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COMPARATIVE EFFICACY OF ULTRASOUND (US) VERSUS (FL) FLUOROSCOPY-GUIDED CAUDAL EPIDURAL STEROID INJECTION (CESI) FOR THE MANAGEMENT OF CHRONIC LOWER RADICULAR BACK PAIN (LBP); A TRANSITION FROM CHRISTMAS TREE TO FROG'S EYES

Original Research

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ABSTRACT

Background: Chronic lower back pain (LBP) with associated radiculopathy presents a significant healthcare burden, often resulting in physical disability and reduced quality of life. Caudal epidural steroid injection (CESI) is a commonly employed interventional approach for symptom relief in these patients. While fluoroscopic (FL) guidance has been the gold standard for CESI, ultrasound (US) guidance is gaining traction as a radiation-free, cost-effective alternative. This study compared both techniques to assess their procedural efficiency and clinical outcomes.

Objective: To evaluate and compare the efficacy, procedural time, and clinical outcomes of ultrasound-guided versus fluoroscopy-guided CESI in patients with chronic LBP and bilateral radiculopathy.

Methods: A randomized trial was conducted involving 110 patients aged 30–60 years with chronic LBP and radicular symptoms unresponsive to conservative treatment. Patients were randomly assigned to two equal groups: Group US (n = 55) received CESI under ultrasound guidance, and Group FL (n = 55) under fluoroscopic guidance. All patients were administered 40 mg of depot methylprednisolone diluted in 3 ml bupivacaine and 10 ml normal saline. Pain intensity and functional disability were assessed using the Visual Analogue Scale (VAS) and Oswestry Disability Index (ODI) at baseline, 2 weeks, 1 month, and 2 months post-procedure. Procedural time and adverse events were recorded.

Results: Needle placement was significantly faster in the ultrasound group (119 ± 7.66 seconds) compared to the fluoroscopy group (222.28 ± 29.65 seconds; $p < 0.001$). Both groups demonstrated significant intragroup improvements in VAS and ODI scores over the follow-up period with no significant differences between them at any timepoint ($p > 0.05$). No major adverse events were reported.

Conclusion: Ultrasound guidance offers a faster and radiation-free alternative to fluoroscopy for CESI without compromising clinical outcomes. Both modalities are effective in managing chronic LBP, but ultrasound significantly reduces procedural time, supporting its broader application in pain clinics.

Keywords: Caudal Epidural Steroid Injection, Chronic Low Back Pain, Fluoroscopy, Needle Placement, Pain Management, Radiculopathy, Ultrasound.

INTRODUCTION

Lower back pain (LBP) is a pervasive musculoskeletal condition that often progresses to a chronic stage when symptoms persist beyond three months, accompanied by anatomical and pathological changes within the lumbar spine. Among the most frequently implicated etiologies are degenerative disc disease, herniated discs, spinal stenosis, and lumbar compression fractures. Degenerative disc disease, in particular, has emerged as a leading contributor to chronic LBP based on epidemiological findings (1). In the Pakistani population, the prevalence of LBP has been reported to range from 8% to 80%, with incidence increasing notably between the ages of 30 to 55 years, aligning with global data indicating a strong association between aging and spinal degeneration (2). Recognizing its growing burden, the World Health Organization declared the first decade of the 21st century as the "Decade of Campaign Against Musculoskeletal Disorders," acknowledging LBP as a silent epidemic (3,4). Management of chronic LBP traditionally begins with conservative treatments, including pharmacological agents, physiotherapeutic interventions, manual therapies, lifestyle modifications, and patient education through programs such as back school. When conservative modalities fail to provide adequate relief, interventional approaches are considered. Since its introduction, the lumbar epidural steroid injection has gained widespread acceptance as a therapeutic intervention for radicular and non-radicular back pain (5). Fluoroscopy-guided caudal epidural injections, in particular, became standard practice due to their proven efficacy in clinical trials (5,6).

