

Original Research Article

INTERVENTIONAL PAIN MANAGEMENT FOR LUMBAR DISC HERNIATION: A SYSTEMATIC REVIEW OF ANESTHETIC AND CORTICOSTEROID INJECTIONS

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ABSTRACT

Background: Lumbar disc herniation (LDH) is a common cause of low back pain and lumbar radiculopathy, resulting in significant disability and reduced quality of life. Although conservative management remains the first-line treatment, many patients experience persistent symptoms requiring interventional pain management. Various minimally invasive procedures, including epidural steroid injections, selective nerve root blocks, pulsed radiofrequency, and image-guided interventions, have been increasingly utilized; however, their comparative effectiveness remains under investigation. The objective is to systematically evaluate the efficacy, safety, and clinical outcomes of interventional pain management techniques for lumbar disc herniation, with particular emphasis on anesthetic and corticosteroid injections.

Materials and Methods: A systematic review was conducted according to PRISMA 2020 guidelines. Electronic databases including PubMed, MEDLINE, Embase, Scopus, Cochrane Library, and Google Scholar were searched for studies published between January 2010 and March 2026. Eligible studies included randomized controlled trials, cohort studies, systematic reviews, and meta-analyses evaluating transforaminal epidural steroid injections (TFESI), interlaminar epidural steroid injections (ILESI), caudal epidural steroid injections (CESI), selective nerve root blocks (SNRB), pulsed radiofrequency (PRF), and image-guided interventions in adults with lumbar disc herniation. Fourteen studies met the inclusion criteria and were included in the qualitative synthesis.

Results: TFESI demonstrated the strongest evidence for short- and medium-term pain relief and functional improvement in lumbar radiculopathy. ILESI and CESI were also effective, although generally less favorable than TFESI. Pulsed radiofrequency of the dorsal root ganglion showed significant and sustained reductions in pain and disability scores, particularly when combined with epidural steroid injections. Fluoroscopy-guided interventions remained the gold standard for procedural accuracy, while ultrasound-guided techniques offered comparable efficacy without radiation exposure. CT-guided procedures provided excellent anatomical precision in complex cases. Overall, interventional techniques were associated with meaningful improvements in pain, function, and quality of life with acceptable safety profiles.

Conclusion: Interventional pain management techniques are effective minimally invasive treatment options for lumbar disc herniation. TFESI currently demonstrates the most robust evidence among epidural approaches, while PRF appears promising for longer-term symptom control. Further high-

quality randomized controlled trials with extended follow-up are needed to establish optimal treatment algorithms and long-term outcomes.

Keywords: Lumbar disc herniation, lumbar radiculopathy, epidural steroid injection, transforaminal epidural steroid injection, pulsed radiofrequency, selective nerve root block, interventional pain management, fluoroscopy-guided injection.

INTRODUCTION

Lumbar disc herniation (LDH) is one of the most prevalent causes of low back pain and lumbosacral radiculopathy worldwide, affecting approximately 1–3% of the adult population annually. It results from displacement of disc material beyond the normal confines of the intervertebral disc, leading to mechanical compression and inflammatory irritation of adjacent nerve roots.^[1] Patients commonly present with low back pain, radiating leg pain, numbness, sensory disturbances, and motor deficits that significantly impair daily activities and quality of life. LDH represents a substantial socioeconomic burden due to healthcare costs, work absenteeism, and disability.^[2]

Conservative treatment, including nonsteroidal anti-inflammatory drugs, physiotherapy, exercise therapy, and activity modification, remains the first-line management for most patients.^[2] However, a considerable proportion of patients continue to experience persistent pain despite adequate conservative care. Although surgical discectomy is effective for selected cases, it is associated with operative risks, hospitalization, and postoperative complications. Consequently, minimally invasive interventional pain management techniques have emerged as valuable therapeutic options for patients with symptomatic lumbar disc herniation.^[3,4]

