Original article

Percutaneous Laser Disc Decompression versus Transforaminal Epidural Steroid Injection in Lumbar Radicular Pain: The Role of Disc Herniation–Nerve Root Contact

Dino Budrovac* [1, 2], Ivan Radoš [1, 2], Ozana Katarina Tot [1, 2], Ivana Haršanji Drenjančević [1, 2], Dijana Hnatešen[1], Iva Dimitrijević [1, 2], Ninoslava Vonić [1, 3], Hrvoje Vinković [1, 2], Sonja Škiljić [1, 2], Matija Budrovac [4]

1 Clinic for anesthesiology, intensive care and pain management, University Hospital Osijek, Osijek, Croatia
2 Faculty of Medicine, Josip Juraj Strossmayer University, Osijek, Croatia
3 Faculty of Dental Medicine and Health Osijek, Josip Juraj Strossmayer University of Osijek, Osijek, Croatia
4 Emergency Medicine Center, General Hospital Našice, Našice Croatia

*Corresponding author: Dino Budrovac, dino.budrovac@gmail.com

Abstract

Aim of the study: To compare the effectiveness of percutaneous laser disc decompression (PLDD) and transforaminal epidural steroid injection with local anesthetic (ESI TF) in participants with lumbar radicular pain caused by intervertebral disc herniation, depending on the presence of disc herniation with nerve root contact.

Methods: A prospective observational study was conducted on 116 participants with unilateral lumbar radicular pain caused by intervertebral disc herniation. Participants were stratified according to the presence of disc herniation in contact with the nerve root and then according to the type of procedure performed. Pain intensity was assessed using the visual analogue scale (VAS), and functional disability was assessed using the Oswestry Disability Index (ODI). Measurements were performed before the procedure and after one, three and six months of follow-up.

Results: In participants with herniated disc and nerve contact, pain was significantly lower in participants who received PLDD compared to ESI TF 30 days after the intervention (P = 0.03), three months after the intervention (P = 0.003) and six months after the intervention (P = 0.004). Analysis of ODI categories showed no consistent difference between treatment methods during follow-up.

Conclusion: Both minimally invasive methods were associated with pain reduction, and PLDD showed a better effect in reducing pain in participants with herniated disc and nerve root contact. The analysis of functional disability did not show a consistent difference between the methods.

Trial registration: ClinicalTrials.gov NCT05601791.

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Introduction

Lumbar radicular pain is defined as pain in the lumbar spine with radiating to the lower extremities (1). Due to the aging of the population, it represents a major public health, social and economic problem and is one of the most common reasons why patients consult a doctor (2). Sciatica is the leading cause of disability worldwide, and the prevalence of lumbosciatica that limits physical activity is up to 20% (3,4). Modern, sedentary lifestyles, excess body weight, and lack of physical activity have led to an increase in the incidence of lumbar radicular pain. It is estimated that about 85% of the world's population experiences lumbar spine pain at least once in their lives (5,6). Despite the high overall costs to the healthcare system, treatment success and reduction of disability have not improved significantly, which is why there is an increased interest in complementary treatment methods. For most patients, this type of pain is self-limiting, as about 80% of patients experience spontaneous pain relief within a few weeks or months, but 10-20% of patients develop chronic pain (4). To diagnose lumbar radicular pain, a clinical examination of the patient, physical tests, and radiological methods, including magnetic resonance imaging, are performed.

Just as the mechanical component is important, the inflammatory component is also important in the etiology of lumbar radicular pain (7). Excessive mechanical stress on the intervertebral disc leads to an inflammatory response, which promotes further damage to the disc, thus creating a vicious cycle (8–10). The protrusion of the nucleus pulposus into the spinal canal triggers an immune and inflammatory reaction near the nerve root that leads to increased activation of the nociceptive system.

