

COMPARISON OF CLINICAL EFFICACY OF TRANSFORAMINAL EPIDURAL STEROID INJECTION VIA KAMBIN'S TRIANGLE VERSUS CLASSICAL SAFE TRIANGLE APPROACH IN LUMBAR DISC HERNIATION WITH RADICULOPATHY

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Abstract

Background: Lumbar disc herniation with radiculopathy is a major cause of chronic low back pain and lower limb disability, often resulting in significant functional impairment and reduced quality of life. Transforaminal epidural steroid injection (TFESI) is a well-established minimally invasive treatment for patients who do not respond to conservative therapy. Although the classical safe triangle approach has been widely adopted, concerns regarding neural irritation and vascular injury have prompted the use of alternative techniques such as the Kambin's triangle approach.

Aim: To compare the clinical efficacy and procedural safety of TFESI performed using the Kambin's triangle approach and the classical safe triangle approach in patients with lumbar disc herniation associated with unilateral radiculopathy.

Materials and Methods: This prospective randomized comparative study included 50 patients with MRI-confirmed lumbar disc herniation and unilateral radiculopathy. Patients were randomly allocated into two equal groups (n=25 each). Group A underwent TFESI using the classical safe triangle approach, whereas Group B received TFESI through the Kambin's triangle approach. Pain intensity was assessed using the Visual Analog Scale (VAS), and functional disability was evaluated using the Oswestry Disability Index (ODI). Clinical assessments were performed before the procedure and at 2 weeks, 1 month, and 3 months after injection. Procedural complications, including nerve root irritation, paresthesia, intravascular uptake, and post-procedural pain flare, were also recorded. Statistical analysis was performed using appropriate parametric and non-parametric tests, with a p-value <0.05 considered statistically significant.

Results: Both groups demonstrated significant reductions in VAS scores and improvements in ODI scores during follow-up, indicating effective pain relief and functional recovery following TFESI. However, patients treated using the Kambin's triangle approach showed greater improvement in pain and disability scores at later follow-up visits. Furthermore, the incidence of procedure-related complications, including nerve root irritation, intravascular uptake, paresthesia, and post-procedural pain flare, was lower in the Kambin group, indicating superior procedural safety and better patient tolerance.

Conclusion: Both the classical safe triangle and Kambin's triangle approaches are effective techniques for transforaminal epidural steroid injection in patients with lumbar disc herniation and radiculopathy. However, the Kambin's triangle approach offers comparable clinical efficacy with a lower complication rate and improved procedural safety. It may therefore be considered a preferable alternative to the conventional safe triangle technique for fluoroscopy-guided TFESI.

Keywords: Lumbar disc herniation, Lumbar radiculopathy, Transforaminal epidural steroid injection, Kambin's triangle, Safe triangle approach, Visual Analog Scale, Oswestry Disability Index, Pain management, sustainable developmental goals(SDG 3:Good health and well being).

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INTRODUCTION

Lumbar disc herniation (LDH) is one of the most common causes of low back pain and lumbar radiculopathy, affecting millions of individuals worldwide and imposing a substantial socioeconomic burden through healthcare costs, absenteeism from work, and reduced quality of life. The condition predominantly affects individuals during their most productive years, leading to considerable functional disability and psychological distress. Lumbar radiculopathy occurs when herniated disc material compresses or irritates

one or more lumbar nerve roots, producing characteristic symptoms such as radiating leg pain, numbness, paresthesia, sensory disturbances, motor weakness, and diminished reflexes corresponding to the affected nerve root distribution. The pathophysiology of lumbar radiculopathy involves not only mechanical compression of the nerve root but also a significant inflammatory response mediated by cytokines, phospholipase A2, prostaglandins, tumour necrosis factor-alpha (TNF- α), and interleukins, which contribute to persistent pain and neurological dysfunction. These inflammatory mediators sensitize nerve roots and perpetuate

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chronic neuropathic pain even in the absence of significant mechanical compression, emphasizing the need for therapeutic interventions targeting both mechanical and inflammatory mechanisms of disease.¹

