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ORIGINAL ARTICLE

A comparative study of ultrasound-guided versus fluoroscopy-guided transforaminal epidural steroid injection in lumbar radiculopathy: Efficacy, safety, and radiation exposure.

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ABSTRACT… Objective: To compares the efficacy, safety, and radiation exposure of ultrasound-guided versus fluoroscopy-guided TFESI. **Study Design:** Prospective, Single Blind, Randomized Controlled Trial. **Setting:** Department of Anesthesia and Pain Medicine, Ghurki Trust Teaching Hospital, Lahore. **Period:** August 2025 to January 2026. **Methods:** 88 patients (44 per group) diagnosed with unilateral lumbar radiculopathy. Group A received fluoroscopy-guided TFESI (FG), and Group B received ultrasound-guided TFESI (USG) with fluoroscopic confirmation. Outcome were assessed at baseline, 1 week, 4 weeks, and 12 weeks; radiation dose (mGy); fluoroscopy time (seconds); and procedure duration (minutes). Results: Significant improvements in VAS and ODI were observed in both groups from baseline, with no significant differences between groups at 12 weeks ($p < 0.001$) (VAS: USG 2.4 ± 1.1 vs. FG 2.3 ± 1.2, $p = 0.68$). Radiation exposure and Mean fluoroscopy time were significantly lower in the USG group (0.27 ± 0.10 mGy vs 3.45 ± 0.65 mGy, $p < 0.001$, and 0.17 ± 0.07 s vs. 52.91 ± 13.91 s, $p < 0.001$, respectively). No major complications occurred in either group. **Conclusion:** Ultrasound-guided TFESI is an effective and radiation-free alternative to fluoroscopy-guided TFESI in the treatment of lumbar radiculopathy.

Key words: Fluoroscopy, Lumbar Radiculopathy, Radiation Safety, Transforaminal Epidural Steroid Injection, Ultrasound Guidance.

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INTRODUCTION

Low back pain with radiculopathy is a major clinical problem that significantly affects the quality of life and productivity. It is mostly caused by disc herniation or foraminal stenosis, where the inflammation and compression of the spinal nerve root is the main pathology. Among the available non-surgical interventions, transforaminal epidural steroid injection (TFESI) is a widely accepted and effective treatment modality, especially when conservative therapy fails to provide adequate relief.[1-3] The technique targets the anterior epidural space, delivering a concentrated dose of corticosteroids and local anaesthetics directly to the site of nerve root inflammation.

Traditionally, TFESI has been performed by fluoroscopy, which allows for real-time imaging of the vertebrae along with their foramens. Using the iodinated contrast dye, one can confirm the anterior epidural spread.[4,5] The fluoroscopy-guided (FG) technique is very effective, but it has many limitations. Exposure to the ionizing radiations is the main concern for both the patient and the healthcare team.[6,7] It also requires specialized imaging equipment and suites, which add to the cost and may not be available in remote settings. Fluoroscopy does not reliably guide intravascular injections. Techniques like digital subtraction angiography have been developed to watch for intravascular spread, but they further adds on the total radiation exposure and ultimately the cost of the procedure.[7,8]

In the last few years, ultrasound (US) guidance has been successfully explored as a safer, cheaper, and better alternative for spinal interventions.[8,9] Ultrasound has several advantages over fluoroscopy, like the absence of ionizing radiation, visualization of soft tissue and vascular structures, and the ability to track the needle in real-time.

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The portability of ultrasound machines allows for procedures to be performed in outpatient settings and in remote areas, with no need for dedicated lead-lined suites and protective wear, as is the case with fluoroscopy.[10,11] Like every technique, ultrasound also has limitations. These include the questions about ultrasound accuracy in deeper anatomical regions, such as the lumbar foramen, as ultrasound beams do not cross the bone and fail to provide a reliable image beyond bones. The steep learning curve of ultrasound is another big hurdle in its widespread acceptance.[12]

An extensive literature search regarding the technical feasibility and acceptability of ultrasound-guided lumbar spinal or paraspinal injections was performed. Some studies suggested high accuracy rates comparable to fluoroscopy, while others highlight the difficulty of visualizing the foramen in patients with high body mass index or advanced degenerative changes.[10-13] There is a paucity of information in the literature concerning well-designed, well-controlled, and well-conducted studies comparing not only efficacy, but also specific quantitative measures of radiation exposure, between these two modalities.