According to guidelines for the treatment of lumbar radicular pain, conservative treatment is preferred (11,12). The gold standard in the treatment of lumbosciatica caused by a herniated disc that does not respond to conservative treatment methods is microdiscectomy. In order to avoid the systemic and unwanted effects of analgesics, anesthesia, and long and extensive surgery, minimally invasive procedures are increasingly used in the treatment of lumbar radicular pain. Epidural steroid injection and local anesthetic (ESI TF) and percutaneous laser disc decompression (PLDD) are some of these methods (13,14). Epidural steroid and local anesthetic injection is a widely used minimally invasive method for the treatment of lumbar radicular pain. On the other hand, percutaneous laser disc decompression is a minimally invasive intradiscal method aimed at reducing intradiscal pressure, thereby reducing mechanical compression and irritation of the nerve root. Although both methods are used in patients with similar clinical presentations of lumbar radicular pain, their mechanisms of action are significantly different.The assumption is that the effectiveness of each treatment method will depend on the relationship between the herniated disc and the nerve root, with PLDD being more effective in reducing pain in patients with contact between the herniated disc and the nerve root, while ESI TF is more effective in patients without contact, in whom the inflammatory component of pain is assumed to play a greater role.

The aim of this study was to compare the efficacy of percutaneous laser disc decompression and transforaminal epidural steroid and local anesthetic administration in patients with lumbar radicular pain caused by intervertebral disc herniation, depending on the presence of disc herniation-nerve root contact. The efficacy of treatment was assessed by changes in pain intensity and functional status, measured by the visual analogue pain scale (VAS) and the Oswestry Disability Index (ODI) questionnaire.

Materials and methods

The study was designed as a prospective observational study and was conducted at the Clinic for Anesthesiology, Resuscitation and Intensive Care Medicine at the Department of Pain Management of the Clinical Hospital Center Osijek from November 30, 2020 to October 19,

2023, on 116 participants after obtaining the approval of the Ethics Committee of Osijek Clinical Hospital Center (R2-18577/2019) and in accordance with the Declaration of Helsinki. The clinical trial was prospectively registered at ClinicalTrials.gov under the identifier NCT05601791.

The participants were divided into two groups according to the presence of contact between the herniated intervertebral disc and the nerve root and the type of procedure performed. Contact between the herniated disc and the nerve root was determined based on magnetic resonance imaging findings.

Inclusion criteria were: patients aged between 18 and 65 years, consent to participate in the study, confirmed by signing a consent form and informed consent, unilateral lumbar radicular pain, pain duration of up to six months, pain that does not respond to conservative treatment, symptomatic disc herniation at one level, magnetic resonance imaging-verified disc herniation, pain intensity measured on a VAS scale from 0 to 10, which is equal to or greater than 5, and pain intensity along the leg is worse than back pain. Exclusion criteria were: patinets younger than 18 and older than 65 years of age, patient refusal to participate in the study, pain intensity measured by the VAS scale less than 5, central stenosis of the lumbar canal, bilateral radicular pain, progressive neurological deficit, lumbar radicular pain caused by causes other than disc herniation, pregnancy, allergy to steroids, local anesthetics, fentanyl, midazolam and contrast medium, positive history of prolonged bleeding, local or systemic infection, previous lumbar spine surgery, opioid abuse, proven inflammatory rheumatic disease, proven inflammatory bowel disease and other infections.

Participants completed the Oswestry Disability Index (ODI) questionnaire prior to the procedure, and pain intensity was assessed using the Visual Analogue Scale (VAS). The participants underwent 4 measurements. The first measurement was taken before the procedure, the second measurement one month after the procedure, the third measurement three months after the procedure, and the fourth 6 months after the procedure. Epidural administration of steroids and local anesthetic via transforaminal approach was performed in the operating room under aseptic conditions. After confirming that the needle tip was in the epidural space, a solution of 40 mg methylprednisolone in 5 ml 0.25% levobupivacaine was administered, according to the institution's protocol. Percutaneous laser disc decompression was performed in the operating room according to the rules of asepsis. The laser device settings were wavelength 1470 nm, power 8 W, pulse duration 500 msec, pause between pulses 1 sec, delivered energy per disc 900 J. The laser device brand is Leonardo Mini. Pain intensity was assessed using a visual analogue scale (VAS) from 0 to 10 (15). Functional status was assessed using the Oswestry Disability Index (ODI), a validated instrument for assessing disability associated with low back pain (16,17) . VAS and ODI were measured before the procedure and after one, three and six months of follow-up. Categorical data are presented with absolute and relative frequencies, and numerical data with median and interquartile range. The normality of the distribution of numerical variables was tested with the Shapiro-Wilk test. Differences between independent groups were analyzed using the Mann-Whitney U test, while changes during follow-up were analyzed using the Friedman test with the Conover post hoc test. Categorical variables were analyzed with the χ^2 test or Fisher's exact test. The level of statistical significance was set at $p < 0.05$. Statistical analysis was performed with MedCalc® Statistical Software version 22.006 and SPSS, version 23.0.