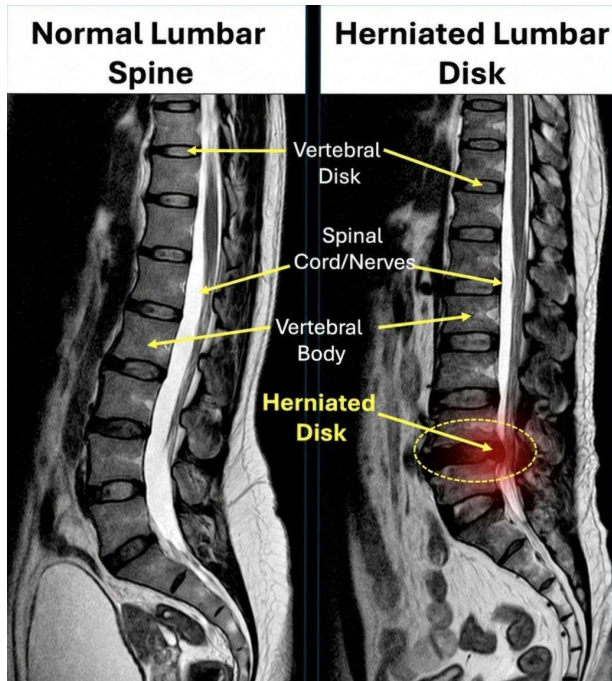
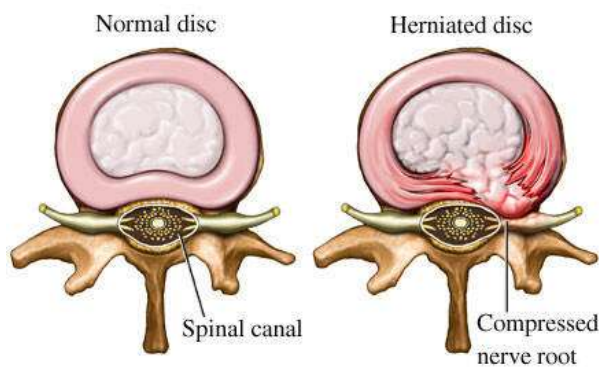


Figure 1: Normal VS Herniated lumbar disk(MRI)

Figure 2: Normal VS Herniated disk(Diagrammatic representation)



Top views of vertebrae

Initial management of lumbar disc herniation generally consists of conservative treatment, including activity modification, nonsteroidal anti-inflammatory drugs (NSAIDs), oral analgesics, muscle relaxants, structured physiotherapy, and lifestyle modifications. Although many patients experience spontaneous improvement within several weeks, approximately 20–30% continue to have persistent symptoms despite adequate conservative management. These patients often experience chronic pain, impaired mobility, sleep disturbances, reduced occupational

productivity, and deterioration in daily functioning. Surgical decompression remains an effective treatment for selected patients with severe neurological deficits or refractory symptoms; however, surgery carries inherent risks, including infection, dural tears, postoperative fibrosis, adjacent segment degeneration, and recurrent disc herniation. Consequently, minimally invasive interventional pain management techniques have become increasingly popular as intermediate therapeutic options before considering surgery.²

Among various interventional procedures, transforaminal epidural steroid injection (TFESI) has gained widespread acceptance because it provides targeted delivery of corticosteroids and local anaesthetic directly into the ventral epidural space adjacent to the affected nerve root. Compared with interlaminar or caudal epidural injections, the transforaminal approach allows higher concentrations of medication to reach the site of pathology while minimizing systemic exposure. Corticosteroids suppress inflammatory mediators, reduce vascular permeability, inhibit ectopic nerve discharge, and decrease nerve root oedema, thereby alleviating pain and improving neurological function. Numerous clinical studies have demonstrated significant short- and intermediate-term improvements in pain, disability, and functional outcomes following TFESI in appropriately selected patients with lumbar radiculopathy.³

