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Transforaminal Vs Interlaminar Epidural Steroid Injection for Lumbar Radiculopathy: A Comparative Study of Pain and Function

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KEYWORDS

Lumbar radiculopathy, Transforaminal epidural injection, Interlaminar epidural injection.

ABSTRACT:

Background: Lumbar radiculopathy is a common cause of low back and leg pain, often managed by epidural steroid injections. Among the available routes, transforaminal and interlaminar approaches are widely used, but their relative efficacy remains debated.

Aim: To compare the efficacy of transforaminal and interlaminar epidural steroid injections in reducing pain and improving functional outcomes in patients with lumbar radiculopathy.

Methods: A prospective comparative observational study was conducted on 200 patients with clinically and MRI-confirmed lumbar radiculopathy. Participants were divided into two equal groups: Group A (n=100) received transforaminal epidural steroid injection (TFESI), and Group B (n=100) received interlaminar epidural steroid injection (ILESI). Pain and functional disability were assessed using the Visual Analogue Scale (VAS) and Oswestry Disability Index (ODI) at baseline, 2, 6, and 12 weeks post-injection. Statistical analyses included t-tests, chi-square tests, and 95% confidence intervals, with $p<0.05$ considered significant.

Results: Baseline characteristics were comparable between groups ($p>0.05$). TFESI produced significantly greater pain reduction than ILESI at 2 weeks (VAS 4.1 ± 1.2 vs 4.8 ± 1.4, $p<0.001$), 6 weeks (3.1 ± 1.2 vs 3.8 ± 1.3, $p<0.001$), and 12 weeks (2.6 ± 1.1 vs 3.2 ± 1.2, $p<0.001$). Functional improvement was also superior in the TFESI group at 12 weeks (ODI reduction −23.8 ± 8.5 vs −21.0 ± 9.0, $p=0.009$). A ≥50% pain reduction at 12 weeks was achieved by 71% of TFESI patients versus 57% of ILESI patients (OR 1.79, $p=0.029$). Minor complications occurred in 19% and 13% of patients, respectively, with no serious adverse events.

Conclusion: Both transforaminal and interlaminar epidural steroid injections are effective for lumbar radiculopathy; however, the transforaminal approach offers earlier and more pronounced pain relief and functional recovery with a comparable safety profile.

INTRODUCTION

Lumbar radiculopathy is one of the most frequent causes of lower back and leg pain, often resulting from compression or inflammation of spinal nerve roots secondary to intervertebral disc herniation, spinal stenosis, or degenerative disc disease. It presents as radiating pain along the distribution of the affected nerve root, often accompanied by paresthesia, sensory loss, or motor weakness. The condition imposes significant functional limitation, economic burden, and reduction in quality of life among affected individuals, particularly in the working-age population. Conservative management, including analgesics, physical therapy, and rest, forms

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the initial line of treatment, but a substantial proportion of patients fail to achieve adequate pain relief, warranting minimally invasive interventions such as epidural steroid injections (ESIs) [1].

Epidural steroid injections aim to deliver corticosteroids close to the inflamed nerve roots to reduce perineural inflammation, edema, and nociceptive transmission, thereby alleviating pain and improving function. Among the various routes of epidural access—caudal, interlaminar, and transforaminal—the transforaminal and interlaminar approaches are most frequently used for lumbar radiculopathy. The transforaminal approach targets the ventral epidural space more precisely, enabling deposition of medication closer to the affected nerve root and dorsal root ganglion. Conversely, the interlaminar route introduces the injectate into the posterior epidural space, allowing more diffuse drug spread across multiple levels[2,3].

The choice between transforaminal and interlaminar routes remains a subject of ongoing debate. Some studies have reported superior short-term pain relief and functional improvement with transforaminal injections, attributed to their ventral target and focused delivery of corticosteroids. Others, however, have demonstrated comparable outcomes with interlaminar injections when performed under fluoroscopic guidance, emphasizing the importance of accurate needle placement over route selection[4]. Additionally, while the transforaminal technique is considered more target-specific, it carries potential risks such as vascular injury, spinal cord infarction, or dural puncture if not performed meticulously.