However, despite their clinical utility, fluoroscopy-based procedures carry inherent risks, including cumulative radiation exposure and adverse reactions to iodinated contrast media. These adverse effects range from mild symptoms such as nausea and urticaria to life-threatening complications like bronchospasm, hypotension, tachycardia, and anaphylaxis (7,8). Recent advancements in musculoskeletal ultrasound (USG) have offered a promising alternative, enabling real-time visualization of anatomical structures without radiation or the need for contrast agents. This technological shift has significant implications for improving procedural safety and accessibility, particularly in resource-limited settings. Despite the theoretical advantages of ultrasound-guided caudal epidural injections, there remains a paucity of literature exploring their efficacy, safety profile, and long-term outcomes. Previous studies have touched on the feasibility of this technique, but comprehensive clinical investigations are limited (9-11). Therefore, this study aims to evaluate the efficacy and safety of caudal epidural steroid injections administered under ultrasound guidance in the management of chronic lower back pain, providing evidence to support its wider clinical adoption.

METHODS

This prospective, randomized comparative study was conducted at Ghurki Trust Teaching Hospital following approval from the Institutional Ethics Committee (IREC-2025-IRB). The study enrolled 110 patients aged between 30 and 60 years who presented with non-resolving chronic lower back pain (LBP) persisting for more than three months and associated with unilateral or bilateral radiculopathy. All participants underwent baseline investigations including hemoglobin levels, fasting blood sugar, serum urea, creatinine, and lumbosacral magnetic resonance imaging (MRI) to confirm lumbar spine segment involvement with disc bulge and protrusion, as well as evidence of nerve root compression. Patients with rapidly progressing neurological deficits, cauda equina syndrome, motor weakness, previous spinal surgeries, prior steroid injections, active site infections, known hypersensitivity to steroids or iodinated contrast agents, or significant medical comorbidities such as uncontrolled hypertension, diabetes mellitus, or ischemic heart disease were excluded. Informed written consent was obtained from each participant prior to inclusion in the study. Enrolled patients were randomly assigned using block randomization into two equal groups: Group US (n=55), which received ultrasound-guided caudal epidural steroid injections (CESI), and Group FL (n=55), which received fluoroscopy-guided CESI. Randomization ensured balanced allocation and minimized selection bias. All patients were maintained on a standardized analgesic regimen throughout the study, including tablet pregabalin, tablet amitriptyline, and a combination of tablet paracetamol and tramadol.

Prior to intervention, baseline assessments were conducted, including measurement of pain intensity using the Visual Analog Scale (VAS) and functional disability using the Oswestry Disability Index (ODI). All patients were instructed to fast before the procedure. In the operating room, intravenous access was established, vital sign monitors were applied, and emergency equipment was made available. Patients were placed in the prone position with a pelvic cushion for support. In Group US, the procedure began with skin preparation

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and sterile draping. A linear array ultrasound transducer, covered in sterile sheath and gel, was used to visualize the sacral cornua, sacral hiatus, and the sacrococcygeal ligament. A local anesthetic—2 ml of preservative-free lignocaine (1%) diluted to 1% using normal saline—was administered subcutaneously. A needle was introduced under real-time ultrasound guidance through the sacrococcygeal ligament into the sacral epidural space. Proper needle placement was confirmed by injecting 2 ml of normal saline and observing hyperechoic turbulence, indicating epidural space entry. In Group FL, the sacral region was sterilized and draped. An 18-gauge Tuohy needle was inserted at a 45° angle into the sacral hiatus. Resistance indicated presumed entry into the epidural space. Fluoroscopic confirmation using anteroposterior and lateral imaging was performed, and 3 ml of nonionic iodinated contrast was injected to confirm appropriate needle positioning. A characteristic 'Christmas Tree' appearance on fluoroscopy or visualization of a ventral contrast spread reaching the S3 level confirmed correct placement.