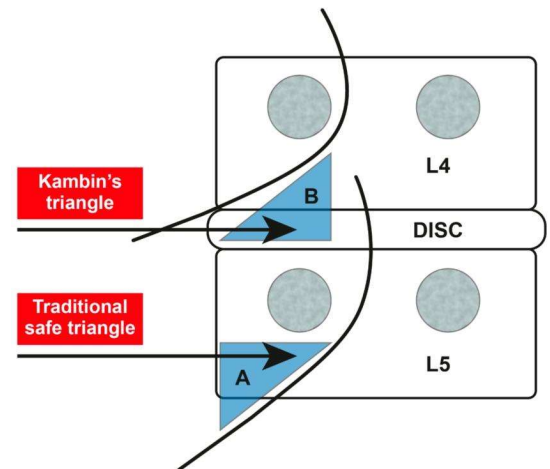


Figure 3: Schematic representation of the two approaches

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The conventional technique for TFESI is the classical safe triangle approach, in which the needle is advanced under fluoroscopic guidance into the superior-anterior aspect of the neural foramen, immediately inferior to the pedicle and lateral to the exiting nerve root. This technique has traditionally been regarded as the standard approach because it provides reliable access to the ventral epidural space and facilitates accurate drug delivery. Nevertheless, the anatomical proximity of the needle trajectory to radiculomedullary arteries, epidural vessels, dorsal root ganglion, and exiting nerve root increases the possibility of complications. Reported adverse events include transient nerve root irritation, intravascular injection, dural puncture, post-procedural pain flare, spinal cord infarction, epidural hematoma, infection, and, in rare instances, catastrophic neurological injury. Although these complications are uncommon, increasing awareness of their potential severity has prompted investigators to explore alternative needle trajectories with improved safety profiles.⁴

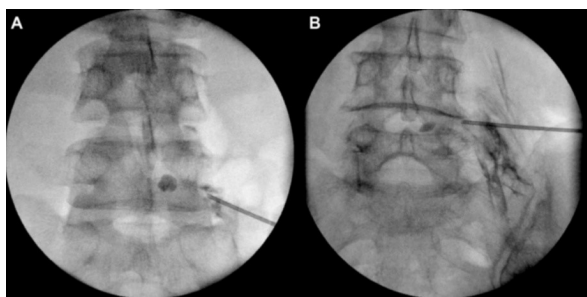


Figure 4 : A -Traditional Safe triangle approach / B – Kambin's Triangle approach

Kambin's triangle is an anatomical triangular working zone located within the posterolateral aspect of the lumbar intervertebral foramen. It is bounded anteriorly by the exiting nerve root, inferiorly by the superior border of the caudal vertebral body, and medially by the traversing nerve root and dural sac. Originally described as a safe corridor for percutaneous endoscopic lumbar discectomy, this anatomical space has subsequently been adapted for transforaminal epidural steroid injections. The Kambin's triangle approach introduces the needle through the posteroinferior portion of the neural foramen, thereby avoiding the highly vascular superior-anterior region targeted by the conventional safe triangle technique. This alternative trajectory potentially reduces contact with neural structures and radicular vessels while maintaining adequate epidural spread of therapeutic medication.⁵

Several anatomical, fluoroscopic, and clinical studies have evaluated the efficacy and safety of the Kambin approach. Available evidence suggests that the approach provides comparable pain relief and functional recovery while reducing the incidence of nerve irritation, vascular penetration, and intravascular contrast uptake. Fluoroscopic studies have demonstrated satisfactory ventral epidural contrast distribution through the Kambin corridor, indicating

