

Research Article

Ultrasound-Guided versus Fluoroscopy-Guided Transforaminal Epidural Steroid Injection for Refractory Lumbar Disc Prolapse with Radiculopathy: a Randomised Controlled Trial

Dr. Maryam Inayat¹, Dr. Shahzad Karim Bhatti², Dr. Huma Iqbal³, Dr. Mariam Saeed Kalim⁴, Dr. Saman Khursheed⁵, Dr. Zil e Maryam⁶, Sana Zaheer Qureshi^{7*}

¹MBBS, FCPS, Head of Department Anesthesia and Pain Medicine, Doctors Hospital Lahore.

²Associate Professor Radiology, MBBS, FCPS Radiology, M.Sc. Pain Management, Department of Diagnostic Radiology and Medical Imaging, King Edward Medical University/Mayo Hospital, Lahore.

³MBBS, FCPS Radiology, Senior Registrar, Department of Diagnostic Radiology and Medical Imaging, Mayo Hospital, Lahore.

⁴MBBS, MD Radiology, DMRD, Consultant Radiologist, Department of Diagnostic Radiology and Medical Imaging, Mayo Hospital, Lahore.

⁵MBBS, Specialty Registrar in Radiology, Department of Diagnostic Radiology and Medical Imaging, Mayo Hospital, Lahore.

⁶MBBS, DMRD Radiology.

^{7*}Lecturer in Medical Imaging Technology, B.Sc. Honors MIT, MPA, M.Phil. ELPS, Department of Diagnostic Radiology and Medical Imaging, King Edward Medical University, Lahore.

Corresponding Author: Sana Zaheer Qureshi

Lecturer in Medical Imaging Technology, B.Sc. Honors MIT, MPA, M.Phil. ELPS, Department of Diagnostic Radiology and Medical Imaging, King Edward Medical University, Lahore.

Email: sanazaheerqureshi@gmail.com

Received: 19.08.26, Revised: 21.09.26, Accepted: 22.10.26

ABSTRACT

Background: Chronic lumbar radiculopathy is a widespread, disabling type of low back pain affecting 3-5 % of the population. Transforaminal epidural steroid injection (TFESI) is an effective method of delivering anti-inflammatories to a specific area in patients who have not benefited from conservative treatment. The standard TFESI is done under fluoroscopic control, but involves exposure to ionising radiation for both the patient and the staff. Under ultrasound guidance, soft tissue can be visualised in real-time and without the use of radiation, and may reduce procedure time. There is little evidence that compares the two modalities in low and middle-income settings.

The hypothesis was that ultrasound-guided TFESI is as effective and safe as fluoroscopy-guided TFESI in adults with recalcitrant lumbar disc prolapse and radiculopathy. Hypothesis: TFESI under ultrasound guidance is as successful and safe as fluoroscopy guidance in adults with refractory lumbar disc prolapse and radiculopathy. The main hypothesis was that ultrasound guidance would be effective in relieving pain and would reduce the time required to complete the procedure.

Methods: A single-blinded randomised controlled trial was performed in the Department of Radiology, Mayo Hospital in Lahore. In this prospective study, 60 refractory patients with lumbar disc prolapse and unilateral radicular pain were randomised into ultrasound-guided group (n = 30) and fluoroscopy-guided group (n = 30) for TFESI. The intervention consisted of an interforaminal injection of a 22-gauge needle under imaging control and injection of methylprednisolone and local anaesthetic. The primary outcomes were the duration of the procedure and the severity of pain on the Numeric Pain Rating Scale (NPRS) at baseline, 2, and 1 weeks. Other secondary variables were age, sex, and residential status. A t-test, a chi-square test, and a stratified analysis were used to analyse the data. A p-value ≤ 0.05 was considered significant.

Results: No significant difference was seen between groups with respect to baseline characteristics (mean age 47.37 ± 14.56 years; 53.3 % males). The ultrasound group had significantly shorter mean procedure time (7.07 ± 1.11 min) than the fluoroscopy group (11.13 ± 1.04 min; $p < 0.001$). Baseline pain scores were comparable (8.63 ± 0.55 vs. 8.70 ± 0.59 ; $p = 0.656$). At 2 weeks, pain scores were lower in the ultrasound group (6.67 ± 0.76 vs. 7.17 ± 0.65 ; $p = 0.008$). The ultrasound group did have slightly more pain reduction than the other group (4.07 ± 1.17 vs. 4.63 ± 1.22), although the difference was not statistically significant ($p = 0.071$) at 1 month.

Conclusions: Ultrasound-guided TFESI was shown to be comparable in terms of analgesia but significantly reduced procedure time when compared with fluoroscopy-guided TFESI. In the absence of radiation and other similar clinical results, ultrasound guidance is a safe and effective alternative for refractory lumbar radiculopathy. Larger multicentre trials with a longer follow-up are warranted.