The rationale for conducting the current study was to determine if Ultrasound guidance for TFESI, when verified with fluoroscopic imaging for safety, was as clinically effective as the traditional Fluoroscopy guidance approach. By focusing on a specific aspect of patient safety, namely, radiation exposure and efficiency, we hope to provide strong evidence to support the integration of Ultrasound guidance into routine interventional pain management practices, thus making patient care safer and reducing occupational hazards to practitioners.

METHODS

This prospective single-blind randomized controlled trial was carried out at the Department of Anesthesia and Pain Medicine, Ghurki Trust Teaching Hospital, Lahore. It was done over a period of six months, starting from August 2025 to January 2026. The Institutional Review Board granted ethical approval (Ref. No.2025/07/R-47), and the trial was carried out in accordance with the Declaration of Helsinki—informed consent.

A total of 88 participants were enrolled from the outpatient department. Adult patients aged 20–70 years with MRI-confirmed unilateral lumbar disc herniation or foraminal stenosis with pain duration > 6 weeks refractory to conservative treatment and baseline VAS score ≥ 4 were included in this study. Patients with coagulopathy, active infection, previous lumbar surgery at the target level, allergy to contrast or steroids, and/or pregnancy were excluded. Patients were randomly allocated to Group A (Fluoroscopy-guided, n=44) or Group B (Ultrasound-guided with fluoroscopic confirmation, n=44) using a lottery method. Patients remained blinded to the guidance modality used during the procedure. A single experienced pain physician performed all procedures.

Patients in Group A (FG) received fluoroscopy-guided TFESI. Under fluoroscopic guidance (standard AP and oblique views), a 22-G spinal needle was advanced to the "6 o'clock" position of the pedicle. Contrast (1 mL) was injected to confirm epidural spread and rule out intravascular uptake. Patients in Group B (USG) received ultrasound-guided TFESI. A curvilinear probe (2–5 MHz) was used in a paramedian oblique sagittal plane to identify the lumbar foramen. The needle was advanced "in-plane" toward the intervertebral foramen. Once the needle tip reached the target, its position was confirmed using a single fluoroscopic shot. No contrast was used unless malposition was suspected on fluoroscopy. In both groups, a mixture of 40 mg triamcinolone acetonide and 2 mL of 0.25% bupivacaine was injected. The primary outcomes were the Visual Analog Scale (VAS) for pain and the Oswestry Disability Index (ODI) for functional status, assessed at baseline, 1 week, 4 weeks, and 12 weeks post-procedure.

Secondary outcomes included Radiation Metrics (Total fluoroscopy time in seconds and radiation dose in mGy as recorded by the C-arm); Procedural Metrics (Total procedure duration from skin prep to needle withdrawal in minutes and number of needle repositioning attempts); Technical Ease (Rated by the physician on a 5-point Likert scale 1 = very difficult, 5 = very easy); and Complications (Incidence of vascular puncture, dural puncture, or post-procedural neurological deficits). The data

was analyzed using SPSS version 25. A Chi-square test was performed to compare groups—repeated measures ANOVA was done to compare longitudinal data for VAS and ODI with $P < 0.05$.

RESULTS

The study successfully enrolled 88 patients, with 44 in each group. Baseline demographic characteristics are shown in Table-I.