that therapeutic drug delivery is not compromised despite the altered needle trajectory. Furthermore, improved patient comfort during needle advancement and lower procedural discomfort have been reported. However, published literature remains limited, with relatively few randomized comparative studies directly evaluating the clinical efficacy, disability improvement, and complication profiles of the Kambin and classical safe triangle techniques. Differences in patient populations, procedural techniques, injectate composition, follow-up duration, and outcome measures have contributed to inconsistent findings across studies.¹⁻⁵ Considering the increasing utilization of fluoroscopy-guided spinal interventions and the growing emphasis on procedural safety, identifying the optimal TFESI technique has considerable clinical importance. A technique capable of achieving equivalent therapeutic efficacy while minimizing complications may improve patient satisfaction, reduce procedure-related morbidity, and enhance overall treatment outcomes. Comparative evaluation of pain reduction, functional recovery, and complication rates between these two approaches can provide valuable evidence to guide interventional pain physicians and spine surgeons in selecting the most appropriate technique for patients with lumbar disc herniation and unilateral radiculopathy.

Therefore, the present prospective randomized comparative study was undertaken to compare the clinical efficacy of fluoroscopy-guided transforaminal epidural steroid injection performed through the Kambin's triangle approach and the classical safe triangle approach in patients with MRI-confirmed lumbar disc herniation associated with unilateral lumbar radiculopathy. Clinical outcomes were assessed using the Visual Analog Scale (VAS) for pain intensity and the Oswestry Disability Index (ODI) for functional disability, while procedural safety was evaluated by comparing the incidence of nerve root irritation, intravascular uptake, paresthesia, post-procedural pain flare, dural puncture, and other complications between the two techniques.

AIM AND OBJECTIVES

Aim:

To compare the clinical efficacy and procedural safety of transforaminal epidural steroid injection performed through the Kambin's triangle approach and the classical safe triangle approach in lumbar disc herniation with radiculopathy.

Objectives:

1. To evaluate pain reduction using Visual Analog Scale (VAS).
2. To assess functional improvement using Oswestry Disability Index (ODI).
3. To compare procedural complications between the two approaches.
4. To evaluate short-term clinical outcome after TFESI.

MATERIALS AND METHODS

This prospective randomized comparative study was conducted in the Department of Orthopaedics/Pain Medicine of a tertiary care teaching hospital over a period of 12 months. A total of 50 patients with MRI-confirmed lumbar disc herniation and unilateral lumbar radiculopathy were included

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in the study. Patients were divided equally into two groups.

Group A: Classical Safe Triangle Approach – 25 patients.

Group B: Kambin's Triangle Approach – 25 patients.

Inclusion Criteria:

- Age between 20 and 70 years.
- MRI-confirmed lumbar disc herniation.
- Unilateral lumbar radiculopathy.
- Failure of conservative management for more than 6 weeks.

Exclusion Criteria:

- Previous lumbar spine surgery.
- Coagulopathy.
- Local infection.
- Pregnancy.
- Allergy to steroids or contrast material.

ETHICAL CONSIDERATION

The study was conducted after obtaining approval from the Institutional Ethics Committee of Saveetha Medical College and Hospital. Written informed consent was obtained from all participants before enrolment. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

PROCEDURE

All procedures were performed under strict aseptic precautions using fluoroscopic guidance. Patients were positioned prone. After identifying the affected level, a spinal needle was advanced using either the classical safe triangle approach or the Kambin's triangle approach according to group allocation. Needle placement was confirmed using non-ionic contrast under anteroposterior and lateral fluoroscopic views before administration of triamcinolone and bupivacaine. Patients were reviewed at 2 weeks, 1 month and 3 months.

STATISTICAL ANALYSIS

Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics version 25.0. Continuous variables were expressed as mean $\pm$ standard deviation (SD), while categorical variables were expressed as frequencies and percentages. Normality of continuous variables was assessed using the Shapiro-Wilk test. Independent Student's t-test was used to compare normally distributed continuous variables between groups, whereas the Chi-square test or Fisher's exact test was used for categorical variables. A p-value <0.05 was considered statistically significant.

RESULTS

Table 1: Demographic Characteristics

Variable	Group A	Group B
Mean Age (years)	45.6 $\pm$ 10.8	44.9 $\pm$ 9.7
Male	13	16
Female	12	9

L4-L5 Herniation	15	13
L5-S1 Herniation	10	12

The two treatment groups were closely matched at baseline, with comparable mean age, sex distribution, and level of disc herniation (L4–L5 and L5–S1). This baseline homogeneity indicates successful randomization and minimizes the likelihood that pre-existing differences confounded the subsequent comparison of clinical outcomes.