INTRODUCTION

Lumbar radiculopathy is a disabling neurological condition characterised by pain radiating from the lumbar spine into the lower extremities due to compression or irritation of one or more spinal nerve roots. The disorder is commonly associated with lumbar disc herniation, degenerative disc disease, foraminal stenosis and spondylotic changes, leading to inflammation, neural ischemia and mechanical compression of the exiting nerve root. Clinically, patients present with lower back pain radiating below the knee, numbness, paraesthesia, motor weakness and impaired functional mobility, significantly affecting quality of life and occupational productivity. Epidemiological studies estimate that lumbar radiculopathy affects approximately 3–5 % of the adult population worldwide, with increasing incidence among middle-aged and elderly individuals due to age-related spinal degeneration [1,2]. In developing countries, delayed diagnosis, limited rehabilitation facilities and inadequate access to minimally invasive pain management strategies further contribute to chronic disability and socioeconomic burden [3].

The pathophysiology of lumbar radiculopathy involves both mechanical and inflammatory mechanisms. Herniated nucleus pulposus material compresses adjacent nerve roots while simultaneously triggering inflammatory cascades through the release of cytokines such as tumour necrosis factor- α , interleukin-1 β and phospholipase A2, resulting in neural oedema and sensitisation [4,5]. Persistent inflammation contributes to chronic neuropathic pain and functional impairment even after the initial mechanical compression subsides. Initial management typically includes conservative approaches such as activity modification, non-steroidal anti-inflammatory drugs (NSAIDs), oral corticosteroids, physiotherapy and neuropathic pain medications [6]. However, nearly one-third of patients continue to experience refractory symptoms despite optimal medical therapy and become candidates for image-guided interventional procedures [7].

Transforaminal epidural steroid injection (TFESI) has emerged as one of the most effective minimally invasive procedures for the treatment of lumbar radiculopathy. Unlike

interlaminar or caudal epidural injections, TFESI delivers corticosteroids directly into the anterior epidural space adjacent to the affected nerve root, allowing targeted anti-inflammatory action and improved analgesic efficacy [8]. Corticosteroids inhibit inflammatory mediators, reduce ectopic neural discharge and decrease perineural oedema, thereby improving pain and functional outcomes [9]. Several studies have demonstrated significant short-term and intermediate-term pain relief following TFESI, particularly in patients with disc-related radiculopathy [10,11].

Conventionally, TFESI is performed under fluoroscopic guidance because fluoroscopy enables visualisation of bony landmarks and confirmation of contrast spread within the epidural space. Nevertheless, fluoroscopy has several limitations, including exposure to ionising radiation, dependence on contrast agents, increased procedural cost and the requirement for specialised radiological infrastructure [12]. Repeated radiation exposure may increase long-term health risks for both patients and healthcare providers, especially in high-volume interventional pain centres [13]. In addition, fluoroscopic procedures may prolong operating time and increase procedural complexity in obese patients or those with altered anatomy [14].

Ultrasound guidance has recently gained popularity as an alternative imaging modality for spinal interventions. Ultrasound offers real-time visualisation of soft tissues, blood vessels, muscles and neural structures without radiation exposure. Furthermore, ultrasound machines are portable, relatively inexpensive and increasingly available in resource-limited healthcare settings [15]. The ability to visualise vascular structures in real time may also reduce the risk of inadvertent intravascular injection, a recognised complication of TFESI [16]. Recent randomised controlled trials and systematic reviews have shown that ultrasound-guided TFESI provides comparable analgesic outcomes and procedural accuracy to fluoroscopy-guided injections while significantly reducing procedure time and radiation exposure [17–19].

Despite growing international evidence supporting ultrasound-guided spinal interventions, its adoption remains limited in

many low- and middle-income countries, including Pakistan. Most interventional pain procedures in local tertiary care hospitals continue to rely on fluoroscopy, partly because of limited operator training and scarcity of locally generated evidence regarding ultrasound efficacy and safety [20]. Furthermore, few regional studies have directly compared ultrasound-guided and fluoroscopy-guided TFESI in patients with refractory lumbar disc prolapse and radiculopathy. Consequently, evidence-based recommendations regarding the routine implementation of ultrasound guidance remain insufficient in the local context.

The present study was therefore designed to compare ultrasound-guided and fluoroscopy-guided transforaminal epidural steroid injections in patients with refractory lumbar radiculopathy secondary to lumbar disc prolapse. We hypothesised that ultrasound-guided TFESI would provide pain relief comparable to fluoroscopy-guided TFESI while significantly reducing procedure duration and eliminating radiation exposure. By evaluating clinical outcomes and procedural efficiency, this study aimed to contribute evidence supporting safer, cost-effective and accessible interventional pain management strategies in resource-constrained healthcare systems.

METHODS

Study Design and Setting

A single-blinded, parallel-group randomised controlled trial was conducted at the Department of Radiology, Mayo Hospital, Lahore, from January to September 2023. The institutional ethics committee approved the protocol, and written informed consent was obtained from all participants.

