (20.5)	
	Severe	10 (13.7)	

IQR: Interquartile range; NRSS: Nerve root sedimentation sign; CFSLS: Cerebrospinal fluid signal loss sign.

fect on treatment success. We determined a positive relationship between the presence of the NRSS on MRI and short-term pain reduction in patients with LSS who underwent ILESIs.

Several studies have evaluated MRI findings affecting treatment outcomes in cases of LSS. However, data on significant imaging findings predicting treatment success for both surgical and conservative treatments are contradictory.[16-19] Amundsen et al. found no relationship between the severity of dural sac narrowing and clinical or treatment success in their evaluations of imaging features in LSS.[5,20] Schizas et al. reported no correlations between stenosis grades or dural cross-sectional area and initial Oswestry Disability Index (ODI) score and surgical treatment success.[21] Weber et al. failed to demonstrate correlations between the radiological severity of LSS and disability, pain, and surgical success.[22] In these studies, the cross-sectional area of the dural sac was generally evaluated.

Barz et al. defined the NRSS as an MRI finding with high sensitivity and specificity in the diagnosis of LSS.[11] They reported that for patients with LSS and neurogenic claudication with a walking distance of <200 m and dural sac of <80 mm^2, the NRSS was always positive regardless of other clinical findings. In another study supporting this, the incidence of the

TABLE 2: Comparison of sedimentation and cerebrospinal fluid sign positivity in terms of significant improvement.

			Successful group	Unsuccessful group	p†
NRSS	Negative	Count	19a*	17b	0.017
		Expected count	13.8	22.2	
		% within column	67.9	37.8	
		Adjusted residual	2.5	-2.5	
	Positive	Count	9a	28b	
		Expected count	14.2	22.8	
		% within column	32.1	62.2	
		Adjusted residual	-2.5	2.5	
CFSLS	Negative	Count	12a	17a	0.806
		Expected count	11.1	17.9	
		% within column	42.9	32.8	
		Adjusted residual	0.4	-0.4	
	Positive	Count	16a	28a	
		Expected count	16.9	27.1	
		% within column	57.1	62.2	
		Adjusted residual	-0.4	0.4	
	Total	Count	28	45	

†Fisher exact test; *Each superscripted letter denotes a subset of meaningful improvement categories whose column proportions do not differ significantly from each other at the 0.05 level; NRSS: Nerve root sedimentation sign; CFSLS: Cerebrospinal fluid signal loss sign.

NRSS was found to be higher in patients with a dural cross-sectional area of <80 mm^2 and impaired walking capacity.[23]

Moses et al. reported better improvement of ODI scores with surgical treatment in patients with positive NRSS findings.[12] Deng et al. found better LBP relief and functional improvement in NRSS-positive patients who underwent lumbar disc herniation surgery.[24] Fazal et al. and Badve et al. stated that the NRSS may help in making the decision for surgical treatment of LSS.[25,26] Conversely, Barz et al. reported that the NRSS could not predict surgical success in the treatment of LSS, but NRSS positivity could be associated with limited outcomes of conservative treatments.[11]

Unlike studies examining the effects of the NRSS on surgical treatment, there is no study examining its effects on ILESI treatment. To the best of our knowledge, this is the first study to examine the effects of the NRSS and CFSLS on the success of ILESI treatment.

Badve et al. reported 34%, Moses et al. 66%, Fazal et al. 89.5%, and Hızal et al. 90.8% NRSS positivity in patients with LSS.[12,14,25,26] In the present study, we found NRSS positivity in 50.7% of our patients. Consistent with the literature, we observed NRSS positivity most frequently in the L4-5 segment. We found that NRSS-positive patients benefited more from ILESIs than NRSS-negative patients. In patients with positive NRSS, there may be more edema and inflammation in the nerve roots, since the nerve roots are more compressed in general. Therefore, pain levels may be reduced more in NRSS-positive patients in the short term as edema and inflammation of the nerve roots are reduced with epidural steroid injection.

Hızal et al. reported CFSLS positivity in 82.7% of patients with LSS, compared to 39.7% in our study.[14] We attribute the low rate of CFSLS in our study compared to that of Hızal et al. to the fact that our patient group mainly consisted of patients with mild stenosis while Hızal et al. reported higher rates of CFSLS positivity among patients with severe (97.5%) and moderate stenosis (75%) than patients with mild stenosis (16.7%).[14]

The present study has several limitations, such as its retrospective nature, a lack of subgroup analysis, short follow-up times, and no evaluation of functional parameters such as the ODI. Another limitation is that pain was evaluated with only the VAS and neuropathic pain scales were not applied. However, this study is valuable because it is the first study in the literature to investigate the effects of the NRSS and CFSLS on ILESI treatment for patients with LSS.

CONCLUSION

The current study has shown that patients with NRSS positivity had better pain relief with ILESIs than patients with NRSS negativity. The NRSS might be a valuable sign in predicting the success of ILESI treatment in patients with LSS.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

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