Among the available interventions, epidural steroid injections remain the most frequently utilized procedures.^[5] These include Transforaminal Epidural Steroid Injection (TFESI), Interlaminar Epidural Steroid Injection (ILESI), and Caudal Epidural Steroid Injection (CESI). These procedures aim to deliver corticosteroids and local anesthetics directly to the site of inflammation, thereby reducing nerve root edema, suppressing inflammatory mediators, and providing pain relief. Recent studies have demonstrated that TFESI may provide superior short-term relief of radicular pain compared with other epidural approaches because of its targeted delivery to the affected nerve root.^[6,7]

In addition to epidural steroid injections, Selective Nerve Root Block (SNRB) has gained popularity both as a diagnostic and therapeutic procedure. By targeting specific nerve roots responsible for symptoms, SNRB can provide temporary pain relief while helping clinicians accurately identify the pain-generating level. Pulsed Radiofrequency (PRF) treatment of the dorsal root ganglion represents another emerging modality that delivers short bursts of radiofrequency energy without causing significant neural destruction. PRF has shown

promising results in reducing chronic radicular pain while minimizing tissue damage and procedural complications.^[8]

The success and safety of these interventions largely depend upon accurate needle placement. Consequently, image-guided techniques such as fluoroscopy-guided injections, ultrasound-guided injections, and CT-guided nerve root blocks have become integral components of modern interventional pain practice. Fluoroscopy remains the most widely used imaging modality because of its ability to provide real-time visualization of contrast spread and needle position.^[9] Ultrasound guidance offers the advantages of radiation-free imaging and portability, whereas CT guidance provides excellent anatomical detail, particularly in complex spinal anatomy.^[10,11]

Recent advances in image-guided interventions and minimally invasive pain procedures have expanded the therapeutic options available for lumbar disc herniation. Nevertheless, considerable variation exists regarding procedural techniques, efficacy, duration of pain relief, safety profiles, and long-term outcomes. Furthermore, the comparative effectiveness of TFESI, ILESI, CESI, SNRB, PRF, and various image-guided approaches remains an area of ongoing investigation.^[12]

Therefore, this systematic review aims to critically evaluate the current evidence regarding interventional pain management techniques for lumbar disc herniation, with particular emphasis on Transforaminal Epidural Steroid Injection, Interlaminar Epidural Steroid Injection, Caudal Epidural Steroid Injection, Selective Nerve Root Block, Pulsed Radiofrequency of the Dorsal Root Ganglion, and image-guided interventions including fluoroscopy-guided, ultrasound-guided, and CT-guided procedures. The review seeks to assess their efficacy, safety, functional outcomes, and role in reducing pain and improving quality of life among patients with lumbar disc herniation.

MATERIALS AND METHODS

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines.^[13]

Search Strategy: A comprehensive literature search was performed in PubMed, MEDLINE, Embase, Scopus, Cochrane Library, and Google Scholar databases for studies published from January 2010 to March 2026. Search terms included combinations of:

"lumbar disc herniation", "lumbar radiculopathy", "epidural steroid injection", "transforaminal epidural steroid injection", "interlaminar epidural steroid injection", "caudal epidural steroid injection", "selective nerve root block", "pulsed radiofrequency", "dorsal root ganglion", "fluoroscopy-guided injection", "ultrasound-guided injection", "CT-guided intervention", and "interventional pain management". Boolean operators (AND, OR) were used to optimize the search strategy. Reference lists of relevant reviews and included articles were manually searched to identify additional eligible studies.

Eligibility Criteria

Inclusion Criteria

- Randomized controlled trials, prospective studies, retrospective studies, cohort studies, systematic reviews, and meta-analyses.
- Adult patients (≥ 18 years) diagnosed with lumbar disc herniation and lumbar radiculopathy.
- Studies evaluating epidural steroid injections (TFESI, ILES, CESI), selective nerve root blocks, pulsed radiofrequency treatment, and image-guided interventional procedures.
- Studies reporting pain relief, functional outcomes, disability scores, quality of life, procedural accuracy, or complications.
- Articles published in English.