Table 2: Comparison of VAS Scores

Follow-up	Group A	Group B	P-value
Pre-procedure	8.2 $\pm$ 0.8	8.1 $\pm$ 0.9	0.74
2 weeks	5.1 $\pm$ 1.0	4.6 $\pm$ 0.9	0.11
1 month	3.9 $\pm$ 0.8	3.3 $\pm$ 0.7	0.04
3 months	3.0 $\pm$ 0.7	2.4 $\pm$ 0.6	0.03

Pre-procedural VAS scores were statistically similar between groups ($p=0.74$), confirming comparable baseline pain intensity. Although the difference at 2 weeks did not reach significance ($p=0.11$), Group B demonstrated significantly greater pain reduction at 1 month ($p=0.04$) and 3 months ($p=0.03$), suggesting that the Kambin's triangle approach confers a more durable analgesic benefit over the course of follow-up.

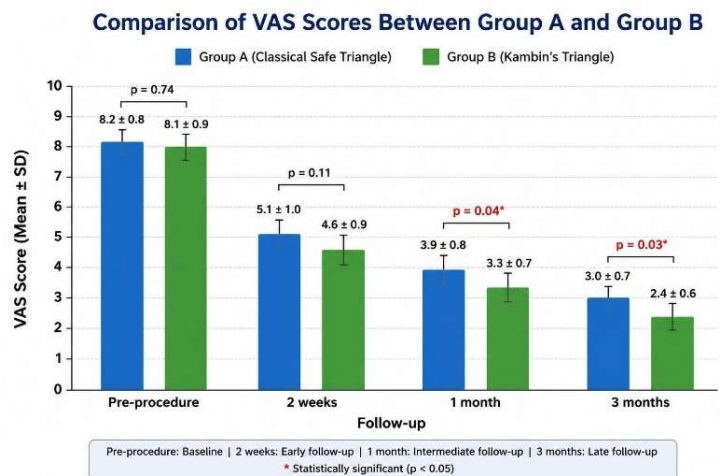


Figure 5: Comparison of Mean VAS Scores

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Table 3: Comparison of ODI Scores

Follow-up	Group A	Group B	p-value
Pre-procedure	61.8 ± 7.5	62.3 ± 7.1	0.83
1 month	35.6 ± 5.8	31.4 ± 5.2	0.03
3 months	25.2 ± 4.9	20.8 ± 4.3	0.01

Baseline ODI scores were comparable between groups ($p=0.83$), indicating similar pre-treatment functional impairment. Both groups showed progressive improvement in disability scores; however, Group B achieved significantly greater functional recovery at 1 month ($p=0.03$) and 3 months ($p=0.01$), supporting a more pronounced and sustained improvement in physical function with the Kambin's triangle approach.

Table 4: Complications

Complication	Group A	Group B
Nerve Root Irritation	5	0
Intravascular Uptake	1	0
Procedure-related Paresthesia	4	2
Post-procedural Pain Flare	6	2
Dural Puncture	1	0
No Complications	8	21

Complication rates were markedly lower in Group B, with no cases of nerve root irritation or intravascular uptake, compared with five and one cases, respectively, in Group A. Overall, 21 of 25 patients (84%) in Group B experienced no procedural complications, compared with 8 of 25 (32%) in Group A, reinforcing the improved procedural safety profile of the Kambin's triangle approach.