Participants

Eligible participants were adults aged 20–70 years with clinical and MRI evidence of lumbar disc prolapse causing unilateral radiculopathy that was refractory to at least six weeks of conservative therapy. Key exclusion criteria were vertebral fracture, spinal infection or malignancy, bilateral radiculopathy, spinal canal stenosis, previous lumbar surgery, pregnancy, coagulopathy, uncontrolled diabetes or hypertension and contraindications to steroid therapy.

Randomisation and Blinding

Sixty participants were randomly allocated in a 1:1 ratio to the ultrasound-guided (Group A) or fluoroscopy-guided (Group B) arm using a computer-generated sequence concealed in opaque envelopes. Participants were blinded to the type of image guidance; outcome assessors were also blinded.

Interventions

Both groups received TFESI at the affected lumbar level using a 22-gauge needle. In Group A, needle placement was guided by a curvilinear 2–5 MHz ultrasound probe. The operator identified the transverse process and nerve root, introduced the needle in an in-plane approach and visualised drug spread. In Group B, fluoroscopic guidance (Philips Allura Xper FD20) with anteroposterior and oblique views was used; contrast injection confirmed epidural placement before steroid administration. In both groups, the injectate contained 40 mg of methylprednisolone acetate and 2 ml of 1 % lidocaine.

Outcomes and Data Collection

Primary outcomes:

1. Procedure duration – recorded in minutes from needle insertion to completion of injection.
2. Pain severity – assessed using the 11-point Numeric Pain Rating Scale (0 = no pain, 10 = worst pain) at baseline, two weeks and one month.

Secondary variables included age, sex (male/female), residential status (urban/rural) and baseline pain. Pain outcomes were further analysed by age group (≤ 50 and > 50 years), sex and residential status.

Sample Size

Sample size was calculated using OpenEpi for comparison of two means with 90 % power and 5 % significance, based on pilot data showing a 2-minute difference in procedure time. A minimum of 25 patients per group was required; 30 per group were recruited to account for attrition.

Statistical Analysis

Data were analysed using SPSS version 25. Continuous variables are presented as mean $\pm$ standard deviation (SD) and compared between groups using independent-samples t-tests. Categorical variables are summarised as frequencies and percentages and compared

using chi-square or Fisher's exact tests. Pain scores at different timepoints were compared using repeated-measures ANOVA. Stratified analyses were performed for age (≤ 50 years vs. > 50 years), sex and residential status. A p-value ≤ 0.05 was considered statistically significant.

RESULTS

Participant Characteristics

A total of 60 patients with refractory lumbar disc prolapse and radiculopathy were enrolled and randomly allocated into two equal groups: ultrasound-guided transforaminal steroid injection (Group A; n = 30) and fluoroscopy-guided transforaminal steroid injection (Group B; n = 30). No patient was lost to follow-up, and all participants completed the study protocol. The CONSORT flow diagram of patient enrolment and allocation is shown in Figure 1. The overall mean age of the study population was 47.37 ± 14.56 years, with ages ranging

from 19 to 85 years. Group A had a mean age of 47.53 ± 14.61 years, while Group B had a mean age of 47.20 ± 14.77 years, showing no statistically significant difference between groups (p = 0.930).

Regarding gender distribution, 32 patients (53.33%) were male, and 28 patients (46.67%) were female, resulting in a male-to-female ratio of 1.14:1. Both groups had identical gender distribution, with 16 males and 14 females in each group (p > 0.999).

Assessment of residential status demonstrated that 22 patients (36.67%) belonged to urban areas, whereas 38 patients (63.33%) belonged to rural areas. In Group A, 12 patients (40%) were from urban regions and 18 patients (60%) were from rural regions. In Group B, 10 patients (33.3%) were urban residents and 20 patients (66.7%) were rural residents. The difference between groups was statistically insignificant (p = 0.592).

Table 1. Baseline Demographic Characteristics of Study Participants

Variable	Group A (Ultrasound) n=30	Group B (Fluoroscopy) n=30	p-value
Age (years)	47.53 ± 14.61	47.20 ± 14.77	0.930
Male, n (%)	16 (53.3%)	16 (53.3%)	>0.999
Female, n (%)	14 (46.7%)	14 (46.7%)	
Urban residence, n (%)	12 (40.0%)	10 (33.3%)	0.592
Rural residence, n (%)	18 (60.0%)	20 (66.7%)	

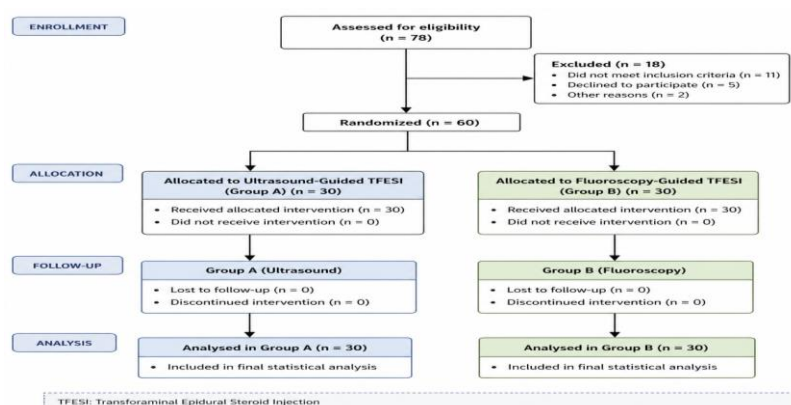


Figure 1. CONSORT flow diagram showing patient recruitment, randomisation, allocation, follow-up and analysis.