Exclusion Criteria

- Case reports, editorials, conference abstracts, expert opinions, and narrative reviews.
- Studies involving cervical or thoracic disc disease without separate lumbar data.
- Animal studies and cadaveric studies.
- Articles with insufficient outcome data.

Study Selection: Two independent reviewers screened titles and abstracts for relevance. Full-text articles of potentially eligible studies were assessed according to predefined inclusion and exclusion criteria. Any disagreements were resolved by discussion and consensus with other reviewers.

Data Extraction

Data extracted included author details, publication year, study design, intervention type, sample size, follow-up duration, outcome measures, pain scores (VAS/NRS), functional outcomes (ODI), complications, and key findings.

Quality Assessment

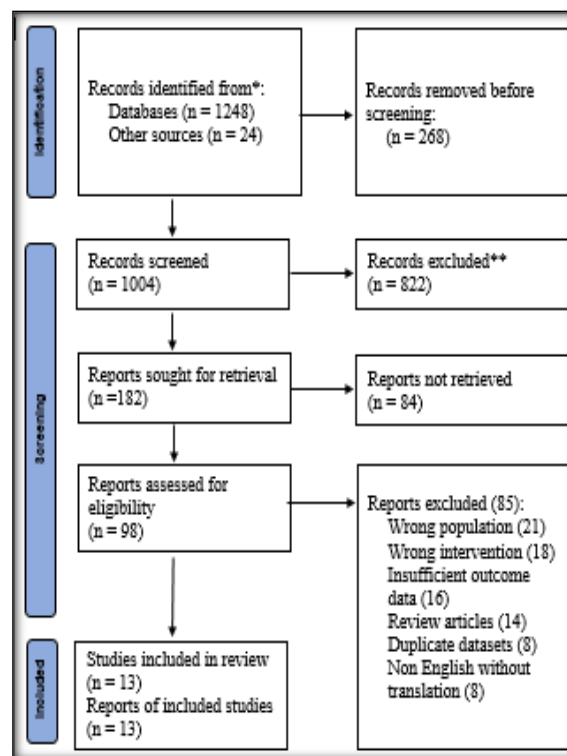
The methodological quality of randomized controlled trials was assessed using the Cochrane Risk of Bias Tool.^[14] Observational studies were evaluated using the ROBINS-I tool.^[15] Each study was categorized as having low, moderate, or high risk of bias.

Data Synthesis

Due to heterogeneity in intervention techniques, outcome measures, and follow-up durations, a narrative synthesis approach was used. Findings were summarized according to intervention type, including epidural steroid injections, pulsed radiofrequency procedures, selective nerve root blocks, and image-guided interventions.

RESULTS

Study Selection and Characteristics.



The database search identified 1,272 records through electronic databases and manual reference screening. After removal of 268 duplicate records, 1,004 studies underwent title and abstract screening. A total of 822 studies were excluded based on irrelevance to the review objectives. Ninety-eight full-text articles were assessed for eligibility, of which 85 were excluded due to inappropriate study design, wrong population, insufficient outcome reporting, duplicate datasets, or non-English publication. Thirteen studies fulfilled the eligibility criteria and were included in the final qualitative synthesis. The study selection process is illustrated in the PRISMA 2020 flow diagram.

Table 1: Characteristics of Studies Evaluating Epidural Steroid Injections (TFESI, ILES, CESI)