The study was conducted after approval by the Ethics Committee of the Clinical Hospital Center Osijek and the Faculty of Medicine Osijek, Josip Juraj Strossmayer University in Osijek. All participants were informed about the type of procedure, possible risks and the right to withdraw before participating in the study, and signed an informed consent. The data were collected and processed anonymously.

Results

Participants characteristics

The study was conducted on 116 participants with unilateral lumbar radicular pain, of which an equal number, 58 participants (50%) had contact between the herniated disc and the nerve and 58 did not. The median age of participants without contact between the herniated disc and the nerve was 49 years, ranging from 26 to 65 years, and of participants with contact between the herniated disc and the nerve was 50 years, ranging from 21 to 62 years. There were no significant differences in age with respect to groups according to contact (P = 0.73). There were 40 men (34%) and 76 women (66%). Most participants had only completed secondary school, 85 of them (73%), while 15 (13%) had only completed primary school. There was a significant difference in the distribution of participants with respect to the level of education and the observed groups (P = 0.03) (Table 1).

Table 1. Participants by basic characteristics

	Number (%) of participants with regard to herniated disc and nerve root contact			*P**
	Without contact (n = 58)	**With contact (n = 58)**	**Total (n = 116)**	
Gender				
Men	19 (33)	21 (36)	40 (34)	0.70
Women	39 (67)	37 (64)	76 (66)	
Proffesional qualification				
Primary school	11 (19)	4 (7)	15 (13)	
High school	39 (67)	44 (76)	85 (73)	0.03
Higher education	41 (71)	5 (9)	5 (4)	
Faculty	6 (10)	5 (9)	11 (9)	

* $\chi 2$ test

Association of pain intensity between ESI TF and PLDD

In the group of participants without disc herniation and nerve contact, the pain at the beginning of treatment was significantly stronger in the PLDD group compared to the ESI TF group (P = 0.04). In participants with herniated disc and nerve contact, pain was significantly lower in participants who received PLDD compared to ESI TF 30 days after the intervention (P = 0.03), three months after the intervention (P = 0.003) and six months after the intervention (P = 0.004) (Table 2).

Analysis of the degree of disability in the group without contact according to ODI categories showed that at three months after the procedure there was a significant difference in the distribution of ODI categories between the PLDD and ESI TF groups (P = 0.03). The ESI TF group had a higher proportion of participants with severe disability compared to the PLDD group (31% vs. 14%), while the PLDD group had the highest proportion of participants in the moderate disability category (Table 3).

Table 2. Differences in pain intensity (VAS scale) between participants with and without contact between herniated disc and nerve depending on the treatment method

With contact of herniated disc and nerve root	Median (IQR) by treatment method						
	PLDD (n = 58)	P*	ESI TF (n = 58)	P*	Difference	95 % CI	P§
Without contact							
initial	8 (8 – 10)	< 0,001‡	7 (7 – 9)	< 0,001‡	-1	-1 do 0	0,04
30 days	3 (2 – 5)		3,5 (0 – 5)		0	-1 do 1	0,98
3 months	3 (2 – 4)		4 (1 – 6)		1	-1 do 2	0,35
6 months	3 (2 – 5)		4 (2 – 6)		1	0 do 2	0,19
With contact							
initial	8 (6 – 10)	< 0,001‡	8 (7 – 8)	< 0,001‡	0	-1 do 1	0,98
30 days	2 (0 – 4)		4 (3 – 6)		1	0 do 3	0,03
3 months	2 (0 – 4)		4 (3 – 7)		3	1 do 4	0,003
6 months	2 (0 – 4)		4 (3 – 7)		2	1 do 4	0,004

IQR = interquartile range; 95% CI = 95% confidence interval; *Friedman test (Conover post hoc test); §Mann-Whitney U test (Hodges-Lehmann median difference); ‡Significant difference at P < 0.05: (Start of treatment) vs. (30 days, 3 and 6 months); (30 days) vs. (6 months) ‡Significant difference at P < 0.05: Start of treatment vs. all others

Table 3. Distribution of participants according to disability (ODI) in relation to treatment method in participants without contact of herniated disc and nerve root