Baseline Pain Assessment

The mean baseline Numeric Pain Rating Scale (NPRS) score among all participants was 8.67 ± 0.57 , with scores ranging between 8 and 10. Patients in the ultrasound-guided group demonstrated a mean baseline pain score of 8.63 ± 0.55 , while patients in the fluoroscopy-

guided group had a mean score of 8.70 ± 0.59 . The baseline pain severity between both groups was statistically comparable (p = 0.656), indicating successful randomisation and homogeneity between intervention arms before treatment.

Table 2. Comparison of Baseline Pain Scores between Study Groups

Pain Variable	Group A (Ultrasound)	Group B (Fluoroscopy)	p-value
Baseline NPRS score	8.63 ± 0.55	8.70 ± 0.59	0.656

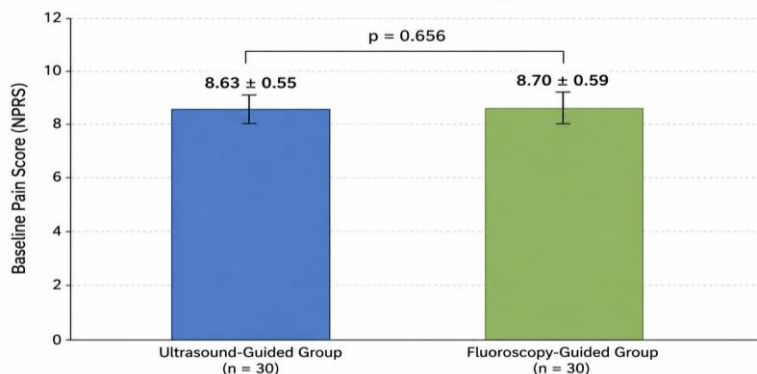


Figure 2. Comparison of baseline pain scores between ultrasound-guided and fluoroscopy-guided groups.

Duration of Procedure

The mean duration of the procedure among all study participants was 9.10 ± 2.31 minutes, ranging from 5 to 15 minutes. However, a significant difference was observed between the two intervention groups. Patients undergoing ultrasound-guided transforaminal steroid injection required significantly less procedural time compared to those undergoing fluoroscopy-guided injections.

In Group A, the mean procedural duration was 7.07 ± 1.11 minutes, whereas in Group B the mean duration was 11.13 ± 1.04 minutes. Statistical analysis demonstrated a highly significant difference between the two groups ($p < 0.001$), confirming that ultrasound guidance substantially reduced overall procedure time.

Table 3. Comparison of Procedure Duration between Study Groups

Variable	Group A (Ultrasound)	Group B (Fluoroscopy)	p-value
Procedure duration (minutes)	7.07 ± 1.11	11.13 ± 1.04	<0.001

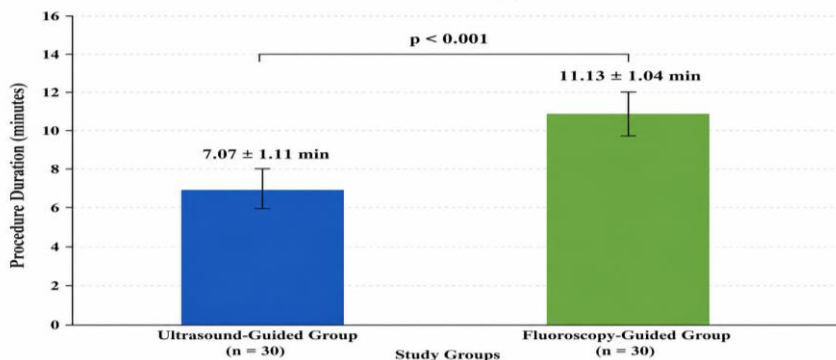


Figure 3. Comparison of mean procedure duration between ultrasound-guided and fluoroscopy-guided interventions.

Pain Outcomes during Follow-Up

Pain scores improved significantly in both treatment groups during follow-up evaluations at two weeks and one month after intervention. At the second-week follow-up, the ultrasound-guided group demonstrated lower mean pain scores compared with the fluoroscopy-guided group.