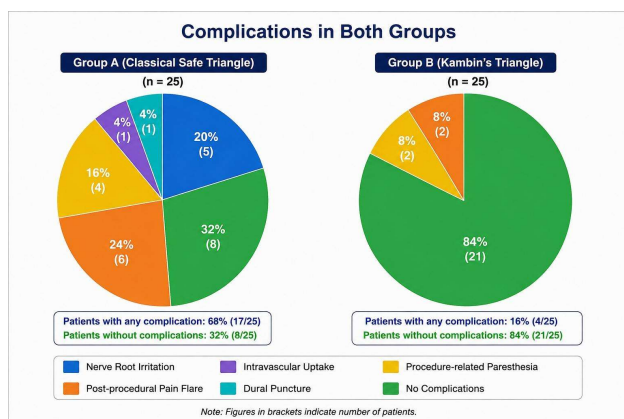


Figure 6: Complication Distribution between Group A and Group B

DISCUSSION

The present prospective randomized comparative study evaluated the clinical efficacy and procedural safety of transforaminal epidural steroid injection (TFESI) performed using the classical safe triangle approach and the Kambin's triangle approach in patients with MRI-confirmed lumbar disc herniation associated with unilateral lumbar radiculopathy. Both treatment groups demonstrated significant improvement in pain intensity and functional disability during the three-month follow-up period, confirming that TFESI remains an effective minimally invasive intervention for patients who fail conservative management. However, patients treated through the Kambin's triangle approach exhibited superior pain relief, greater improvement in functional status, and a lower incidence of procedure-related complications, indicating that this approach offers an improved safety profile while maintaining equivalent therapeutic efficacy. These findings support the growing body of literature advocating alternative needle trajectories that minimize the risk of neural and vascular injury during lumbar transforaminal epidural injections.⁶

Baseline demographic characteristics were comparable between the two groups, with no statistically significant differences in age distribution, gender, or level of lumbar disc herniation. The majority of patients presented with L4-L5 disc herniation, followed by L5-S1 involvement, which corresponds well with the epidemiological distribution of lumbar disc disease reported in previous studies. Comparable baseline characteristics reduce the possibility of confounding variables influencing treatment outcomes and strengthen the validity of the comparative analysis. Similar demographic distributions have also been reported in randomized studies evaluating different TFESI techniques for lumbar radiculopathy.⁷

Pain reduction, assessed using the Visual Analog Scale (VAS), improved significantly in both treatment groups throughout follow-up. Although pain scores were comparable before the procedure and at two weeks, statistically significant differences emerged at one month and three months, with the Kambin group demonstrating lower VAS scores. This observation suggests that both techniques effectively reduce inflammatory irritation of the affected nerve root, while the Kambin approach may facilitate more sustained clinical improvement. The targeted delivery of corticosteroids into the ventral epidural space suppresses inflammatory cytokines, decreases nerve root oedema, and interrupts nociceptive transmission, thereby improving pain and neurological function. The superior outcomes observed in the Kambin group may also reflect reduced procedural trauma and less irritation of the exiting nerve root during needle placement. Similar improvements in VAS scores have been documented in comparative studies evaluating Kambin's triangle and conventional approaches.⁸

Functional disability, evaluated using the Oswestry Disability Index (ODI), also improved significantly in both groups following treatment. Patients undergoing the Kambin approach demonstrated greater improvement at both one- month and three-month follow-up, indicating enhanced recovery of daily functional activities. Reduction in disability is clinically important because lumbar radiculopathy frequently impairs walking, sitting, occupational performance, and overall quality of life. Improved functional outcomes likely result from effective suppression of inflammation combined with early restoration of mobility due to

reduced post-procedural discomfort. Previous investigators have similarly demonstrated that successful pain reduction following TFESI is accompanied by substantial improvements in physical function and patient-reported disability scores.⁹

One of the most important findings of the present study was the lower complication rate observed with the Kambin's triangle approach. Procedure-related nerve root irritation occurred only in patients undergoing the classical safe triangle technique, whereas no such cases were recorded in the Kambin group. Likewise, intravascular uptake, which represents a potentially serious complication capable of causing catastrophic neurological injury if particulate steroids are injected into radicular vessels, was observed only in the classical group. These findings support anatomical studies demonstrating that the superior-anterior portion of the neural foramen contains a greater concentration of vascular structures, whereas the posteroinferior corridor utilized in the Kambin approach avoids these critical structures. Consequently, the Kambin technique appears to provide a safer needle trajectory while maintaining adequate epidural access.¹⁰