In both groups, a therapeutic injection of 40 mg depot methylprednisolone acetate mixed with 3 ml of bupivacaine and 10 ml of normal saline was administered following confirmation of proper needle placement. The needle was then removed, and a sterile dressing was applied. The primary outcomes assessed were the time taken to achieve successful needle placement and the improvement in pain and function as reflected by changes in VAS and ODI scores. Follow-up evaluations were conducted at two weeks, one month, and two months post-procedure. The ODI was scored using a validated 10-item questionnaire, with each item scored on a six-point Likert scale from 0 to 5. The total score was summed, divided by 50, and multiplied by 100 to yield the percentage of disability. For example, a total score of 18 would yield an ODI of 36%. The sample size was calculated to detect a 100% effect size for the difference in needle placement efficiency between the two modalities, using an alpha level of 0.05 and a study power of 80%, resulting in 55 patients per group. Data were analyzed using IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY). Continuous variables were expressed as mean ± standard deviation. Independent sample t-tests and paired t-tests were used for intragroup and intergroup comparisons, while categorical data were analyzed using the Chi-square test. A p-value of <0.05 was considered statistically significant.

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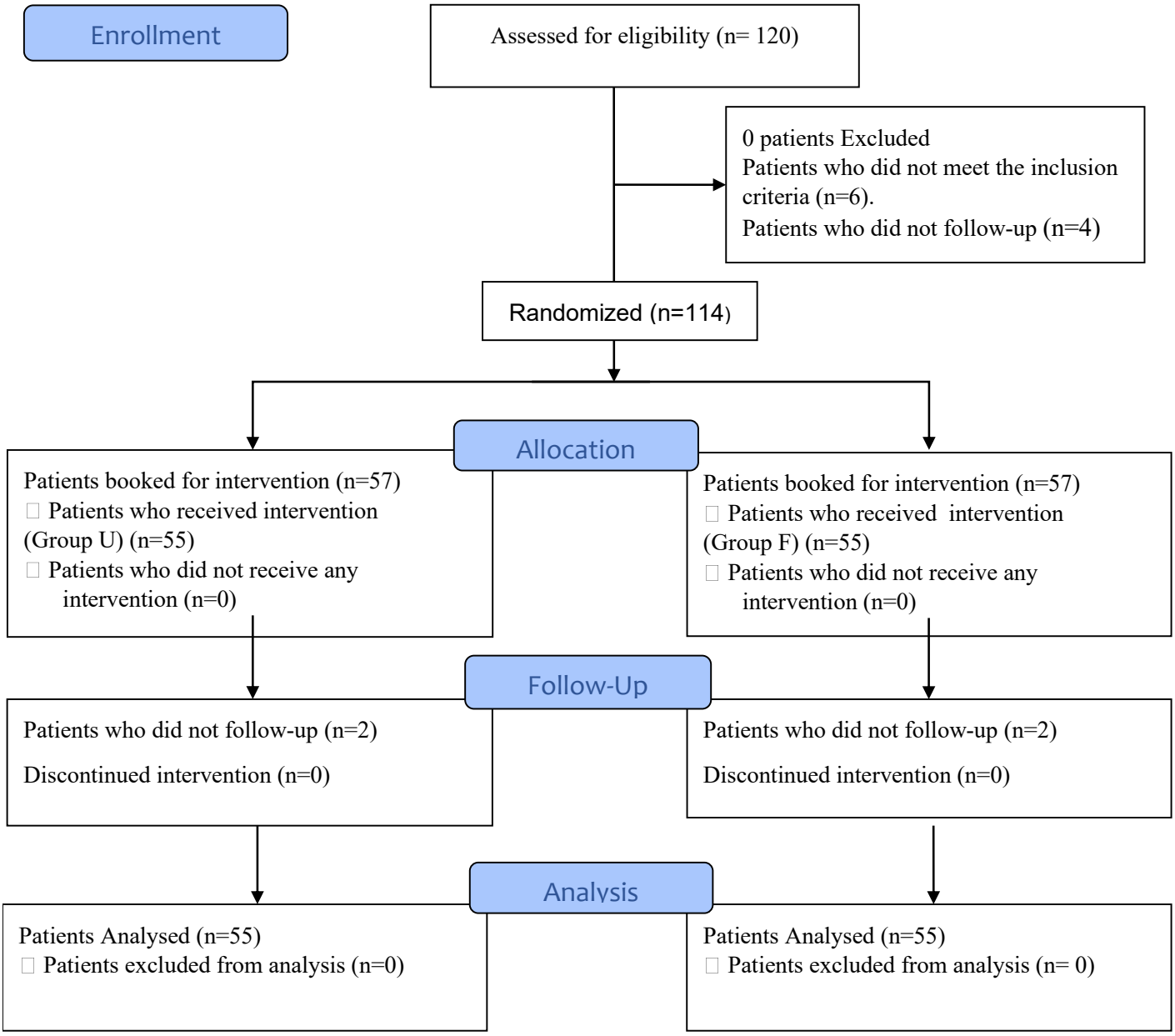
CONSORT Flow Diagram