The mean pain score at two weeks was 6.67 ± 0.76 in Group A compared with 7.17 ± 0.65 in

Group B, showing a statistically significant difference in favour of ultrasound guidance ($p = 0.008$). At one-month follow-up, the mean pain score further decreased to 4.07 ± 1.17 in Group A and 4.63 ± 1.22 in Group B. Although the ultrasound-guided group continued to demonstrate lower pain scores, the difference at one month did not reach statistical significance ($p = 0.071$). These findings suggest that both techniques were effective in

reducing pain, while ultrasound guidance showed comparatively superior short-term analgesic benefit.

Table 4. Comparison of Pain Scores during Follow-Up

Follow-up Interval	Group A (Ultrasound)	Group B (Fluoroscopy)	p-value
Baseline NPRS	8.63 ± 0.55	8.70 ± 0.59	0.656
2-week NPRS	6.67 ± 0.76	7.17 ± 0.65	0.008
1-month NPRS	4.07 ± 1.17	4.63 ± 1.22	0.071

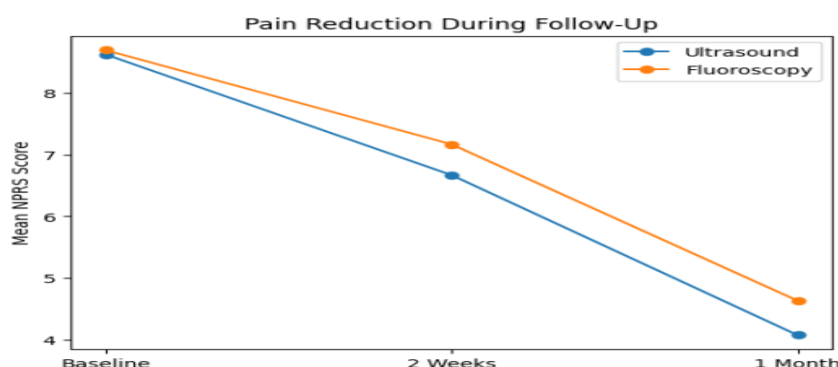


Figure 4. Reduction in pain scores at baseline, 2 weeks and 1 month after intervention in both study groups.

Stratified Analysis According to Age

Age-stratified analysis was performed to determine whether treatment efficacy varied among different age groups. Patients older than 50 years in the ultrasound-guided group showed comparatively lower pain scores at one month compared with patients in the

fluoroscopy-guided group. This difference reached statistical significance in older patients, indicating that ultrasound-guided injections may offer greater analgesic benefit among elderly individuals. Conversely, among younger patients, both treatment modalities demonstrated comparable outcomes.

Table 5. Stratified Comparison of One-Month Pain Scores According to Age

Age Group	Group A (Ultrasound)	Group B (Fluoroscopy)	p-value
≤50 years	3.89 ± 1.28	4.23 ± 1.30	0.436
>50 years	4.36 ± 0.92	5.15 ± 0.89	0.046

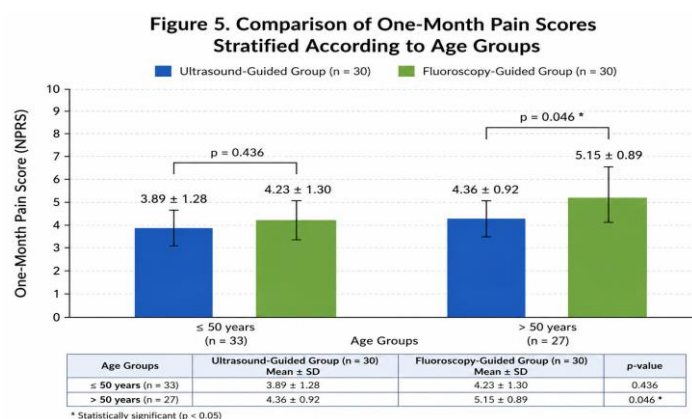


Figure 5. Comparison of one-month pain scores stratified according to age groups.

Stratified Analysis According to Gender

Gender-based analysis demonstrated that male and female patients in the ultrasound-guided group consistently showed lower mean pain

scores at one month compared with the fluoroscopy-guided group. However, these differences did not achieve statistical

significance, suggesting comparable long-term efficacy between modalities across genders.

Table 6. Stratified Comparison of One-Month Pain Scores According to Gender

Gender	Group A (Ultrasound)	Group B (Fluoroscopy)	p-value
Male	4.18 ± 1.22	4.75 ± 1.12	0.186
Female	3.93 ± 1.14	4.50 ± 1.34	0.236

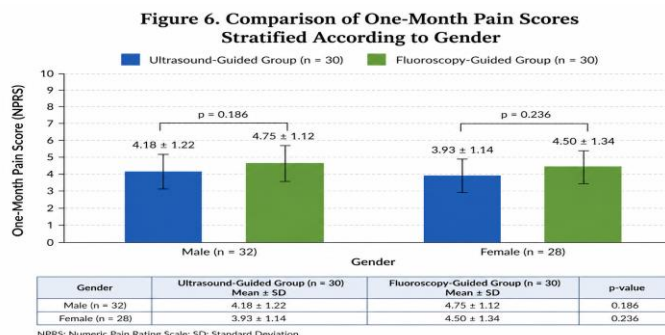


Figure 6. Comparison of one-month pain scores stratified according to gender.