In both Groups, significant reductions in pain intensity and functional disability were evident at all follow-up intervals compared to baseline ($p < 0.001$). As shown in Figure-1, there were no statistically significant differences in mean VAS scores between the groups at any time point. Similarly, functional improvement measured by ODI showed comparable results between the USG and FG groups, as shown in Figure-2. The USG group exhibited a profound reduction in radiation exposure compared to the FG group, as shown in Figure-3. The mean radiation dose in the USG group was 0.27 ± 0.10 mGy, compared to 3.45 ± 0.65 mGy in the FG group ($p < 0.001$). This was accompanied by a significant reduction in fluoroscopy time (0.17 ± 0.07 seconds vs. 52.91 ± 13.91 seconds, $p < 0.001$). The mean procedure duration was slightly longer in the USG group (11.64 ± 3.22 minutes) compared to the FG group (11.44 ± 3.16 minutes), but this difference did not reach clinical significance ($p = 0.77$). The technical ease Likert scores were higher in the FG group (4.6 ± 0.5) compared to the USG group (4.1 ± 0.7, $p = 0.04$), reflecting the initial learning curve associated with ultrasound. The number of needle repositioning attempts was more in the USG group (34 cases in the USG vs. 20 cases in the FG, $p = 0.00$). No major complications, such as intravascular injection, dural puncture, or infection, were reported in either group. Minor complications like vascular puncture and transient post-injection neurological deficit were equally distributed.

DISCUSSION

This comparative study proves that the ultrasound-guided TFESI is as effective as the fluoroscopy-guided TFESI in the management of pain and functional status in patients with lumbar radiculopathy while reducing the exposure to radiation and improving the safety profile. The main finding is the comparison in terms of clinical efficacy between the two methods, as measured by VAS and ODI, which is in line with the results of previous reviews.

TABLE-I

Patient demographic characteristics in both groups

Characteristic	Group A (FG)	Group B (USG)	P-Value
Age (years)	49.36 ± 11.07	47.43 ± 13.96	0.47
Gender (M/F)	20 / 24	22 / 22	0.67
BMI (kg/m²)	27.92 ± 2.66	27.95 ± 2.56	0.95
Baseline VAS	7.78 ± 0.66	7.84 ± 0.67	0.69
Baseline ODI (%)	56.86 ± 7.94	54.95 ± 8.53	0.28

