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# The Association Between Morphometric Features of Neural Foramen and Intervertebral Disc and Treatment Success of Lumbar Transforaminal Epidural Steroid Injection: An Observational Study

## Nöral Foramen ve İntervertebral Diskin Morfolojik Özelliklerinin Transforaminal Epidural Steroid Enjeksiyonunun Başarısına Etkisi: Gözlemsel Bir Çalışma

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**ABSTRACT Objective:** To investigate the impact of morphometric characteristics of neural foramen (NF) and intervertebral disc (ID) on magnetic resonance imaging (MRI) to the treatment outcomes after transforaminal epidural steroid injection (TFESI). Few clinical and radiological features are suggested predicting treatment success after epidural steroid injection. However, the impact of morphometric characteristics of the relevant NF to the response to TFESI is unknown. **Material and Methods:** This study was carried out prospectively with the participation of 45 patients who were treated with single level TFESI to L5 nerve root. Pain intensity, disability, and depression levels were assessed at baseline, 3rd week and 3rd month. The morphometrics of the relevant NF and ID were evaluated on sagittal MRI scans and compared between patients who responded and did not respond to the treatment. **Results:** The interrater reliability of all morphometric measurements of NF and ID performed by 2 physicians were high or excellent. Pain, depression, and disability scores were improved significantly at 3rd month compared to baseline. No statistically significant difference was found between responders and non-responders regarding morphometric evaluation (p>0.05). **Conclusion:** The results of the present study indicate that MRI based morphometric parameters like disc height, pedicle length, minimum and maximum foraminal width, foraminal cross-sectional area (CSA), and nerve root CSA have no effect on the efficacy of TFESI.

**Keywords:** Epidural steroid injection; intervertebral foramen; morphometry; neural foramen

**ÖZET Amaç:** Bu çalışmanın amacı, nöral foramen ve intervertebral diskin manyetik rezonans görüntülemede (MRG) değerlendirilen morfometrik özelliklerinin transforaminal epidural steroid enjeksiyonunun başarısına etkisini araştırmaktır. Epidural steroid enjeksiyonundan sonra tedavi başarısını öngören birkaç klinik ve radyolojik özellik öne sürülmüştür. Bununla birlikte ilgili nöral foramenlerin morfometrik özelliklerinin transforaminal epidural steroid enjeksiyonuna verilen cevaba etkisi bilinmemektedir. **Gereç ve Yöntemler:** Bu çalışma, prospektif olarak tek taraflı L5 sinir köküne transforaminal epidural steroid enjeksiyonu uygulanan 45 hastanın katılımıyla gerçekleştirildi. Ağrı şiddeti, dizabilite ve depresyon düzeyleri başlangıçta, 3. hafta ve 3. ayda değerlendirildi. İlgili nöral foramen ve intervertebral diskin morfometrileri sagittal MRG taramalarında değerlendirildi ve tedaviye yanıt veren ve yanıt vermeyen hastalar arasında karşılaştırıldı. **Bulgular:** Nöral foramen ve intervertebral diskin yapılan tüm morfometrik ölçümlerinin iki değerlendirici' arası güvenilirliği yüksek veya mükemmeldi. Ağrı, depresyon ve dizabilite skorları başlangıca göre 3. ayda önemli ölçüde iyileşti. Morfometrik değerlendirme açısından yanıt verenler ve yanıt vermeyenler arasında istatistiksel olarak anlamlı bir fark bulunmadı (p>0,05). **Sonuç:** Bu çalışmanın sonuçları, disk yüksekliği, pedikül uzunluğu, minimum ve maksimum foraminal genişlik, foraminal kesit alanı, sinir kökü kesit alanı gibi MRG tabanlı morfometrik parametrelerin transforaminal epidural steroid enjeksiyonu etkinliği üzerinde bir etkisi olmadığını göstermektedir.

**Anahtar Kelimeler:** Epidural steroid enjeksiyonu; intervertebral foramen; morfometri; nöral foramen

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Epidural steroid injection is a minimally invasive treatment option for lumbosacral radicular pain, which provide quick resolution in pain and improvement in function. Anterior epidural spread achieved by transforaminal delivery of the injectate makes transforaminal epidural steroid injection (TFESI) target specific and many authors believe it is more efficacious than interlaminar route.[1-3] Steroids reduce inflammation around the compressed nerve root; in addition, washing effect of the injectate and blockage of pain transmission are suggested theories for mechanisms of action.[4,5] Various techniques were defined to perform TFESIs including safe triangle approach, posterolateral approach or Kambin triangle approach.[6,7]