Without contact between the herniated disc and the nerve root	Number (%) of participants			
	PLDD (n = 29)	ESI TF (n = 29)	*Total (n = 58)*	P*
Before the treatment	0	1 (3)	1 (2)	0.63
Minimal disability (OW 0 – 20 %)	12 (41)	10 (34)	22 (38)	
Moderate disability (OW 21 – 40 %)	12 (41)	15 (52)	27 (47)	
Severe disability (OW 41 – 60 %)	5 (17)	3 (10)	8 (13,8)	
Crippled (OW 61 – 80 %)				
30 days from the treatment	6 (21)	9 (31)	15 (26)	0.71
Minimal disability (OW 0 – 20 %)	15 (52)	15 (52)	30 (52)	
Moderate disability (OW 21 – 40 %)	5 (17)	4 (14)	9 (16)	
Severe disability (OW 41 – 60 %)	3 (10)	1 (3)	4 (6,9)	
Crippled (OW 61 – 80 %)				
3 months from treatment	2 (7)	7 (24)	9 (16)	0.03
Minimal disability (OW 0 – 20 %)	23 (79)	13 (45)	36 (62)	
Moderate disability (OW 21 – 40 %)	4 (14)	9 (31)	13 (22)	
Severe disability (OW 41 – 60 %)				
6 months from treatment	6 (21)	10 (34)	16 (28)	0.14
Minimal disability (OW 0 – 20 %)	21 (72)	13 (45)	34 (59)	
Moderate disability (OW 21 – 40 %)	2 (7)	5 (17)	7 (12)	
Severe disability (OW 41 – 60 %)	0	1 (3)	1 (1,7)	
Crippled (OW 61 – 80 %)	0	1 (3)	1 (2)	

* Fisher's exact test

In the group of participants with contact of the herniated disc with the nerve root, no statistically significant difference was found in the distribution of the degree of disability according to ODI categories between the PLDD and ESI TF groups during follow-up (Table 4).

Table 4. The relationship of the three-month mortality status (survived vs. died) after hospitalization with the therapy that the patients were taking before the admission for heart failure

With contact between herniated disc and nerve root	Number (%) of participants			
	PLDD (n = 29)	ESI TF (n = 29)	*Total (n = 58)*	*P**
Before the treatment				
Minimal disability (OW 0 – 20 %)	0	3 (10)	3 (5)	
Moderate disability (OW 21 – 40 %)	16 (55)	12 (41)	28 (48)	0.37
Severe disability (OW 41 – 60 %)	11 (38)	12 (41)	23 (40)	
Crippled (OW 61 – 80 %)	2 (7)	2 (7)	4 (7)	
30 days from the treatment				
Minimal disability (OW 0 – 20 %)	9 (31)	5 (17)	14 (24)	
Moderate disability (OW 21 – 40 %)	15 (52)	14 (48)	29 (50)	0.17
Severe disability (OW 41 – 60 %)	2 (7)	8 (28)	10 (17)	
Crippled (OW 61 – 80 %)	3 (10)	2 (7)	5 (9)	
3 months from treatment				
Minimal disability (OW 0 – 20 %)	11 (37,9)	8 (28)	19 (32,8)	
Moderate disability (OW 21 – 40 %)	12 (41)	12 (41)	24 (41)	0.73
Severe disability (OW 41 – 60 %)	4 (14)	7 (24)	11 (19)	
Crippled (OW 61 – 80 %)	2 (7)	2 (7)	4 (7)	
6 months from treatment				
Minimal disability (OW 0 – 20 %)	12 (41)	9 (31)	21 (36)	0.55
Moderate disability (OW 21 – 40 %)	13 (45)	13 (45)	26 (45)	
Severe disability (OW 41 – 60 %)	4 (14)	7 (24)	11 (19)	

* Fisher's exact test

Discussion

Clinical practice has shown that lumbar radicular pain can be present in patients with contact between a herniated intervertebral disc and the spinal nerve root, but also in patients with a herniated disc that is not in contact with the nerve root. The assumption underlying this study is that there are two dominant mechanisms of pain, direct pressure from the herniated disc on the nerve root and an inflammatory process that leads to irritation of the spinal nerve root.

In this prospective observational study, the effectiveness of transforaminal epidural administration of steroids and local anesthetic and percutaneous laser disc decompression in participants with unilateral lumbar radicular pain caused by intervertebral disc herniation was compared. The main finding of the study is that both methods were associated with a reduction in pain intensity during the six-month follow-up.