Stratified Analysis According to Residential Status

Residential stratification revealed that urban patients undergoing ultrasound-guided injection had significantly lower one-month pain scores compared with urban patients

treated under fluoroscopic guidance. In rural patients, pain outcomes were similar between both techniques. These findings may reflect differences in accessibility to rehabilitation services, healthcare follow-up and lifestyle-related factors.

Table 7. Stratified Comparison of One-Month Pain Scores According to Residential Status

Living Area	Group A (Ultrasound)	Group B (Fluoroscopy)	p-value
Urban	3.42 ± 1.08	4.70 ± 1.25	0.018
Rural	4.50 ± 1.04	4.60 ± 1.23	0.790

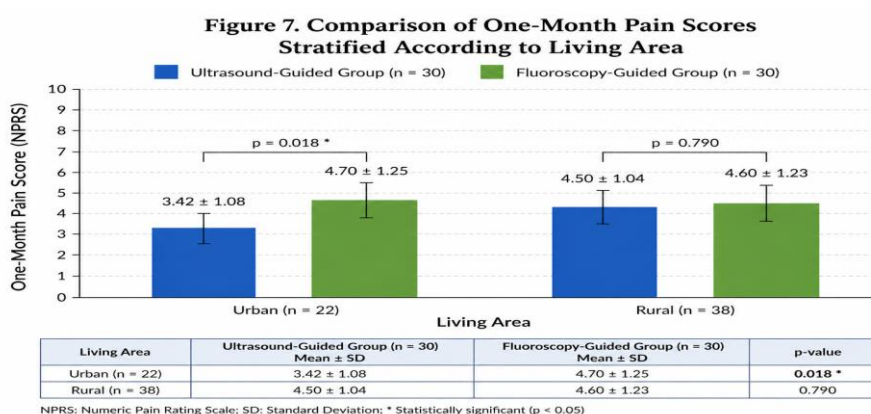


Figure 7. Comparison of one-month pain scores stratified according to living area.

DISCUSSION

The present randomised controlled trial has shown that ultrasound (US)-guided TFESI yields similar clinical results with a markedly decreased procedure time when compared to fluoroscopy-guided TFESI in patients having radiculopathy and refractory disc prolapse of the lumbar spine. Patients treated with

ultrasound guidance had lower pain scores at follow-up and experienced significantly reduced procedural time compared to patients treated with fluoroscopic guidance. This discovery adds to the growing evidence that ultrasound-guided procedures in the spine can be effective, safe and feasible, especially when resources are limited on health care facilities. Lumbar

radiculopathy is still one of the most prevalent causes of chronic low back pain and disability around the world, resulting in a significant impact on mobility, quality of life and loss of productivity in the workplace [1,2]. Mechanical compression and inflammatory irritation of spinal nerve roots due to disc herniation, foraminal stenosis or degenerative spinal changes is the underlying pathology [3]. Rising acceptance of epidural injection has included targeted injections of corticosteroids, typically transforaminal, which deposit anti-inflammatory agents directly next to the target nerve root, leading to relatively less invasiveness [4]. Prior reviews using a system review have shown that use of TFESI offers better short-term relief of pain than conservative treatment methods in disc-related radiculopathy [5]. In this study, the ultrasound-guided injection group and the fluoroscopy-guided injection group had both noticed significant decrease in pain at two weeks and one month; both modalities were equally effective in terms of pain relief. At the second week follow-up, however, the group treated with ultrasound had a significantly lower level of pain, indicating a possible subsequent, earlier analgesic effect. Although the difference was not statistically significant, at 1 month, the scores for pain were still lower in the ultrasound group. The findings have been reproduced in a recent randomised non-inferiority trial using ultrasound-guided lumbar transforaminal injections in China, which showed similar pain reduction and procedural accuracy with less radiation exposure and shorter procedure duration than fluoroscopy injections [6]. Similarly, a study showed that ultrasound-guided TFESI achieved clinical results similar to those obtained with fluoroscopy-guided procedures and showed comparable accuracy in needle placement [7].