Neural foramen (NF) is an opening at each vertebral level on either side of spinal column where nerve roots traverse while surrounded by vessels and epidural fat. Comprehensive knowledge of neural foraminal anatomy is critical when undertaking TFESIs.[8] On the other hand, it is unknown whether the morphological features of the NF affect the response to TFESI. Few clinical and radiological features are suggested to predict response to TFESI, which are grade of nerve root compression, duration of symptoms, baseline vitamin D status, initial pain level, response to positive provocative maneuvers etc.[9-11] However, to date there have been no study focusing on the association between morphometric characteristics of the relevant NF and intervertebral disc (ID) and the treatment success of TFESI. Therefore, in this study, our aim was to investigate the impact of morphometric characteristics of NF and ID on magnetic resonance imaging (MRI) to the treatment outcomes after TFESI. We also inquired any difference in these morphometric features regarding age, gender, height, and body mass index (BMI).

## MATERIAL AND METHODS

Approval was taken from Marmara University Clinical Research Ethics Committee (date: November 1, 2019; number: 09.2019.981) prior to the study and Declaration of Helsinki was approached during all steps. The study was carried out prospectively with the participation of 45 patients who applied to Marmara University School of Medicine, Pain Medicine outpatient clinic between December 2019 and March 2021 and who were treated with single level TFESI to L5 nerve root. Inclusion criteria were as follows: age 18 to 65 years, having paramedian disc herniation at L4-L5 level, presence of radicular symptoms at least 3 months and accessible MRI scan obtained within the last 6 months before the procedure. Patients having any contraindication for epidural injections, foraminal/ central stenosis or congenital abnormalities like lumbosacral transitional vertebra were excluded. A verbal and written informed consent were assured from each participant before enrollment.

Demographic and clinical data were collected before TFESI. Numeric Rating Scale (NRS-11), Oswestry Disability Index and Beck Depression Inventory were used for evaluation of pain intensity, disability, and depression respectively at baseline, 3rd week, and 3rd month. Treatment success was determined as 50% or more reduction in NRS-11, less improvement in pain scores or progression to surgery was accepted as failure. Patients were divided into groups as responders and non-responders to TFESI and the two groups were compared with respect to morphometric features of NF and ID on MRI. The correlation between morphometric features and the change in NRS-11 score through follow-up period was also checked.

Morphometric evaluation on sagittal MRI scans was conducted by two physicians having 5 years of experience in neuroradiology. They were blinded with treatment responses and the measurements were carried out independently to depict interrater reliability. L4-L5 disc height, L5 pedicle length, L5 minimum and maximum foraminal width, L5 foraminal cross-sectional area (CSA), L5 nerve root CSA and L5 nerve root CSA/L5 foraminal CSA were measured as defined in previous studies.[12,13]

### PROCEDURE

The patient was positioned prone on the table with a pillow under the belly to minimize lumbar lordosis. C-arm was positioned obliquely and craniocaudally to visualize L5 foramen. After sterile prepping and draping needle entry point was anesthetized and a 22-gauge 3.5-inch spinal needle was advanced in

line with subpedicular approach. Lateral and anteroposterior images were obtained before injecting 1 mL of contrast dye. A mixture of triamcinolone acetonide 40 mg (1 mL) 0.5% bupivacaine (1 mL) and saline (1 mL) was given following confirmation of epidural contrast spread. All procedures were performed by an interventional pain specialist with at least 10 years of experience in epidural injections. Patients were discharged one hour after the procedure to be seen at 3rd week control visit. Another physician conducted the whole follow-up process including assessment of pain, disability, and depression scores.

### STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS version 21.0 software (IBM Corp., Armonk, NY, USA). Intraclass correlation coefficients (ICC) were calculated to analyze the reliability of measurements of NF and ID made by 2 assessors. For ICC, <0.5 was interpreted as "unacceptable", 0.5-0.75 as "moderate", 0.75-0.90 as "high", and above 0.90 as "excellent" interrater reliability. The relationship between the morphometric features of the NF and ID with age, height, BMI, pain, disability, and depression levels was evaluated using Pearson correlation analysis. Independent sample t-test was used to compare the height and width of the NF and the height of the ID between male and female genders. Independent sample t-test was also used to compare the numerically measured morphometric variables of the NF and ID between patients who responded and did not respond to TFESI, and the chi-square test was used for categorical variables. Repeated measures analyses of variance test was used to compare pain, disability, and depression scores at baseline, 3 weeks, and 3 months after TFESI. Bonferroni test was used for post-hoc pairwise comparisons. Correlation between morphometric parameters of NF and the change in NRS-11 score was calculated with Kendall's Tau and Spearman's rank correlation coefficient. Significance level was accepted as $p<0.05$ in all statistical tests. The sample size of the study was determined based on the treatment success at 3 months. Referring to the method of Hulley et al., it was calculated that at least 39 patients are required for the final analysis (a=0.05 and power=0.80).[14] Considering possible dropouts in follow-up, 45 patients were planned to be included in the study.