FIGURE-1

Comparison of mean VAS scores in both groups

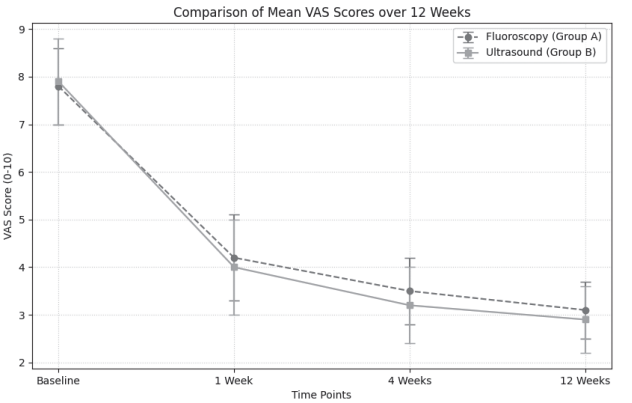


FIGURE-2

Comparison of mean ODI scores in both groups

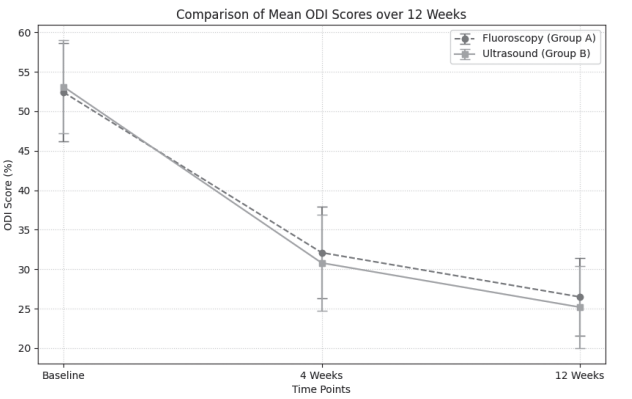
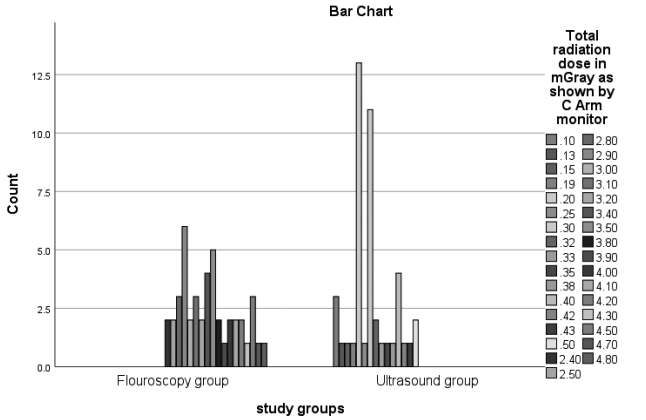


FIGURE-3

Comparison of total radiation exposure in both groups



The study by Viderman et al.[14] was conducted, where the researchers found that there was no significant difference between the pain relief in the Ultrasound-guided TFESI group and the Fluoroscopy-guided TFESI group at any interval during the 3 months of the follow-up period. Kimura et al.[15] also found that although the functional outcomes were slightly higher in the Fluoroscopy-guided TFESI group, the pain score reduction was almost the same in both the Ultrasound-guided TFESI group and the Fluoroscopy-guided TFESI group.

Regarding the radiation exposure, our study also showed a significant decrease in fluoroscopy time and radiation dose in the US group. This is in agreement with the study by Wang et al.[3] who showed that US-guided nerve blocks significantly reduced radiation exposure compared to fluoroscopy. With respect to the ALARA principles, the use of US will give a great safety advantage to clinicians performing a high volume of interventional procedures. It will effectively reduce the risk of radiation-induced problems such as cataracts, thyroid problems, gonad problems, malignancies, etc. This will give a great sense of relief and mental satisfaction to the performing physician.

Procedural efficiency and time management are another critical variable. While Goel et al.[16] noted that fluoroscopy-guided caudal blocks were faster than ultrasound-assisted ones, our study found that ultrasound-guided lumbar TFESI took a little more time than fluoroscopy, although the difference was minimal and insignificant. Interestingly, Hazra et al.[12] reported that ultrasound actually decreased needle placement time in caudal epidural injections. This difference with previous studies may be due to a comparatively lesser experience in ultrasound guided spine injections, as the technique is relatively new and learning curve is steep. However, this shortcoming was improved with time and experience, as was observed in the late phases of this study. The initial setup for ultrasound may take longer, but the real-time tracking of the needle can streamline the advancement phase, provided the operator has sufficient expertise. Interestingly the procedure duration also varied with patients BMI. With increasing BMI, the visualization of deeper structure becomes difficult with ultrasound thus increasing the difficulty and total procedure time. Further research in this regard is needed to prove these observations.

The technical difficulty of ultrasound-guided TFESI remains a point of discussion. Our findings showed a slightly lower Likert score for technical ease in the Ultrasound group. This may be attributed to the prolonged experience in fluoroscopy-guided injection. This is supported by Evansa et al.[17], who observed that while procedural times were similar, the cognitive load and spatial orientation required for ultrasound-guided spinal needle placement are higher than for fluoroscopy. Again, the steep learning curve of the ultrasound may be the reason behind this. Hashemi et al.[18] suggested that with adequate training, ultrasound-guided S1 transforaminal blocks can reach a 100% success rate, indicating that technical difficulty is a modifiable factor through experience.

Safety outcomes in our study were exemplary, with no major adverse events. This is in line with the results of Kesikburun et al.[10], who emphasized the safety of epidural injections when performed with precise guidance. Ultrasound has the unique benefits of real-time visualization of vascular structures (using colour or power Doppler) and avoiding important vessels like the segmental artery, which are not visible under standard fluoroscopy unless contrast is injected. This "real-time" vascular avoidance is a distinct safety advantage of the Ultrasound technique.