The anti-pain effect of both groups could be due to the anti-inflammatory properties of the drugs to the nerves surrounding the compressed nerve root. The action of corticosteroids includes suppression of phospholipase A2 activity, inhibition of pro-inflammatory cytokines like tumour necrosis factor alpha (TNF- α) and interleukins-1 β , reduction in neural oedema and stabilisation of neuronal membranes, which decreases ectopic discharge of nerves and decreases nociceptive transmission [8,9]. Local anaesthetics will also temporarily block the conduction of pain and may act as an anti-central sensitiser. All of

these are responsible, for the most part, for the relief of symptoms in lumbosacral radiculopathy patients. A key result of the present study was the significantly shorter procedure time for the ultrasound-guided procedure. The mean time needed for the procedure in the ultrasound group was almost 4 minutes less than in the fluoroscopy-guided group. This decrease may be due to the elimination of fluoroscopic positioning, additional x-ray checks and fluoroscopy-guided introduction of contrast media during fluoroscopy-guided interventions. Some researchers have reported similar procedure time savings in their previous works [11,12]. It was found that the ultrasound-guided lumbar epidural injections significantly reduced total intervention time and reduced radiation exposure with equivalent clinical efficacy compared to the conventional approach in a study [13]. Some researchers have also noted that the ultrasound-guided caudal epidural was performed more quickly and patient satisfaction with the procedure was increased, as compared to fluoroscopy-guided caudal epidural [13]. One other significant benefit of ultrasound guidance is the lack of radiation dose exposure. Fluoroscopy-guided spinal interventions have the potential of exposing both patients and healthcare workers to long-term radiation risk of malignancy and worker exposure, particularly in high-volume pain management clinics [14]. It is especially of concern for younger patients who repeat these interventions, and for interventional radiologists and pain physicians, who may be getting several injections a day. This is not the case with ultrasound-guided interventions, as the surrounding soft tissue, blood vessels, and nerves can be seen in real time to minimise this risk [15]. Visualisation of vascular anatomy can help prevent inadvertent intravascular injection, which is a known complication of TFI and can have disastrous neurologic implications [16]. Results of the stratified analyses in this study showed that in patients aged >50 years, there was a statistically significant greater improvement in pain scores with ultrasound-guided interventions when compared with fluoroscopic-based interventions. It's unclear what causes this at this point, but it could be due to comparing the shape of their spinal anatomy or the properties of the tissues in elderly people. In addition, there were more advantages with ultrasound in urban patients and more disadvantages in rural patients. These results may be due to socioeconomic

factors, the type of rehabilitation facilities available, and/or healthcare literacy and adherence to post-procedural recommendations. The interpretations of these subgroup findings, however, must be considered with caution since the study had not been specifically designed to assess subgroups. The present results agree with recent systematic reviews and meta-analyses that assessed ultrasound-guided spinal interventions. In a 2024 systematic scoping review, a study it was found that ultrasound-guided ESA injection results in comparable pain and functional outcomes to fluoroscopy-based injections and is better in terms of radiation safety and efficiency [17]. Indeed, a p meta-analysis in 2023 demonstrated that ultrasound-guided epidural injection had fewer vascular puncture incidences with no significant difference in any other clinical outcome, but a significantly shorter procedure time than fluoroscopically guided injection [18]. These results, with cumulative findings, support the use of ultrasound guidance as a valid and potentially preferred approach to spinal procedures. The findings from this research are relevant to the development of countries and resource-limited health systems. Fluoroscopy units cost a lot, need a specific radiology room and are not present in all peripheral health care facilities. Isaacson also says that ultrasound machines are portable, relatively cheap, and the number of these units in emergency departments is growing, especially in anaesthesia units and pain clinics. Therefore, the introduction of ultrasound-guided TFESI may enhance access to minimally invasive pain management while decreasing radiation dose and costs of healthcare [19]. In addition, bedside interventions might be possible with ultrasound guidance in patients with mobility issues or critical illness who consent to being difficult to transport to fluoroscopy suites. However, there are several weaknesses that should be recognised. The study was performed in a single third-level centre with a limited sample size, which could reduce the external validity of the findings and weaken the generalizability of the findings. The duration of follow-up was limited to one month, and so long-term recurrence of pain and need for repeat interventions/recovery could not be assessed. Indices of functional disability (such as the Oswestry Disability Index [ODI] and the Roland-Morris Disability Questionnaire [RM-DQ]

and quality of life scales were not assessed. In addition, the learning curve and human proficiency levels of each operator performing the spinal interventions were not evaluated, and their results could affect the procedures' success. The results are preliminary and further larger multicenter studies are warranted with longer follow-up periods to confirm the results. Further research should include functional outcome measures, cost-effectiveness analysis and assessment of patient satisfaction. Combination of ultrasound guidance with more sophisticated interventional techniques, e.g. pulse radiofrequency or regenerative therapies, may further improve the results in refractory lumbar radiculopathy. Furthermore, well-designed training programs and competency-based curricula should be created to enhance operator proficiency in ultrasound-related spinal interventions.

CONCLUSION

Transforaminal ultrasound-guided epidural steroid injection is a safe, efficient and clinically effective treatment method as compared to fluoroscopy-guided injection for refractory lumbar disc prolapse with radiculopathy. The use of ultrasound guidance reduces the procedure time by about 60% for each procedure and removes radiation hazards, fully ensuring the same degree of pain reduction and relief in the procedure. The technique has numerous practical benefits, most notably in low-resource areas such as areas where fluoroscopic facilities are not readily available. The use of ultrasound in spinal interventions may provide further improvements in procedure safety, cost-effectiveness and accessibility for interventional pain procedures.