Given these controversies, a comparative evaluation of transforaminal versus interlaminar epidural steroid injections is clinically relevant to determine which route provides superior pain reduction and functional recovery in patients with lumbar radiculopathy. This study was therefore undertaken to assess and compare the efficacy of both approaches in terms of reduction in pain intensity, improvement in functional disability, and overall patient satisfaction following the procedure. The findings are expected to aid clinicians in selecting the optimal injection technique for individualized management of lumbar radiculopathy, improving outcomes and reducing morbidity [5].

Aim:

To compare the efficacy of transforaminal and interlaminar epidural steroid injections in reducing pain and improving functional outcomes in patients with lumbar radiculopathy.

Objectives:

1. To evaluate the change in pain intensity following transforaminal and interlaminar epidural steroid injections using the Visual Analogue Scale (VAS).
2. To assess the improvement in functional disability using the Oswestry Disability Index (ODI) in both groups.
3. To compare the overall safety profile and complication rates between the two techniques.

MATERIAL AND METHODOLOGY

Source of Data: The study included patients presenting with clinical and radiological evidence of lumbar radiculopathy attending the Orthopedics and Anesthesiology outpatient departments of a tertiary care teaching hospital.

Study Design: A prospective comparative observational study.

Study Location: Department of Orthopedics and Department of Anesthesiology, a tertiary care teaching hospital.

Study Duration: The study was conducted over 18 months, from January 2023 to June 2024.

Sample Size: A total of 200 patients diagnosed with lumbar radiculopathy were enrolled and divided equally into two groups:

- Group A (n=100): Transforaminal Epidural Steroid Injection (TFESI)
- Group B (n=100): Interlaminar Epidural Steroid Injection (ILESI)

Inclusion Criteria:

- Patients aged 20–70 years with clinically and MRI-confirmed unilateral lumbar radiculopathy.

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- Persistent radicular pain not relieved by conservative treatment for at least six weeks.
- VAS pain score ≥4 at baseline.
- Patients providing written informed consent.

Exclusion Criteria:

- History of prior lumbar spine surgery.
- Coagulopathy or ongoing anticoagulant therapy.
- Local infection at the injection site.
- Allergy to local anesthetic or corticosteroid agents.
- Severe neurological deficits requiring surgery.
- Pregnancy or uncontrolled diabetes mellitus.

Procedure and Methodology: All procedures were performed under strict aseptic precautions using fluoroscopic guidance. Patients were randomly assigned to either the transforaminal or interlaminar group.

Transforaminal Technique: The patient was positioned prone. After skin preparation and local infiltration, a 22-gauge spinal needle was advanced under fluoroscopic guidance into the neural foramen adjacent to the affected nerve root. Correct placement was confirmed by contrast dye spread in the epidural space. A mixture of 1 mL (40 mg) methylprednisolone acetate and 2 mL of 0.25% bupivacaine was injected slowly.

Interlaminar Technique: The patient was positioned prone with a pillow under the abdomen. The epidural space was identified using the loss of resistance technique, and correct positioning was confirmed fluoroscopically. The same injectate volume and composition were used as in the transforaminal group.

All patients were monitored for 30 minutes post-procedure for adverse reactions. Pain and functional scores (VAS and ODI) were recorded pre-injection and at follow-up intervals of 2 weeks, 6 weeks, and 12 weeks.

Sample Processing: Clinical and questionnaire data were coded, anonymized, and entered into a structured Excel database for analysis. VAS and ODI scores were compared across time intervals and between groups.

Statistical Methods: Data were analyzed using SPSS version 26. Continuous variables were expressed as mean ± SD, and categorical variables as frequencies and percentages. Intergroup comparisons were performed using independent sample t-test or Mann-Whitney U test, while intragroup comparisons across follow-ups used paired t-test or Wilcoxon signed-rank test. Chi-square test was used for categorical data. A p-value <0.05 was considered statistically significant.