## RESULTS

Forty-five patients with unilateral paramedian lumbar disc herniation at L4-L5 level were included in the study. No major complications were seen during and after TFESI and no patients were lost during the follow-up period. All patients were able to answer the questionnaires and no missing data occurred. There were 25 women and 20 men with a mean age of 47 years. Demographic features of the participants were given in Table 1. Mean symptom duration was 18 months. Baseline pain, disability, and depression levels were given in Table 2.

The interrater reliability of morphometric measurements of NF and ID performed by 2 physicians on MRI is given in Table 3. The L4-L5 disc height measurement was found to have "high" reliability, and all other measurements had "excellent" reliability according to ICC. There was no statistically sig-

**TABLE 1:** Demographic features of the participants.

| | |
|---|---|
| Age | 47.11±9.92 (27-65) |
| Sex | |
| Female | 25 (56%) |
| Male | 20 (44%) |
| Height (m) | 1.69±0.10 (1.52-1.90) |
| Weight (kg) | 83.51±15.51 (54-130) |
| Body mass index (kg/m$^2$) | 29.16±4.28 (20.08-39.06) |

Values are presented as mean±standard deviation (minimum-maximum) or n (%).

**TABLE 2:** Baseline clinical features of the participants.

| | |
|---|---|
| **Symptomatic side** | |
| Right | 19 (42%) |
| Left | 26 (58%) |
| **Symptom duration (months)** | 18.13±38.65 (3-240) |
| Baseline NRS-11 (0-10) | 7.87±1.41 (4-10) |
| Baseline BDI (0-63) | 10.44±8.34 (0-32) |
| Baseline ODI (0-100) | 54.44±20.47 (12-90) |

Values are presented as mean±standard deviation (minimum-maximum) or n (%); NRS-11: Numeric Rating Scale; BDI: Beck Depression Inventory; ODI: Oswestry Disability Index.

**TABLE 3:** Interrater reliability of the morphometric measurements.

| | Affected side | Unaffected side |
|---|---|---|
| L5 maximum foraminal width | 0.993 | 0.996 |
| L5 minimum foraminal width | 0.994 | 0.990 |
| L5 pedicle length | 0.984 | 0.985 |
| L5 foraminal CSA | 0.992 | 0.995 |
| L5 nerve root CSA | 0.995 | 0.985 |
| L5 nerve root CSA/L5 foraminal CSA | 0.993 | 0.990 |
| L4-L5 disk height | 0.799 | |

Intraclass correlation coefficients were shown; CSA: Cross-sectional area.

nificant difference between affected and unaffected sides in terms of morphometric measurements of NF (p>0.05) (Table 4).

In men, L4-L5 disc height, L5 neural foramen maximum width (NFMW) on the affected side and L5 nerve root CSA on the unaffected side were statistically higher than women (p=0.036, p=0.003, p=0.017 respectively). Height was positively correlated with NFMW on the affected side (p>0.05) and age was negatively correlated with NFMW on the unaffected side (p>0.05).

Baseline depression and disability levels were statistically higher in women than men (p=0.04 and p=0.032, respectively) but none of the outcome measures were significantly correlated with any morphometric parameters of NF and ID. 1st hour after TFESI mean NRS-11 score was decreased from 7.87±1.41 to 0.76±1.58 (p<0.001). The effect of TFESI on pain, depression, and disability scores at 3rd week and 3rd month were shown in Table 5. All assessment parameters were improved significantly at both time periods compared to baseline. The treatment success (50% or more reduction in NRS-11) was found 69% at 3rd week without any significant difference in terms of morphometric features of NF and ID between patients who responded and did not respond to TFESI (p>0.05) (Table 6). At 3rd month, treatment success of TFESI was 60%, again no statistically significant difference was found between responders and non-responders regarding morphometric evaluation (p>0.05) (Table 7). Nonetheless, initial pain, disability, and depression levels of the 2 groups were similar. There was not any correlation between morphometric parameters of NF and the change in NRS-11 score from baseline to 3rd month after TFESI.