RESULTS

The study was conducted from January 2025 to the end of March 2025 and enrolled 110 participants, evenly randomized into two groups. Baseline characteristics including age, height, weight, duration of pain, VAS scores, ODI scores, and sex distribution showed no statistically significant differences between the groups, confirming comparability at the outset. The mean age was 45.41 ± 6.40 years in the ultrasound-guided group and 44.88 ± 6.05 years in the fluoroscopy-guided group (p = 0.211). The average baseline VAS scores were

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7.91 ± 0.71 and 8.15 ± 0.73 for Group US and Group FL respectively (p = 0.596), while baseline ODI scores were 64.01 ± 7.01 and 63.50 ± 6.73 respectively (p = 0.490). Significant differences were observed in the time required for needle placement between the two groups. Group US achieved correct needle placement in 119 ± 7.66 seconds, whereas Group FL required 222.28 ± 29.65 seconds, a statistically significant difference (p = 0.0001). Additionally, eight patients in the fluoroscopy group displayed a radiographic filling defect during epidurography. No procedural complications or adverse events occurred in either group throughout the study period.

Both groups demonstrated statistically significant improvements in pain intensity and functional disability over time. At the second week, mean VAS scores had decreased to 6.96 ± 0.00 in the ultrasound group and 6.90 ± 0.001 in the fluoroscopy group (p < 0.001 intragroup; p = 0.881 intergroup). By the first month, VAS scores further declined to 4.01 ± 0.75 and 3.84 ± 0.91 respectively (p < 0.001 intragroup; p = 0.701 intergroup), and at the second month reached 2.97 ± 0.83 and 2.87 ± 0.69 respectively (p < 0.001 intragroup; p = 0.396 intergroup), with no significant differences between the two groups at any post-intervention timepoint. ODI scores followed a similar pattern. At the second week, scores improved to 61.94 ± 7.09 in Group US and 60.15 ± 3.86 in Group FL (p < 0.001 intragroup; p = 0.365 intergroup). At the first month, scores dropped to 35.01 ± 5.03 and 32.91 ± 4.05 respectively (p < 0.001 intragroup; p = 0.278 intergroup), and by the second month, further decreased to 31.84 ± 3.96 in Group US and 30.06 ± 3.99 in Group FL (p < 0.001 intragroup; p = 0.263 intergroup). Across all timepoints, the intergroup differences in ODI were not statistically significant, indicating comparable functional outcomes.

The study observed four participant dropouts over the course of follow-up. No post-procedural complications were recorded, and all patients completed a two-month follow-up without serious adverse effects. Although both groups demonstrated statistically significant improvements in pain and functional outcomes over the two-month follow-up period, a closer examination of procedural nuances and side effect profiles revealed notable distinctions. No contrast-related side effects were reported in either group; however, eight patients (14.5%) in the fluoroscopy-guided group exhibited procedure-specific complications in the form of contrast "filling defects" on epidurogram imaging, whereas the ultrasound-guided group reported none. Despite this, the fluoroscopy group showed a slightly higher mean reduction in VAS score (5.28 points) and ODI score (33.44 points) compared to the ultrasound group, which achieved a VAS reduction of 4.94 points and an ODI reduction of 32.17 points. These differences, though modest, did not reach statistical significance and were observed despite the considerably longer mean procedural time in the fluoroscopy group (222.28 seconds versus 119 seconds in the ultrasound group).