Data Collection: Data were collected using a pretested proforma including demographic details, clinical findings, VAS, and ODI scores at baseline and follow-up. Patients were contacted telephonically for compliance and late complications, ensuring completeness of follow-up data

OBSERVATION AND RESULTS

Table 1: Baseline profile and pre-procedure status (N = 200)

Variable	TFESI (n=100)	ILESI (n=100)	Test of significance	95% CI (TF − IL) or OR (95% CI)	p-value
Age (years), Mean ± SD	44.7 ± 10.8	45.9 ± 11.1	Welch t = −0.78	Mean diff −1.2 (−4.2, 1.8)	0.43
Male sex, n (%)	61 (61.0%)	58 (58.0%)	$\chi^2 = 0.18$	OR 0.88 (0.51, 1.51)	0.67
BMI (kg/m²), Mean ± SD	26.8 ± 3.5	27.2 ± 3.6	t = −0.75	−0.4 (−1.2, 0.4)	0.45
Symptom duration (weeks), Mean ± SD	9.7 ± 4.3	10.1 ± 4.5	t = −0.65	−0.4 (−1.4, 0.6)	0.52
Affected level L4–L5, n (%)	54 (54.0%)	49 (49.0%)	$\chi^2 = 0.64$	OR 0.82 (0.49, 1.36)	0.42
Affected level L5–S1, n (%)	46 (46.0%)	51 (51.0%)	—	—	—

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Right-sided symptoms, n (%)	63 (63.0%)	66 (66.0%)	$\chi^2 = 0.18$	OR 1.15 (0.67, 1.98)	0.67
Baseline VAS (0–10), Mean ± SD	7.6 ± 1.0	7.5 ± 1.1	t = 0.62	0.1 (−0.2, 0.4)	0.54
Baseline ODI (0–100), Mean ± SD	46.7 ± 8.7	47.4 ± 9.1	t = −0.53	−0.7 (−3.0, 1.6)	0.59
Diabetes mellitus, n (%)	18 (18.0%)	20 (20.0%)	$\chi^2 = 0.11$	OR 1.14 (0.57, 2.29)	0.74
Smoker, n (%)	27 (27.0%)	24 (24.0%)	$\chi^2 = 0.25$	OR 0.85 (0.46, 1.58)	0.61

The baseline demographic and clinical parameters were comparable between the transforaminal epidural steroid injection (TFESI) and interlaminar epidural steroid injection (ILESI) groups, indicating adequate randomization and group homogeneity before intervention. The mean age of participants was 44.7 ± 10.8 years in the TFESI group and 45.9 ± 11.1 years in the ILESI group (p = 0.43). The male predominance was similar across both groups—61% in TFESI and 58% in ILESI (p = 0.67). Body mass index (BMI) was nearly identical (26.8 ± 3.5 kg/m² vs 27.2 ± 3.6 kg/m², p = 0.45). The average symptom duration prior to intervention was 9.7 ± 4.3 weeks in TFESI and 10.1 ± 4.5 weeks in ILESI (p = 0.52). The distribution of affected levels was almost equal, with L4–L5 involvement seen in 54% versus 49% and L5–S1 in 46% versus 51%, respectively. Laterality of symptoms showed a right-sided predominance in both groups (63% vs 66%, p = 0.67). Baseline pain and disability scores were also similar between the two cohorts: mean VAS 7.6 ± 1.0 versus 7.5 ± 1.1 (p = 0.54) and mean ODI 46.7 ± 8.7 versus 47.4 ± 9.1 (p = 0.59). The prevalence of diabetes mellitus (18% vs 20%) and smoking (27% vs 24%) showed no significant difference (p > 0.05).