Furthermore, the accuracy of the USG group in our study was ensured by fluoroscopy confirmation. This is a hybrid approach that is recommended by Sahu et al.[8] The advantage of this method is that it allows for a smooth transition from the use of fluoroscopy alone to the use of ultrasound. With the use of a single shot of fluoroscopy for confirmation of needle placement, it is possible to maintain the 100% accuracy of the gold standard while also reaping most of the benefits of the use of ultrasound in reducing radiation. With respect to functional outcomes, although some studies, such as those by Viderman et al.[14], showed a slight trend towards fluoroscopy being better for ODI in a meta-analysis, our study showed no significant difference. This is an indication that the accuracy of needle placement is sufficient for the injectate to reach the anterior epidural space for functional recovery.

The study also has some limitations. First of all, the study design and the use of a single operator may influence the results of the procedural time and ease of procedure. Secondly, the study did not analyze the group of patients with a BMI of over 30 kg/m^2, despite the difficulty of visualization in such patients. Finally, the study period of 12 weeks may not be enough to assess the long-term results.

We recommend that future research focuses on the learning curve of Ultrasound guided TFESI and the development of standardized training protocols. Additionally, multicentred trials involving diverse patient populations (especially those with severe spinal deformity or high BMI) are necessary to further validate the role of ultrasound as a standalone guidance modality.

CONCLUSION

Ultrasound-guided transforaminal epidural steroid injection is a highly effective, safe, and radiation-sparing alternative to traditional fluoroscopy-guided techniques for managing lumbar radiculopathy. It provides equivalent pain relief and functional improvement while extensively reducing ionizing radiation exposure for both patients and clinicians. While it requires a higher degree of operator skill and a dedicated learning curve, its benefits in terms of safety and potential portability make it a superior choice in the evolving landscape of interventional pain management.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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REFERENCES

1. Manchikanti L, Sanapati MR, Soin A, Manchikanti MV, Pampati V, Singh V, et al. **An updated analysis of utilization of epidural procedures in managing chronic pain in the medicare population from 2000 to 2018.** Pain Physician. 2020; 23:111-26.
2. Vydyanathan A, Agrawal P, Donia K, Wahezi SE, Koushik SS, Slinchenkova K, et al. **Feasibility of ultrasound-guided lumbar transforaminal epidural steroid injections for management of lumbar radicular back pain.** J Pain Res. 2025; 18:759-67.
3. Wang B, Sun Y, Zhang J, Meng H, Zhang H, Shan L. **Ultrasound-guided versus fluoroscopy-guided lumbar selective nerve root block: A retrospective comparative study.** Scientific Reports. 2024 Feb 8; 14(1):3235.
4. Gelinimoghaddam A, Hashemi M, Dadkhah P, Taheri M. **Comparative studies on the success level of sonographic guided epidural steroid injection and its effectiveness with fluoroscopy techniques in treating lumbar radicular pain.** Biosci. Biotech. Res. Comm. 2017; 10(2):148-54.
5. Yue L, Zheng S, Hua L, Li H, Yang Y, Li J, et al. **Ultrasound-guided versus computed tomography fluoroscopy-assisted cervical transforaminal steroid injection for the treatment of radicular pain in the lower cervical spine: A randomized single-blind controlled noninferiority study.** The Clinical Journal of Pain. 2023 Feb 1; 39(2):68-75.
6. Xu Z, Wu S, Li X, Liu C, Fan S, Ma C. **Ultrasound-guided transforaminal injections of platelet-rich plasma compared with steroid in lumbar disc herniation: A prospective, randomized, controlled study.** Neural Plasticity. 2021; 2021(1):5558138.
7. Choi EJ, Park SJ, Yoo YM, Yoon JU, Shin SW, Byeon GJ. **Comparison of the oblique interlaminar and transforaminal lumbar epidural steroid injections for treatment of low back and lumbosacral radicular pain.** J Pain Res. 2021; 14:407-14.
8. Sahu DK, Sharma A, Kothari K, Wani P, Patel C, Parampill R. **Ultrasound-guided fluoroscopic-verified lumbar transforaminal epidural injection: A clinical evaluation of technique.** Indian Journal of Pain. 2016 Sep 1; 30(3):158-61.
9. Hashemi M, Dadkhah P, Taheri M, Haji Seyed Abootorabi SM, Naderi-Nabi B. **Ultrasound-guided lumbar transforaminal epidural injections; A single center fluoroscopic validation study.** Bull Emerg Trauma. 2019 Jul; 7(3):251-55.