Table 1: Demographic data

Group Parameters	(n=55) Group US	(n=55) FL	P value
Age (years)	45.41±6.40 (1.287)	44.88±6.05 (1.390)	0.211
Height (cm)	161.01±6.12 (1.7801)	160.76±5.89 (1.259)	0.239
Weight (kg)	63.71±9.01 (1.697)	61.801±7.93 (1.575)	0.069
Duration of pain(months)	12.40±6.01 (1.210)	14.12±7.12 (1.359)	0.721
VAS score	7.91±0.71 (0.121)	8.15±0.73 (0.123)	0.596
ODI	64.01±7.01 (1.312)	63.50±6.73 (1.358)	0.490
Sex (female: male)	*14:91	17:1	0.801

Table 2: Comparison between baseline and post-procedural VAS & ODI

Parameters	Group US (n=55)	Group FL (n=55)	Intragroup significance (Group US) (two-tailed)	Intragroup significance (Group FL) (two-tailed)	Intragroup significance (two-tailed)
Baseline VAS	7.91±0.71	8.15±0.73			0.597
2nd week VAS	6.96±0.00	6.90±0.001	0.00*	0.00*	0.881
1st month VAS	4.01±0.75	3.84±91	0.00*	0.00*	0.701
2nd month VAS	2.97±0.83	2.87±0.69	0.00*	0.00*	0.396
Baseline ODI	64.01±7.01	63.50±6.73			0.601
2nd week ODI	61.94±7.09	60.15±3.86	0.00*	0.00*	0.365
1st month ODI	35.01±5.03	32.91±4.05	0.00*	0.00*	0.278
2nd month ODI	31.84±3.96	30.06±3.99	0.00*	0.00*	0.263

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Table 3: Contrast-related and procedure-specific side effects, along with treatment outcome correlations

Group	Contrast-related Side Effects (n)	Procedure-specific Side Effects (n)	VAS Reduction at 2 Months	ODI Reduction at 2 Months	Mean Time for Needle Placement (s)
Ultrasound (US)	0	0	4.94	32.17	119
Fluoroscopy (FL)	0	8	5.28	33.44	222.28