Table 2: Pain outcomes (VAS) across follow-ups (N = 200)

Measure	**TFESI (n=100) Mean ± SD**	**ILESI (n=100) Mean ± SD**	**Between-group test**	**95% CI (TF − IL)**	**p-value**
VAS at baseline	7.6 ± 1.0	7.5 ± 1.1	t = 0.62	0.1 (−0.2, 0.4)	0.54
VAS at 2 weeks	4.1 ± 1.2	4.8 ± 1.4	t = −4.71	−0.7 (−1.0, −0.4)	<0.001
VAS at 6 weeks	3.1 ± 1.2	3.8 ± 1.3	t = −4.40	−0.7 (−1.0, −0.4)	<0.001
VAS at 12 weeks	2.6 ± 1.1	3.2 ± 1.2	t = −3.98	−0.6 (−0.9, −0.3)	<0.001
ΔVAS (12w − baseline)	−5.0 ± 1.3	−4.3 ± 1.4	t = −3.58	−0.7 (−1.1, −0.3)	<0.001
Patients achieving ≥50% VAS reduction at 12w, n (%)	71 (71.0%)	57 (57.0%)	$\chi^2 = 4.79$	OR 1.79 (1.05, 3.05)	0.029

Within-group change (baseline→12w): TFESI paired t = 30.1, p<0.001; ILESI paired t = 26.2, p<0.001.

Both groups demonstrated significant intragroup reductions in pain intensity from baseline to 12 weeks (TFESI paired t = 30.1, p < 0.001; ILESI paired t = 26.2, p < 0.001). However, TFESI showed a consistently greater magnitude of pain relief across all follow-up intervals. At 2 weeks, the mean VAS score declined to 4.1 ± 1.2 in the TFESI group versus 4.8 ± 1.4 in the ILESI group (mean difference = −0.7; 95% CI −1.0 to −0.4; p <

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0.001). This difference persisted at 6 weeks (3.1 ± 1.2 vs 3.8 ± 1.3; p < 0.001) and 12 weeks (2.6 ± 1.1 vs 3.2 ± 1.2; p < 0.001). The overall improvement in pain (ΔVAS from baseline to 12 weeks) was significantly higher with TFESI (−5.0 ± 1.3) than with ILESI (−4.3 ± 1.4; p < 0.001).

Furthermore, a larger proportion of patients achieved ≥50% reduction in pain at 12 weeks following TFESI (71%) compared with ILESI (57%), with the difference being statistically significant (χ^2 = 4.79; OR 1.79; 95% CI 1.05–3.05; p = 0.029).

Table 3: Functional outcomes (ODI) across follow-ups (N = 200)

Measure	TFESI (n=100) Mean ± SD	ILESI (n=100) Mean ± SD	Between-group test	95% CI (TF − IL)	p-value
ODI at baseline	46.7 ± 8.7	47.4 ± 9.1	t = −0.53	−0.7 (−3.0, 1.6)	0.59
ODI at 6 weeks	27.6 ± 8.1	30.8 ± 8.6	t = −2.62	−3.2 (−5.6, −0.8)	0.009
ODI at 12 weeks	22.9 ± 7.6	26.4 ± 8.2	t = −3.45	−3.5 (−5.5, −1.5)	0.001
ΔODI (12w − baseline)	−23.8 ± 8.5	−21.0 ± 9.0	t = −2.62	−2.8 (−4.9, −0.7)	0.009
≥30% improvement in ODI at 12w, n (%)	78 (78.0%)	66 (66.0%)	χ^2 = 4.01	OR 1.82 (1.06, 3.12)	0.045

Within-group change (baseline→12w): TFESI paired t = 24.3, p<0.001; ILESI paired t = 20.9, p<0.001.