Author (Year)	Study Design	Intervention Category	Intervention	Sample Size	Follow-up	Outcome Measures	Key Findings
Murakibhavi et al. (2011), ^[16]	RCT	ESI	Caudal Epidural Steroid Injection	100	12 months	VAS, ODI	Significant improvement compared with

							conservative treatment
Manchikanti et al. (2014), ^[17]	Double-blind RCT	ESI	ILESI (LA ± steroid)	120	24 months	NRS, ODI	Significant improvement in pain and function
De et al. (2019), ^[18]	Triple-blind RCT	PRF/SNRB	DRG PRF + TF Epidural LA	50	6 months	VAS, ODI	Superior pain relief and functional recovery
Helm et al. (2021), ^[19]	Systematic Review & Meta-analysis	TFESI	TFESI	1,870 pooled	6 months	Pain, Function	Level I evidence supporting TFESI
El-Yahchouchi et al. (2023), ^[9]	Prospective Cohort	TFESI/Image-guided	Fluoroscopy-guided TFESI	300	12 months	VAS, ODI	Significant pain reduction
Kim et al. (2023), ^[11]	Prospective Cohort	SNRB/Image-guided	CT-guided SNRB	95	12 months	Pain Relief	Significant improvement
Lee et al. (2023), ^[8]	Prospective RCT	PRF	DRG Pulsed Radiofrequency	60	6 months	VAS, ODI	Significant improvement
Zhang et al. (2024), ^[6]	Meta-analysis	ESI	Epidural Steroid Injection	1500+	6 months	VAS, ODI	Short- and medium-term benefit
Jain et al. (2024), ^[10]	Randomized Comparative Study	Image-guided	US-guided vs Fluoroscopy-guided	80	6 months	VAS, ODI	Similar efficacy
Abdalla et al. (2024), ^[20]	Retrospective Cohort	Disc Resorption	ESI/IPM	128	MRI follow-up	MRI Disc Resorption	37.5% disc resorption
Yan et al. (2025), ^[21]	Retrospective Study	PRF + TFESI	Modified TFESI + PRF	106	12 months	VAS, ODI, MacNab	Sustained pain relief
Jang et al. (2025) ^[22]	Double-blind RCT	PRF	Long-duration PRF	72	6 months	VAS, ODI	Greater pain relief
Kourounis et al. (2025), ^[2]	Comparative Study	Image-guided	Various Image-guided Techniques	800+	12 months	Pain, Function	Improved accuracy and safety

Table 2: Risk of Bias Assessment of Included Original Studies

Study	Quality/Risk Assessment	Overall Risk
Murakibhavi et al. (2011)	Some concerns in randomization and allocation concealment	Moderate
Manchikanti et al. (2014)	Low risk across domains	Low
De et al. (2019)	Low risk across domains	Low
Helm et al. (2021)	Comprehensive methodology, AMSTAR-2 compliant	Low
El-Yahchouchi et al. (2023)	Moderate risk due to confounding and selection bias	Moderate
Kim et al. (2023)	Moderate risk due to non-randomized design	Moderate
Lee et al. (2023)	Low risk across domains	Low
Zhang et al. (2024)	Comprehensive methodology with low publication bias risk	Low
Jain et al. (2024)	Some concerns regarding blinding	Moderate
Abdalla et al. (2024)	Moderate risk due to retrospective design	Moderate
Yan et al. (2025)	Moderate risk due to selection bias and confounding	Moderate
Jang et al. (2025)	Low risk across domains	Low
Kourounis et al. (2025)	Good methodological quality with moderate heterogeneity	Low

Table 3: Summary of Clinical Outcomes of Included Studies

Study	Intervention	Pain Relief	Functional Improvement	Long-Term Benefit	Major Conclusion
Murakibhavi et al. (2011)	CESI	Significant	Significant ODI improvement	Up to 12 months	CESI superior to conservative treatment
Manchikanti et al. (2014)	ILESI	Significant reduction in NRS	Significant ODI improvement	24 months	Steroid group demonstrated slightly better outcomes
De et al. (2019)	DRG PRF + TFESI	Superior pain reduction	Significant ODI improvement	6 months	PRF enhanced therapeutic efficacy
Helm et al. (2021)	TFESI	Strong evidence of pain relief	Functional improvement	Moderate-term benefit	Level I evidence supports TFESI
El-Yahchouchi et al. (2023)	Fluoroscopy-guided TFESI	Significant reduction in radicular pain	Improved ODI scores	12 months	Reduced need for surgery
Kim et al. (2023)	CT-guided SNRB	Significant pain reduction	Neurological improvement	12 months	Effective minimally invasive option
Lee et al. (2023)	DRG PRF	Significant reduction in pain scores	Improved disability scores	6 months	Effective for chronic lumbar radicular pain
Zhang et al. (2024)	Epidural Steroid Injection	Significant short-term pain relief	Moderate ODI improvement	Limited beyond 6 months	Effective for short- and medium-term management