**TABLE 4:** Morphometric measurements of affected and unaffected sides.

| | Affected side | Unaffected side | p value |
|---|---|---|---|
| L5 maximum foraminal width (mm) | 8.47±1.80 (4.60-11.35) | 8.29±2.17 (4.35-13.52) | 0.500* |
| L5 minimum foraminal width (mm) | 4.48±1.52 (1.99-8.26) | 4.25±1.56 (1.15-6.81) | 0.291* |
| L5 pedicle length (mm) | 4.60±0.90 (2.87-6.94) | 4.51±1.01 (2.29-6.61) | 0.430* |
| L5 foraminal CSA ($mm^2$) | 100.61±27.96 (44.93-163.55) | 99.92±33.50 (36.01-180.84) | 0.861* |
| L5 nerve root CSA ($mm^2$) | 31.91±18.38 (10.44-133.43) | 28.86±9.61 (11.59-46.92) | 0.217* |
| L5 nerve root CSA/L5 foraminal CSA (%) | 32.54±17.29 (11.56-126.17) | 31.72±15.42 (12.65-95.79) | 0.578* |
| L4-L5 disk height (mm) | 11.01±2.10 (4.98-15.25) | | |

*Independent t-test; values are presented as mean±standard deviation (minimum-maximum); CSA: Cross-sectional area.

**TABLE 5:** Pain, depression, and disability scores after TFESI.

| | Baseline | 3rd week | 3rd month | | Baseline vs. 3rd week | Baseline vs. 3rd month |
|---|---|---|---|---|---|---|
| NRS-11 | 7.87±1.41 | 2.84±2.38 | 4.04±2.62 | **p<0.001*** | **p<0.001**** | **p<0.001**** |
| BDI | 10.44±8.34 | 7.64±8.75 | 8.36±9.20 | **p=0.001*** | **p=0.002**** | **p=0.041**** |
| ODI | 54.44±20.47 | 27.78±20.88 | 33.82±20.20 | **p<0.001*** | **p<0.001**** | **p<0.001**** |

Values are presented as mean±standard deviation. *One-way analysis of variance test; **Post hoc Bonferroni test; TFESI: Transforaminal epidural steroid injection; NRS-11: Numeric Rating Scale; BDI: Beck Depression Inventory; ODI: Oswestry Disability Index.

**TABLE 6:** Comparison of morphometric features of patients regarding treatment success of TFESI at 3rd week.

| | Successful (n=31) | Failed (n=14) | p value |
|---|---|---|---|
| L5 maximum foraminal width (mm) | 8.81±1.73 | 7.73±1.80 | 0.062* |
| L5 minimum foraminal width (mm) | 4.63±1.57 | 4.17±1.42 | 0.352* |
| L5 pedicle length (mm) | 4.58±0.90 | 4.64±0.92 | 0.859* |
| L5 foraminal CSA ($mm^2$) | 102.25±25.92 | 96.98±32.78 | 0.564* |
| L5 nerve root CSA ($mm^2$) | 33.79±20.29 | 27.73±12.89 | 0.311* |
| L5 nerve root CSA/L5 foraminal CSA (%) | 33.82±19.37 | 29.69±11.52 | 0.465* |
| L4-L5 disk height (mm) | 11.14±2.31 | 10.74±1.58 | 0.564* |

*Independent sample t-test; TFESI: Transforaminal epidural steroid injection; CSA: Cross-sectional area.

**TABLE 7:** Comparison of morphometric features of patients regarding treatment success of TFESI at 3rd month.

| | Successful (n=31) | Failed (n=14) | p value |
|---|---|---|---|
| L5 maximum foraminal width (mm) | 8.24±1.81 | 8.82±1.78 | 0.295* |
| L5 minimum foraminal width (mm) | 4.61±1.56 | 4.30±1.49 | 0.504* |
| L5 pedicle length (mm) | 4.60±0.88 | 4.60±0.94 | 0.989* |
| L5 foraminal CSA ($mm^2$) | 102.17±26.82 | 98.28±30.23 | 0.653* |
| L5 nerve root CSA ($mm^2$) | 29.44±10.27 | 35.61±26.24 | 0.275* |
| L5 nerve root CSA/L5 foraminal CSA (%) | 29.27±8.41 | 37.43±24.96 | 0.122* |
| L4-L5 disk height (mm) | 10.86±2.37 | 11.25±1.65 | 0.543* |

*Independent sample t-test; TFESI: Transforaminal epidural steroid injection; CSA: Cross-sectional area.