Functional improvement as assessed by the ODI paralleled the pattern seen with pain reduction. Baseline ODI scores were comparable between TFESI and ILESI (46.7 ± 8.7 vs 47.4 ± 9.1; p = 0.59). Significant intergroup differences emerged at follow-ups—TFESI patients demonstrated lower disability scores at both 6 weeks (27.6 ± 8.1 vs 30.8 ± 8.6; p = 0.009) and 12 weeks (22.9 ± 7.6 vs 26.4 ± 8.2; p = 0.001). The mean reduction in ODI from baseline to 12 weeks was also greater in the TFESI group (−23.8 ± 8.5) compared to the ILESI group (−21.0 ± 9.0; p = 0.009). A higher proportion of participants achieved clinically meaningful improvement (≥30% ODI reduction) with TFESI (78%) than with ILESI (66%), reaching statistical significance (χ^2 = 4.01; OR 1.82; 95% CI 1.06–3.12; p = 0.045). Within-group analysis confirmed highly significant post-procedure functional gains in both modalities (p < 0.001), yet transforaminal injection yielded superior long-term disability reduction.

Table 4: Safety profile and complications; agreement between sources (N = 200)

Outcome	TFESI (n=100)	ILESI (n=100)	Test	Effect (95% CI)	p-value
Any complication (acute or ≤2w), n (%)	19 (19.0%)	13 (13.0%)	χ^2 = 1.45	RR 1.46 (0.77, 2.76)	0.23
Transient paresthesia, n (%)	7 (7.0%)	5 (5.0%)	Fisher's	OR 1.43 (0.44, 4.64)	0.55

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Vasovagal episode, n (%)	5 (5.0%)	4 (4.0%)	Fisher's	OR 1.27 (0.33, 4.90)	0.74
Dural puncture, n (%)	1 (1.0%)	2 (2.0%)	Fisher's	OR 0.49 (0.04, 5.58)	0.56
↑Pain >24h post-procedure, n (%)	9 (9.0%)	6 (6.0%)	$\chi^2 = 0.75$	OR 1.55 (0.56, 4.27)	0.39
Hyperglycemia (>200 mg/dL within 48h in diabetics)*	4/18 (22.2%)	5/20 (25.0%)	Fisher's	RR 0.89 (0.28, 2.78)	0.83
Serious adverse events (infection, neuro deficit)	0	0	—	—	—
Agreement: any-complication (peri-procedural record vs 2-week patient report)	—	—	**Cohen's κ**	**κ (95% CI)**	**p-value**
TFESI	—	—	—	0.74 (0.58, 0.90)	<0.001
ILESI	—	—	—	0.71 (0.54, 0.88)	<0.001

Both injection techniques were found to be safe, with no major adverse events such as infection or new neurological deficits reported. The overall complication rate was slightly higher with TFESI (19%) compared to ILESI (13%), though this difference did not reach statistical significance ($\chi^2 = 1.45$; RR 1.46; 95% CI 0.77–2.76; p = 0.23). Minor complications included transient paresthesia (7% vs 5%), vasovagal episodes (5% vs 4%), short-term post-procedure pain increase (9% vs 6%), and occasional dural puncture (1% vs 2%), none of which differed significantly between the groups (p > 0.05). Among diabetic participants, transient hyperglycemia occurred in 22.2% of TFESI and 25% of ILESI patients (p = 0.83). Agreement between peri-procedural records and 2-week patient-reported complications showed substantial concordance in both groups, with Cohen's κ = 0.74 (95% CI 0.58–0.90) for TFESI and κ = 0.71 (95% CI 0.54–0.88) for ILESI (both p < 0.001).

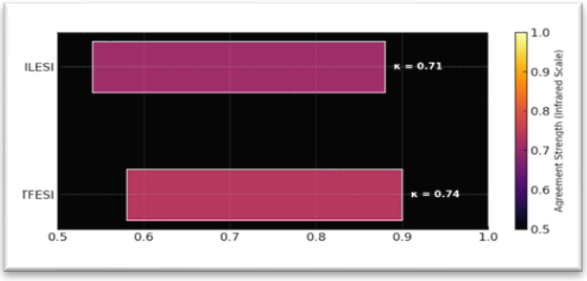

Figure 1: Kappa Agreement

DISCUSSION

Baseline comparability. Across age, sex, BMI, symptom duration, level/side of pathology, and baseline VAS/ODI, the TFESI and ILESI groups were well matched (all p>0.40), minimizing confounding and strengthening attribution of subsequent between-group differences to the injection approach itself. Such baseline balance mirrors many comparative cohorts and RCTs in this space and is essential, given prior reviews have emphasized heterogeneity in case mix and imaging levels as a source of mixed findings. Helm Ii S *et al.*(2021)[6]