10. Kesikburun S, Artuç ŞE, Karbancioğlu EÇ, Kesikburun B, Adigüzel E, Yaşar E. **The effect of hybrid ultrasound/ fluoroscopy guidance vs only fluoroscopy guidance on procedure time and radiation exposure in caudal epidural steroid injections.** Interventional Pain Medicine. 2025 Mar 1; 4(1):100567.
11. Hofmeister M, Dowsett LE, Lorenzetti DL, Clement F. **Ultrasound-versus fluoroscopy-guided injections in the lower back for the management of pain: A systematic review.** European Radiology. 2019 Jul 1; 29(7):3401-9.
12. Hazra AK, Bhattacharya D, Mukherjee S, Ghosh S, Mitra M, Mandal M. **Ultrasound versus fluoroscopy-guided caudal epidural steroid injection for the treatment of chronic low back pain with radiculopathy: A randomized, controlled clinical trial.** Indian Journal of Anaesthesia. 2016 Jun 1; 60(6):388-92.
13. Aykaç B, Küçükalp A. **The relationship of the clinical results of the patients undergoing transforaminal epidural injection with preoperative magnetic resonance imaging findings.** J Turk Spinal Surg. 2022 Feb 9; 33(1):30-35.
14. Viderman D, Aubakirova M, Aryngazin A, Yessimova D, Kaldybayev D, Tankacheyev R, et al. **Ultrasound-Guided vs. Fluoroscopy-Guided interventions for back pain management: A systematic review and meta-analysis of randomized controlled trials.** Diagnostics. 2023; 13(22):3474.
15. Kimura R, Yamamoto N, Watanabe J, Ono Y, Hongo M, Miyakoshi N. **Comparative efficacy of ultrasound guidance and fluoroscopy or computed tomography guidance in spinal nerve injections: A systematic review and meta-analysis.** European Spine Journal. 2023 Dec; 32(12):4101-10.
16. Goel S, Mitra S, Singh J, Jindal S, Upadhyay P, Jindal R. **Comparison of ultrasound and fluoroscopy-guided caudal epidural block in low back pain with radiculopathy: A randomized controlled study.** Journal of Anaesthesiology Clinical Pharmacology. 2025 Jan 1; 41(1):106-11.
17. Evansa I, Logina I, Vanags I, Borgeat A. **Ultrasound versus fluoroscopic-guided epidural steroid injections in patients with degenerative spinal diseases: A randomized study.** European Journal of Anaesthesiology| EJA. 2015 Apr 1; 32(4):262-8.
18. Hashemi M, Khoshooei A, Amanollahi A, Asgari S. **Comparative evaluation of caudal epidural method to ultrasound-guided s1 transforamen block in patient's lumbar discectomy with failed back syndrome symptoms: A double-blind clinical trial.** Anesth Pain Med. 2023; 13(6):e137325.

AUTHORSHIP AND CONTRIBUTION DECLARATION	
1	**Umer Farooq:** Conceptualization of study.
2	**Adeel Shahid:** Critical review.
3	**Leena Aziz:** Supervisor of study.
4	**Shahid Rasool Dar:** Literature review.
5	**Adnan Umer:** Data collection.
6	**Waseem Younis:** Critical review.