Jain et al. (2024)	Ultrasound vs Fluoroscopy-guided Injection	Comparable pain relief	Comparable functional outcomes	6 months	Ultrasound avoids radiation with similar efficacy
Abdalla et al. (2024)	ESI/IPM	Clinical improvement observed	Not specifically reported	MRI follow-up	37.5% demonstrated radiological disc resorption
Yan et al. (2025)	Modified TFESI + PRF	Sustained pain reduction	Significant ODI improvement	12 months	Combined approach provided durable benefit
Jang et al. (2025)	Long-duration PRF	Greater pain reduction than standard PRF	Better ODI improvement	6 months	Longer PRF duration improved outcomes
Kourounis et al. (2025)	Image-guided Interventions	Improved pain outcomes	Better functional recovery	12 months	Image guidance enhanced accuracy and safety

Table 4: Subgroup Analysis of Included Studies

Subgroup	Studies Included	Main Findings
CESI	Murakibhavi 2011	Effective but generally less targeted than TFESI
ILESI	Manchikanti 2014	Effective long-term pain control, especially when combined with steroids
TFESI	Helm 2021, El-Yahchouchi 2023, Yan 2025	Greatest short-term pain reduction and functional improvement
PRF of DRG	De 2019, Lee 2023, Yan 2025	Superior medium- and long-term pain relief compared with injections alone
Fluoroscopy-guided Interventions	El-Yahchouchi 2023	Gold-standard imaging guidance with high procedural accuracy
Ultrasound-guided Interventions	Jain 2024	Comparable efficacy with elimination of radiation exposure
CT-guided Interventions	Kim 2023	Highest anatomical precision, particularly in complex cases
Combined TFESI + PRF	Yan 2025	Best overall long-term outcomes among evaluated interventions

DISCUSSION

The present systematic review evaluated the efficacy and safety of various interventional pain management techniques for lumbar disc herniation, including Transforaminal Epidural Steroid Injection (TFESI), Interlaminar Epidural Steroid Injection (ILESI), Caudal Epidural Steroid Injection (CESI), Selective Nerve Root Block (SNRB), Pulsed Radiofrequency (PRF) of the Dorsal Root Ganglion, and image-guided injection techniques. The findings demonstrate that interventional procedures provide substantial short- to medium-term pain relief and functional improvement in patients with lumbar radiculopathy secondary to lumbar disc herniation. Among all epidural injection approaches, TFESI emerged as the most consistently effective intervention. Multiple studies demonstrated superior pain reduction and functional recovery following TFESI compared with interlaminar and caudal approaches. The targeted delivery of corticosteroids directly adjacent to the affected nerve root likely contributes to its enhanced clinical effectiveness. The evidence synthesis by Helm et al. reported Level I evidence supporting TFESI for lumbar disc herniation-associated radicular pain.^[19] while the recent meta-analysis by Brotis et al. confirmed that TFESI generally provides superior outcomes among epidural injection techniques. Interlaminar epidural steroid injections also demonstrated favorable outcomes, particularly in patients with chronic radicular symptoms.^[23] The randomized trial conducted by Manchikanti et al. reported sustained improvement in pain and disability scores over a two-year period, indicating