The results obtained are consistent with other studies that have shown that female gender is a risk factor for a higher prevalence of painful musculoskeletal conditions, although the reasons are not entirely clear (18,19). In other studies, it is stated that the pain caused by a herniated disc is more common in men between the ages of 30 and 50 (20).

In group of participants with disc herniation in contact with the nerve root, participants treated with PLDD had significantly lower VAS values compared to participants treated with the ESI TF method after 30 days, three months, and six months of follow-up. In group of participants without disc herniation in contact with the nerve root, no difference in pain intensity was found between the treatment methods during follow-up.

Numerous studies have investigated the effects of epidural steroid and local anesthetic administration and percutaneous laser disc decompression in the treatment of lumbar radicular pain caused by intervertebral disc herniation, and the results show that these methods are effective, although the results of individual studies vary (21–25). Despite the increasing use of ESI, there are still no clear guidelines for its use in terms of the method of administration into the epidural space, as well as the type of drugs used, their doses, volumes and concentrations.

The results showed that PLDD was more effective in both groups of participants. The assumption was that ESI TF would be more effective in the group withuot contact due to the anti-inflammatory effects of corticosteroids and local anesthetics, as the inflammatory process was considered to be the dominant mechanism of pain in this group of participants. Despite the fact that the dominant mechanism of PLDD is considered to be mechanical decompression, the photochemical reaction modulates the inflammatory response, which is why PLDD as a method proved to be superior in reducing pain intensity in both groups of participants. The short-term effectiveness of ESI TF during the three-month follow-up of the participants has been confirmed in other studies (22).

In addition to the short-term effects, long-term effects of PLDD are also known (21,23). Over four years, 73% of 200 participants experienced pain reduction (24). Menchetti et al. in a multicenter retrospective study that included 900 participants over five years of follow-up found that pain reduction after PLDD was significant even after five years (25).

The role of magnetic resonance imaging as a predictor of the outcome of ESI TF treatment was studied by Tecer et al. They studied the type of hernia (bulging, protrusion, extrusion), the location of the hernia (central, subarticular, foraminal, extraforaminal), the zone of high intensity and discoradicular contact. The decrease in pain intensity was significantly lower in each group of participants, but there were no significant differences according to the type and location of the hernia, while the decrease in pain intensity was significantly lower in participants with high intensity zones in the second week and in participants with discoradicular contact in the third month (26).

Similar to previous research a group of Korean authors investigated the association between MRI findings and treatment outcome in ESI TF. The researchers found that there was no significant difference in treatment outcome based on the type and size of the herniation. The location of the herniation and the degree of nerve root compression were good predictors of treatment outcome. Participants with central and extraforaminal herniation had better treatment outcome compared to participants with subarticular herniation. Participants with lower degrees of compression had worse treatment outcome than those with higher degrees of compression (27). In this study, participants were divided into groups depending on the presence of herniated disc contact with the nerve, but the degree of compression was not investigated, which is why the results are not directly comparable.

On the other hand, Ghahreman et al. found that ESI TF is more successful in participants without significant compression, in whom the pain would be caused primarily by an inflammatory process compared to participants with significant compression (28).

A recent systematic review by the American Academy of Neurology in 2025 showed that epidural steroid administration may have a short-term (< 3 months) effect in reducing radicular pain, but that the effect diminishes over longer follow-up (> 6 months) and is not clearly associated with long-term functional

improvement or a reduction in the need for surgical treatment. Such findings are consistent with the results of this study (29).

Based on several previously mentioned studies, we can conclude that the results are not uniform, which may be a consequence of inconsistent methodology and a smaller number of participants. In addition to the expected effect of certain treatment methods on reducing the size of the herniated disc, the inflammatory response can induce spontaneous hernia retraction in some patient, which explains why in some patients the pain decreases even without treatment (1).

The secondary outcome of the study was functional disability assessed by the Oswestry Disability Index questionnaire. Analysis of ODI categories did not show a consistent difference between the PLDD and ESI TF methods throughout the entire follow-up period. In the group of participants without contact of the herniated disc with the nerve root, a statistically significant difference in the distribution of ODI categories was found after three months, with a higher proportion of participants with severe disability in the ESI TF group. However, this difference was not maintained after six months. In the group of participants with contact of the herniated disc with the nerve root, no significant difference in the distribution of ODI categories was found between the PLDD and ESI TF groups during follow-up.