## DISCUSSION

The current study focused on the relationship between MRI-based morphometric features of NF and treatment success of TFESI. Although interrater reliability of the measurements was high or excellent, morphometric measurements did not differ statistically between responders and non-responders. NF or intervertebral foramen is a complex path between 2 movable joints (intervertebral and zygapophysial joints) that spinal nerve roots and other neurovascular structures pass. Many studies inquired a link between back and radicular pain and lumbar NF morphometry however, Rühli and Henneberg concluded that alterations in NFMW and NF height are not associated with radiculopathy alone.[15,16] Another research of the same authors could not delineate any correlation of NF width with individual age or stature apart from the finding that females show larger NF width which is in contrast with our findings.[17] On the contrary, Senoo showed in a 3 dimensional in-vivo analysis that foraminal height and width both decreases with age in all lumbar levels and a recent paper of Yan et al. which subdivided the NF into three zones revealed aging cause divergent alterations in dimensions of NF in different lumbar levels.[18,19] Our results also showed that older age was associated with smaller NFMW which was significant on the unaffected side.

Several morphological factors are proposed to be associated with TFESI outcomes. Ekedahl et al. found that high grade of nerve root compression presages high chance of treatment success. Conversely, Ghahreman and Bogduk reported that low grade of nerve root compression is the only radiologic feature associated with favorable response.[20,21] Our study population was composed of individuals having one-sided paramedian subarticular disc herniation at L4-L5 level and the selected route for epidural injection was the transforaminal route. Thus, we wondered whether morphometrics of the NF that is traversed during the procedure will affect the efficacy of TFESI

despite the absence of foraminal compression on MRI. If our study population was composed of patients with foraminal disc herniation, these morphometric parameters would be much more important. In a recent research, Yusof et al. concluded that transverse diameter of the NF is much more likely to affect the severity of nerve root compression rather than vertical diameter, which might also influence the intensity of pain and response to TFESI.[22] However, foraminal disc herniation is considerably rare compared to paramedian disc herniation.[23]

The results obtained from our study show that L4-L5 disc height, L5 pedicle length, L5 minimum and maximum foraminal width, L5 foraminal CSA, L5 nerve root CSA and L5 nerve root CSA/L5 foraminal CSA have no effect on the efficacy of L5 TFESI for L4-L5 level paramedian disc herniation. Moreover, they were not associated with baseline pain, depression, and disability levels. The overall success rate of TFESI at 3rd month was 60% which was similar with our previous report.[9] Depression and disability scores were also significantly reduced at 3rd week and 3rd month compared to baseline. Having a comprehensive knowledge about the anatomic features and dimensions of the NF may not only serve for good outcomes after interventions to this area but may also help avoiding life-threatening complications.[8] Although TFESI is the most performed procedure in interventional pain centers, it can rarely result in spinal cord infarction, epidural hematoma, or epidural abscess.[24] In our study, no major complications were seen after TFESI, and we could not find any association between NF morphometrics and minor adverse reactions (vasovagal reaction etc.)

A limitation of the present study is including only patients with paramedian disc herniation. One may say that morphometric evaluation of NF would be more convenient for those having foraminal disc herniation. Nonetheless, morphometric parameters of NF may affect the treatment success of TFESI by altering contrast spread, prolonging procedure time, increasing the possibility of nerve root injury or any other adverse effect regardless of the type of herniation. Another thing to specify is that TFESI is found to be more effective for paramedian disc herniation than the foraminal one and given the high frequency of paramedian disc herniations, we excluded participants with foraminal or extra-foraminal disc herniation.[25] Albeit we could not find any association between TFESI outcomes and morphometric parameters of NF, further studies may focus on the relationship between NF characteristics and contrast spread patterns or procedure time. Relatively short follow-up period and wide range of age groups are other limitations of this research. Further studies with larger and homogeneous samples may contradict with our results as we made the power analysis based on the treatment success at 3rd month.

## CONCLUSION

This is the first study to investigate the relationship between TFESI outcomes and the morphometric features of the relevant NF and ID. The results of the present study indicate that disc height, pedicle length, minimum and maximum foraminal width, foraminal CSA, nerve root CSA and nerve root CSA/foraminal CSA have no effect on the efficacy of TFESI. Research supporting or opposing our results are warranted to enlighten pain physicians on this issue.

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*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.*

***Authorship Contributions***

***Design:*** *Elif Zeren, Ümit Süleyman Şehirli, Yasin Arifoğlu, Osman Hakan Gündüz;* ***Control/Supervision:*** *Elif Zeren, Ekim Can Öztürk, Osman Hakan Gündüz;* ***Analysis and/or Interpretation:*** *Elif Zeren, Ekim Can Öztürk;* ***Writing the Article:*** *Ekim Can Öztürk.*

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