The incidence of procedure-related paresthesia and post-procedural pain flare was also lower in the Kambin group. Paresthesia during needle advancement generally results from direct mechanical irritation of the exiting nerve root or dorsal root ganglion. Because the Kambin approach traverses the inferior aspect of the neural foramen rather than the superior neural corridor, mechanical contact with neural structures is minimized. Similarly, post-procedural pain flare may reflect transient neural irritation or local inflammatory responses induced during needle manipulation. The reduced frequency of these complications further supports the technical advantages of the Kambin approach. Comparable observations have been described by investigators evaluating fluoroscopy-guided TFESI using modified needle trajectories.¹¹

No major complications such as permanent neurological deficit, infection, epidural abscess, spinal cord infarction, or severe allergic reactions were encountered in the present study. The absence of serious adverse events can be attributed to meticulous patient selection, strict adherence to aseptic precautions, fluoroscopic guidance, contrast confirmation of epidural spread, and careful procedural technique. Nevertheless, the occurrence of minor complications in the classical safe triangle group highlights the importance of optimizing procedural safety, particularly because rare but devastating neurological complications have been documented following conventional transforaminal injections. The increasing emphasis on image-guided interventions has therefore encouraged the development of safer anatomical approaches such as the Kambin technique.¹²

The anatomical rationale underlying the Kambin approach deserves particular consideration. Kambin's triangle represents a relatively avascular anatomical window bounded by the superior endplate of the lower vertebra, the traversing nerve root medially, and the exiting nerve root laterally. Needle advancement through this corridor minimizes contact with radicular arteries and sensitive neural structures while allowing satisfactory ventral epidural distribution of contrast and injectate. Fluoroscopic studies have confirmed that adequate ventral epidural spread can be achieved through this approach without compromising therapeutic efficacy. These anatomical advantages likely explain the lower incidence of vascular penetration and nerve irritation observed in both previous studies and the present investigation.¹³

The findings of this study are consistent with previously published clinical investigations comparing Kambin's triangle and conventional safe triangle approaches. Most studies have reported comparable analgesic efficacy, with several demonstrating fewer vascular complications and improved procedural tolerance using the Kambin technique. Although differences in study design, sample size, steroid preparation, and follow-up duration make direct comparisons difficult, the overall evidence increasingly supports the Kambin approach as a reliable alternative for lumbar transforaminal epidural steroid injections. Meta-analyses evaluating fluoroscopy-guided TFESI similarly conclude that procedural safety can be improved through careful modification of needle trajectory without compromising pain relief.¹⁴⁻¹⁶

The present study has several strengths. Its prospective randomized design minimizes selection bias, while standardized fluoroscopic guidance and uniform injectate composition ensure procedural consistency between groups. The use of validated outcome measures such as VAS and ODI enhances the reliability of clinical assessment. Furthermore, systematic documentation of procedural complications provides valuable information regarding comparative safety, which is increasingly recognized as an essential outcome in spinal interventions.¹⁷

Despite these strengths, certain limitations should be acknowledged. The study included 50 patients (25 in each group), which may still limit statistical power and generalizability. Follow-up was restricted to three months, preventing evaluation of long-term pain relief recurrence, and need for repeat intervention. The study was conducted at a single tertiary care centre, which may limit external validity. Future multicentre randomized controlled trials involving larger sample sizes and longer follow-up are warranted.

CONCLUSION

Both the classical safe triangle and the Kambin's triangle approaches provided significant pain relief and functional improvement following transforaminal epidural steroid injection. The Kambin approach demonstrated a lower incidence of procedure-related complications while achieving comparable clinical outcomes. These findings suggest that the Kambin approach may be considered a safe and effective alternative for fluoroscopy-guided TFESI in appropriately selected patients with lumbar disc herniation and unilateral radiculopathy.

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