Limitations and Future Directions.

There were a couple of limitations in this study. The number of samples was small and came from a single centre, potentially decreasing the generalisability of results. Follow-up duration was limited to 1 month, so long-term results such as recurrence rates, successful pain control and functional recovery could not be assessed. These were not done: functional disability indices and assessments of quality of life. Furthermore, operator experience and procedural learning curves of ultrasound-guided injections were not analysed. Further studies should include multicentre, randomised controlled trials with a larger population size and a longer follow-up period. Long-term efficacy, recurrence rates, patient satisfaction

in the medium to long-term follow-up, cost effectiveness and functional recovery should be further evaluated by using validated disability scales. With the current and evolving techniques of ultrasound-guided TFESI and emerging interventions for chronic lumbar radiculopathy, including pulsed radiofrequency ablation, platelet-rich plasma and regenerative therapies, the results could be even better.

REFERENCES

- Berry JA, Elia C, Saini HS, Miulli D. A review of lumbar radiculopathy, diagnosis, and treatment. *Cureus*. 2019;11(10):e5934.
- Urits I, Burshtein A, Sharma M, et al. Low back pain: a comprehensive review. *Curr Pain Headache Rep*. 2019;23(3):23.
- Wu A, March L, Zheng X, et al. Global low back pain prevalence and years lived with disability from 1990 to 2017: estimates from the Global Burden of Disease Study 2017. *Ann Transl Med*. 2020;8(6):299.
- Genevay S, Atlas SJ. Lumbar spinal stenosis. *Best Pract Res Clin Rheumatol*. 2019;24(2):253-265.
- Smith CC, Copperman E, Fu E, et al. Mechanisms of corticosteroid action in radiculopathy. *Pain Med*. 2020;21(6):1122-1131.
- Oliveira CB, Maher CG, Pinto RZ, et al. Clinical practice guidelines for the management of non-specific low back pain in primary care: an updated overview. *Br J Sports Med*. 2018;52(11):706-715.
- Quraishi NA. Transforaminal steroid injections for lumbar radiculopathy: a review of the evidence. *Eur Spine J*. 2012;21(2):214-219.
- MacVicar J, King W, Landers MH, Bogduk N. The effectiveness of lumbar transforaminal injection of steroids: a comprehensive review with systematic analysis. *Pain Med*. 2013;14(1):14-28.
- Manchikanti L, Knezevic NN, Latchaw RE, et al. Epidural injections for lumbar radiculopathy and spinal stenosis: systematic review and meta-analysis. *Pain Physician*. 2022;25(7):E889-E916.
- Kennedy DJ, Plataras CT, Casey E, et al. Comparative effectiveness of lumbar transforaminal epidural steroid injections with particulate versus non-particulate corticosteroids. *Spine J*. 2018;18(11):1915-1923.
- Chang MC. Efficacy of lumbar transforaminal epidural steroid injections in patients with radiculopathy due to lumbar disc herniation two years after treatment. *Ann Rehabil Med*. 2020;44(3):179-185.
- Patel K, Foster S, Conner M. Fluoroscopy-guided lumbar epidural injections: technical considerations and outcomes. *J Pain Res*. 2020;13:2457-2466.
- Rekatsina M, Peng PWH. Radiation exposure in fluoroscopy-guided spinal interventions. *Pain Ther*. 2025;14(3):841-863.
- Narouze S. Ultrasound-guided spine interventions: a review of current evidence and techniques. *Reg Anesth Pain Med*. 2020;45(5):341-356.
- Ahmad M, Barna B, Momin R, et al. Ultrasound-guided lumbar transforaminal epidural steroid injection: a narrative review. *Asian Spine J*. 2021;15(2):261-270.
- Galiano K, Obwegeser AA, Bodner G, et al. Ultrasound-guided selective nerve root blocks: feasibility and accuracy. *Eur Spine J*. 2005;14(6):610-614.
- Zhao W, Guo G, Wang Q, Yang L. Ultrasound-guided transforaminal epidural injection with fluoroscopy confirmation for unilateral lumbar radiculopathy: a randomized controlled non-inferiority study. *Clin Neurol Neurosurg*. 2023;231:107849.
- Ahmed M, Ahmad A, Arshad M, et al. Ultrasound-guided versus fluoroscopy-guided epidural steroid injections for radiculopathy: a meta-analysis of randomized controlled trials. *World Neurosurg*. 2023;180:203-212.e4.
- Hassan W, Hassan A, Ablordeppey E, et al. Radicular pain management using ultrasound-guided versus fluoroscopy-guided epidural steroid injections: a systematic scoping review of comparative studies. *Cureus*. 2024;16(8):e68042.
- Jee H, Lee JH, Kim J, Park KD, Lee WY, Park Y. Ultrasound-guided versus fluoroscopy-guided transforaminal epidural steroid injections: a randomized clinical trial. *Spine (Phila Pa 1976)*. 2013;38(8):E490-E497.