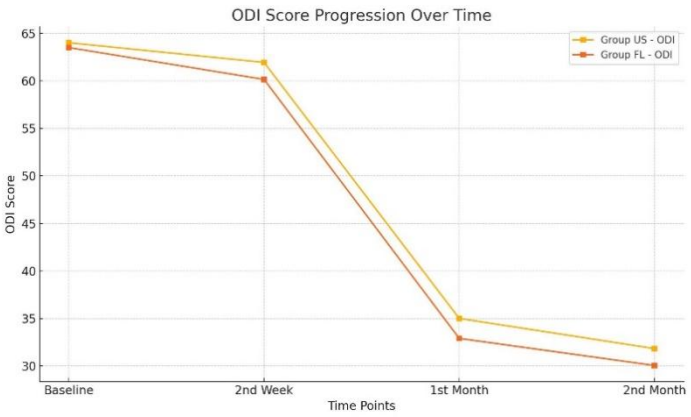

Figure 1 ODI Score Progression Over Time

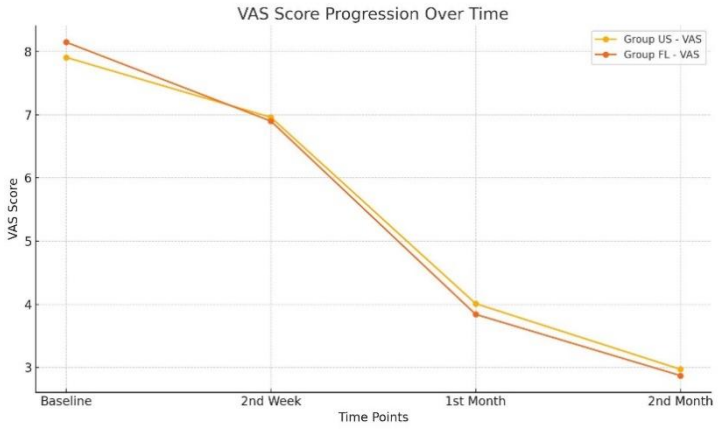

Figure 2 VAS Score Progression Over Time

DISCUSSION

The findings of this study demonstrated that caudal epidural needle placement was significantly faster under ultrasound guidance compared to fluoroscopy, highlighting a notable procedural advantage in terms of time efficiency. Ultrasound-guided interventions allowed real-time visualization of soft tissues and facilitated membrane puncture at the sacrococcygeal junction, yet failed to clearly delineate the epidural space or confirm the precise needle tip location at the S3 vertebral level. In contrast, fluoroscopy enabled visualization of the classical epidurographic spread pattern, offering enhanced anatomical confirmation of the drug delivery route. Although this visual clarity allowed fluoroscopic guidance to detect filling defects in eight patients, necessitating hyaluronidase-mediated adhesiolysis after four weeks, both groups ultimately achieved comparable clinical outcomes, as reflected in the reduction of VAS scores and ODI values over the two-month follow-up (12,13). Despite the superior anatomical confirmation in fluoroscopic guidance, the absence of adverse effects in both groups reinforces the procedural safety of both techniques. The clinical efficacy of epidural steroid injections was consistent across both modalities, further aligning with prior literature that supports their use in patients with lumbar disc pathology and radicular symptoms (14,15). Additionally, the use of 15 mL injectate volume contributed to sufficient medication dispersion within the epidural space, enhancing pain relief. The combined steroid and saline administration is known to produce both anti-inflammatory and mechanical decompression effects, contributing to the therapeutic outcomes reported in this study (16,17). Notably, individual variations in response to methylprednisolone could affect long-term efficacy, a factor that was not explored in depth due to the short follow-up duration.

The Oswestry Disability Index served as a robust functional outcome measure, reaffirming its status as the gold standard for quantifying disability due to lower back pain (18). Patients in both groups showed a shift from severe to moderate disability by the end of the study period, suggesting a clinically meaningful improvement. Although no complications such as dural puncture, hematoma, or nerve injury were observed—adverse events well-documented in previous literature (19)—the small sample size limits the generalizability of the safety profile. A larger cohort could provide a more comprehensive risk assessment. One of the strengths of this investigation was its randomized design and use of validated clinical outcome tools, which ensured objective and reliable evaluation of treatment efficacy. The standardized injectate composition and procedure protocol further enhanced the study's internal consistency. However, limitations were evident, including a relatively short two-month follow-up period, which may not fully capture the durability of treatment effects.

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Additionally, the absence of epidurographic imaging in the ultrasound group precluded identification of adhesions or anatomical anomalies at the time of injection. The exclusion of patients with rapidly progressive neurological deficits or complex comorbidities narrowed the applicability of findings to a broader patient population. Moreover, the study did not quantify the clinical impact of the filling defects identified in the fluoroscopy group, nor did it explore the necessity of adhesiolysis in the ultrasound group due to lack of contrast-based imaging.

Future studies should consider longer follow-up intervals, ideally extending to six months or more, to evaluate the sustained effectiveness and delayed complications of caudal epidural injections. A comparative cost-effectiveness analysis between ultrasound and fluoroscopy could also inform clinical decision-making, particularly in settings with limited access to imaging infrastructure (20). Incorporating larger, more diverse populations and stratifying outcomes based on anatomical findings such as epidurographic defects may provide deeper insight into patient selection and individualized treatment planning. While both techniques yielded favorable results, ultrasound guidance emerges as a practical, radiation-free, and efficient option, especially in environments where fluoroscopic capabilities are unavailable or contraindicated.

CONCLUSION

This study concluded that ultrasound guidance offers a safe and efficient alternative to fluoroscopy for caudal epidural needle placement, allowing for quicker access without compromising clinical outcomes. While both techniques demonstrated comparable effectiveness in pain relief and functional improvement, fluoroscopy retains its value due to superior anatomical visualization and the ability to detect epidurographic abnormalities. These findings support the broader use of ultrasound as a practical, radiation-free approach in clinical settings, particularly where imaging resources are limited or rapid procedural execution is prioritized.

AUTHOR CONTRIBUTION

Author	Contribution
Shahid Rasool Dar*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Leena Aziz	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Waqas Ashraf Chaudhary	Critical Review and Manuscript Writing
Waseem Younis	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Adeel Shahid	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Abubakar Tariq	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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