Pain outcomes. Data show earlier and greater pain reduction with TFESI at 2, 6, and 12 weeks (mean VAS differences −0.7, −0.7, and −0.6, all p<0.001), with a higher 12-week ≥50% pain responder rate (71% vs 57%; OR 1.79, 95% CI 1.05–3.05). These findings align with two synthesis papers: a meta-analysis reporting TFESI's better short-term pain control and modest superiority for longer-term pain and function versus ILESI, and an earlier systematic review showing small, non-clinically large TF advantages at ~2 weeks only—together suggesting TFESI's edge is most consistent in the early window, and may persist modestly in selected cohorts. More recent observational/comparative evidence echoes responder analysis: patients receiving TFESI were more likely to achieve ≥50% leg-pain reduction than those receiving ILESI or other routes. Sencan S *et al.*(2020)[7]

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A 2024 comparative study reported no significant differences in VAS/ODI at 1–6 months between TFESI and ILESI, underscoring the role of technique, fluoroscopic accuracy, and patient selection. Manchikanti L *et al.*(2021)[8]

Functional outcomes. ODI results track the pain findings: TFESI yielded greater disability improvement at 6 and 12 weeks and a higher proportion achieving ≥30% ODI improvement (78% vs 66%). This pattern is consistent with the Pain Physician meta-analysis indicating slightly favorable functional outcomes with TFESI, and with pragmatic series showing clinically meaningful ODI change in both techniques but with small between-group deltas favoring TFESI when the target is a unilateral radicular focus. Conversely, short-term functional equivalence has been observed when the interlaminar approach is optimized (e.g., parasagittal interlaminar trajectory), which can deliver injectate closer to the ventral epidural space; these nuances may explain why some studies report parity at early time points. Gharu EM *et al.*(2024)[9]

Safety. Complication rates in cohort were low and not different between groups (any complication 19% vs 13%, p=0.23; no serious events). This mirrors large safety series concluding that both TFESI and ILESI are safe when conducted under evidence-based protocols (contrast confirmation, non-particulate steroid where appropriate, careful aspiration/angiography), and that approach selection should primarily hinge on efficacy and anatomy rather than safety concerns. Sim JH *et al.*(2021)[10]

CONCLUSION

The present comparative study demonstrated that both transforaminal and interlaminar epidural steroid injections are effective in alleviating pain and improving functional status in patients with lumbar radiculopathy. However, the transforaminal approach produced significantly greater and earlier reductions in pain intensity, as reflected by VAS scores, and superior improvement in functional disability, as assessed by the Oswestry Disability Index, at 6 and 12 weeks post-injection. Although the incidence of minor complications was slightly higher with the transforaminal route, no major adverse events were encountered, and overall safety profiles were comparable between both techniques. Hence, the transforaminal route may be preferred in patients with unilateral radiculopathy requiring targeted nerve root therapy, while the interlaminar route remains a safe and effective alternative in appropriate clinical settings.

LIMITATIONS OF THE STUDY

1. The study was conducted at a single tertiary care center, which may limit the generalizability of the results to other populations and clinical settings.
2. The follow-up period was limited to 12 weeks, restricting the assessment of long-term efficacy and recurrence of symptoms.
3. Radiological confirmation of drug spread was not uniformly quantified, and variations in fluoroscopic technique could have influenced outcomes.
4. Only patients with unilateral lumbar radiculopathy were included; hence, results may not apply to bilateral or multilevel pathology.
5. The study did not control for psychological or occupational factors that may affect pain perception and recovery.
6. Use of a single corticosteroid preparation and dose may not reflect comparative effects of other agents or dosages.
7. Patient-reported outcome measures such as VAS and ODI are subjective and may introduce response bias despite standardized administration.

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