that ILESI remains a valuable treatment option when TFESI is contraindicated or technically difficult.^[17,24] However, the magnitude of pain relief was generally lower than that observed with TFESI. Caudal epidural steroid injections showed beneficial effects in reducing pain and disability, although the available evidence suggests relatively lower efficacy compared with transforaminal injections. This finding may be explained by less selective medication delivery and greater dilution of injectable before reaching the affected nerve root. Nevertheless, CESI remains a useful alternative in patients with multilevel pathology, previous spinal surgery, or anatomical limitations. An important finding of this review is the growing role of Pulsed Radiofrequency of the Dorsal Root Ganglion. Studies by De et al., Lee et al., and Yan et al. consistently demonstrated significant reductions in pain intensity and disability scores following PRF treatment.^[8,18,21] Unlike conventional radiofrequency ablation, PRF produces neuromodulation without substantial neural destruction, thereby minimizing the risk of neurological complications. Furthermore, combined TFESI and PRF therapy demonstrated particularly favorable long-term outcomes, with sustained symptom relief observed up to 12 months. These findings suggest that PRF may represent an effective adjunctive therapy for patients with chronic or recurrent lumbar radiculopathy. The review also highlights the importance of image guidance in modern interventional pain management. Fluoroscopy-guided procedures remain the current standard because of their ability to provide real-time visualization of contrast spread and needle placement. Ultrasound-guided injections

demonstrated comparable clinical efficacy while eliminating radiation exposure, making them an attractive alternative in selected patients.^[10] CT-guided nerve root blocks offered superior anatomical precision, particularly in patients with altered spinal anatomy or complex foraminal pathology, although concerns regarding radiation exposure and cost remain.^[11]

Another noteworthy observation was the potential relationship between interventional procedures and spontaneous disc resorption. Abdalla et al. reported radiological evidence of disc regression in approximately one-third of patients following interventional pain management.^[20] Although the exact mechanism remains unclear, reduction of local inflammation and enhancement of macrophage-mediated phagocytosis may contribute to accelerated disc resorption. Further prospective studies are required to clarify this relationship.

Despite favorable short-term outcomes, long-term efficacy remains an area of uncertainty. Most studies demonstrated maximal benefits within the first three to six months after intervention, with gradual reduction in treatment effects thereafter. This finding is consistent with previous systematic reviews indicating that epidural steroid injections primarily serve as symptom-modifying rather than disease-modifying therapies. Consequently, these procedures should be integrated into a comprehensive treatment strategy that includes rehabilitation, exercise therapy, lifestyle modification, and appropriate patient education.

The overall quality of evidence included in this review was moderate to high. Randomized controlled trials generally demonstrated low risk of bias, whereas observational studies exhibited moderate methodological limitations related to patient selection and follow-up procedures. Heterogeneity among injection techniques, steroid preparations, outcome measures, and follow-up durations limited direct comparison across studies and precluded definitive conclusions regarding optimal treatment protocols.

Clinical Implications

The findings of this review support the use of image-guided interventional pain management techniques as effective minimally invasive options for lumbar disc herniation. TFESI appears to provide the most favorable balance between efficacy and safety among epidural injection techniques. PRF of the dorsal root ganglion offers promising long-term benefits and may be particularly useful in patients with persistent radicular symptoms. Image-guided procedures improve procedural accuracy and reduce complications, supporting their routine use in contemporary clinical practice.

Limitations

Several limitations should be acknowledged. First, considerable heterogeneity existed among included studies regarding intervention protocols, steroid type, dosage, and follow-up duration. Second, long-term data beyond one year were limited. Third,

publication bias cannot be excluded because positive studies are more likely to be published. Finally, several studies employed observational designs, which may be susceptible to selection bias and confounding factors.

CONCLUSION

Interventional pain management techniques provide significant short- and medium-term improvements in pain and functional outcomes in patients with lumbar disc herniation. TFESI demonstrates the strongest evidence among epidural injection approaches, while PRF of the dorsal root ganglion offers promising sustained benefits. Fluoroscopy-guided, ultrasound-guided, and CT-guided interventions all contribute to improved procedural accuracy and safety. Although these techniques effectively reduce symptoms and improve quality of life, further high-quality randomized controlled trials with longer follow-up periods are required to establish optimal treatment algorithms and determine long-term efficacy.

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