The effectiveness of ESI TF and PLDD in reducing the intensity of pain, improving the quality of life, reducing disability and reducing the intake of opioid analgesics has been proven in other studies (30,31) Other studies have found that PLDD is non-inferior to conventional microdiscectomy, the gold standard of treatment, at one-year follow-up. Pain intensity and disability reduction were comparable (32).

These findings suggest that the effect of PLDD compared to ESI TF in this study was more clearly expressed through a reduction in pain intensity than through a change in the degree of functional disability. This is not unexpected because functional recovery depends on multiple factors, including duration of symptoms, level of physical activity, psychological factors, fear of movement, comorbidities, and participants expectations. Pain reduction may precede functional recovery, but does not necessarily lead to a proportional improvement in ODI category over a relatively short follow-up period.

This study has some limitations. Although the total number of participants was 116, the division according to discoradicular contact and type of procedure resulted in smaller subgroups, which may reduce the statistical power of some analyses. Participants follow-up was limited to six months, so conclusions about the long-term effectiveness of the methods cannot be drawn. Contact of the herniated disc with the nerve root was analyzed without a detailed assessment of the degree of compression, morphology and localization of the herniation.

Despite these limitations, the results of this study suggest that both minimally invasive methods may have a place in the treatment of participants with lumbar radicular pain caused by herniated discs. In this study, PLDD was associated with a greater reduction in pain intensity in participants with disc herniation-nerve root contact, while functional disability analysis did not show a consistent difference between methods. Future studies should include a larger number of participants, longer follow-up, and more detailed radiological classification of disc herniation to more precisely determine which participants benefit most from each interventional method.

For all of the above, the results of this study should be interpreted as a contribution to a better understanding of the possible significance of the relationship between disc herniation and nerve roots, but not as a definitive predictive model of treatment success.

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Competing interests. The authors declare that they have no conflict of interest.

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Author contribution.

Acquisition of data: DB, DH, SŠ
Administrative, technical, or logistic support: DH, MB
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Final approval of the article: IR, OKT, IHD
Guarantor of the study: DB, IR, IHD
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Statistical expertise: ID, DH, NV

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Perkutana laserska dekompresija diska nasuprot epiduralnoj primjeni steroida transforaminalnim pristupom kod lumbalne radikularne boli: uloga kontakta između hernije diska i korijena živca

Sažetak

Cilj: Usporedba učinkovitosti perkutane laserske dekompresije diska (PLDD) i transforaminalne epiduralne injekcije steroida s lokalnim anestetikom (ESI TF) kod sudionika s lumbalnom radikularnom boli uzrokovanom hernijom intervertebralnog diska, ovisno o prisutnosti kontakta hernije diska s korijenom živca.

Metode: Provedena je prospektivna opservacijska studija na 116 sudionika s jednostranom lumbalnom radikularnom boli uzrokovanom hernijom intervertebralnog diska. Sudionici su podijeljeni prema prisutnosti kontakta hernije diska s korijenom živca, a zatim prema vrsti provedenog postupka. Intenzitet boli procijenjen je pomoću vizualne analogne ljestvice (VAS), a funkcionalna onesposobljenost procijenjena je pomoću Oswestry indeksa onesposobljenosti (ODI). Mjerenja su provedena prije postupka te nakon jednog, tri i šest mjeseci praćenja.

Rezultati: Kod sudionika s hernijom diska i kontaktom živca, bol je bila značajno niža kod sudionika koji su primili PLDD u usporedbi s ESI TF 30 dana nakon intervencije (P = 0,03), tri mjeseca nakon intervencije (P = 0,003) i šest mjeseci nakon intervencije (P = 0,004). Analiza ODI kategorija nije pokazala konzistentnu razliku između metoda liječenja tijekom praćenja.

Zaključak: Obje minimalno invazivne metode bile su povezane sa smanjenjem boli, a PLDD je pokazao bolji učinak u smanjenju boli kod sudionika s hernijom diska i kontaktom korijena živca. Analiza funkcionalne onesposobljenosti nije pokazala konzistentnu razliku između metoda.

Registracija ispitivanja: ClinicalTrials.gov NCT05601791.

Ključne riječi: Radikulopatija; Epiduralna injekcija; Laserska terapija