



CLINICAL UTILITY OF TRANSFORAMINAL EPIDURAL STEROID INJECTION: A SYSTEMATIC REVIEW AND META-ANALYSIS TO STUDY THE PREDICTORS OF FAVORABLE SURGICAL OUTCOMES

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INTRODUCTION

Low back pain (LBP), with or without radiculopathy, is a prevalent health issue and a leading cause of disability and healthcare costs globally. It affects approximately 80% of adults at some point in their lives. [1-2]. It is a significant public health problem that has significant socio-economic impacts, including reduced quality of life, reduced work productivity, and increased healthcare resource needs [3]. Lumbar radiculopathy is the most common of the various causes of low back pain (LBP) that can be caused by disc herniation or foraminal stenosis. This is normally presented by herniation of the nerves as radiating leg pain, numbness or weakness of the muscles as a result of compression or irritation of the nerve root [4]. The lumbar radiculopathy management usually oscillates between conservative treatments, which include the intake of pharmacological agents (e.g., NSAIDs, muscle relaxants), participation in physical therapy, and changes in day-to-day activities, to more complex treatments when a need arises [5]. Even though the majority of patients feel better when treated by non-invasive methods, some still maintain chronic pain and functional limitation, which promotes the idea of using interventional methods. Included in these are epidural steroid injections (ESIs), which are widely used to diagnose and treat. There are three broad types of ESIs, which include caudal, interlaminar and transforaminal approaches [6]. Transforaminal epidural steroid injection (TFESI) is considered to be the most focused and effective form of epidural procedure for unilateral radiculopathy, in particular [7]. Transforaminal epidural steroid injection (TFESI) allows direct delivery of corticosteroids and local anaesthetics to the specific anterior epidural space adjacent to the involved nerve root to enhance anti-inflammatory and analgesic effects [8]. It has both diagnostic and therapeutic benefits [9]. Some of them demonstrated that TFESI is superior to interlaminar or caudal methods, such as reduced pain, better functional outcomes, and the capacity to prevent or delay surgery [10-11]. Also, image-guided TFESI, either fluoroscopy-based or CT-based, is safer and more accurate and reduces the risks of accidental dural puncture or vascular injection [12]. Despite the extensive use of TFESI, its clinical impact is rather unstable, and the response rates to the treatment range between 40% and 80% [13]. Depending on the patient, there is significant and long-term relief that is realised by some patients, and there would be limited or short-term relief realised by others [14]. The inconsistency of the results has resulted in an abundance of research work dedicated to

determining the factors that could possibly forecast a positive response to TFESI, especially in the context of the possibility of avoiding or delaying surgery. These predictive variables include demographic characteristics (age and gender), clinical characteristics (duration of symptoms and patterns of pain), imaging results (degree of nerve root compression and spread pattern of contrast), and procedural characteristics (level of injection and type and dosage of corticosteroid injected) [15-17]. There are a lot of original research studies that explored potential factors that can predict good outcomes following TFESI as younger age, less duration of symptoms, appearance of disc herniation instead of spinal stenosis, high levels of baseline pain (measured with the help of the use of the visual analog scale or the numerical rating scale) or imaging changes such as compression of nerve roots or some MRI changes [18-20]. Nonetheless, the existing literature is incomplete, and the works focus on these factors separately, and their results among themselves are most of the time inconsistent or limited by the low number of participants, lack of a control group, and change in methodological characteristics. Moreover, the research lacks thorough studies that provide quantitative measurements of the predictors of successful results after TFESI. As the world of precision medicine and tailored interventional treatment approaches approaches, it is highly important to determine which patients are most likely to undergo a favourable response to TFESI to enhance the clinical decision-making process and to utilise the available resources most effectively [21]. The objective of the systematic review and meta-analysis will be to assess the clinical utility of transforaminal epidural steroid injection (TFESI) comprehensively to predict positive postoperative outcomes in patients with lumbar radiculopathy and other spinal troubles. In particular, it aims at synthesising the existing evidence to establish key predictors that include demographic, clinical and procedural factors which affect surgical success after TFESI, and as a result determine its prognostic value in predicting surgical success and improving patient selection.

Methodology

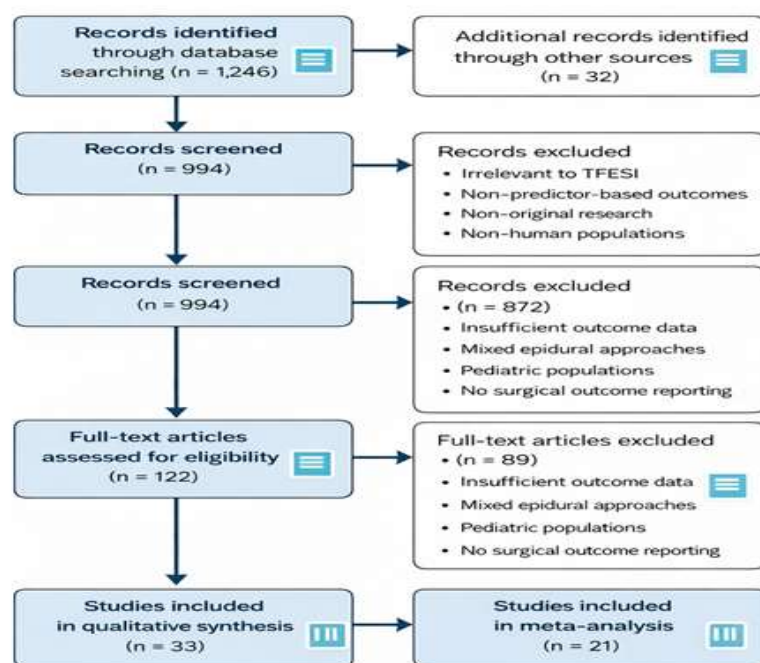
The present Study was a systematic review and meta-analysis executed Neurosurgery deptt MTI Hayatabad Medical Complex Peshawar from Jan 2023 to Jan 2024. to assess the clinical usefulness of transforaminal epidural steroid injection (TFESI) and to determine the predictors of positive surgical outcomes in patients with lumbar radiculopathy and other spinal diseases. The methodology was drafted based on the Preferred Reporting Items in Systematic Reviews and Meta-Analysis (PRISMA) 2020 guideline in order to give the report transparency, reproducibility, and methodological rigour. A priori structured review protocol was elaborated in accordance with internationally accepted evidence synthesis standards. The search of the literature was conducted with the use of the main electronic databases such as PubMed/MEDLINE, EMBASE, Scopus, Web of Science, and Cochrane Central Register of Controlled Trials (CENTRAL). The search involved those that were published between January 2000 and December 2024, covering the timeframe in which image-guided TFESI became commonly adopted as a clinical practice. Medical Subject Headings (MeSH) and free-text terms were entered in different combinations, which included transforaminal epidural steroid injection, TFESI, lumbar radiculopathy, disc herniation, predictors and surgical outcomes. Furthermore, the reference lists of the found articles and existing reviews published earlier were sifted manually to find more qualified studies. The studies had to be eligible by meeting the criteria of including adult patients (age 18 years or older) who were diagnosed or treated with lumbar radiculopathy, lumbar disc herniation, foraminal stenosis, or degenerative lumbar spine disorders who received TFESI as a diagnostic or treatment intervention. Trial studies such as randomised controlled trials, prospective and retrospective cohort studies, and case control studies assessing clinical outcomes or predictors of response following TFESI were eligible. Research involving other types of epidural procedures, but not transforaminal, case reports, narrative reviews, editorials, abstracts of conferences lacking complete text, and studies on animals were excluded. The outcomes of primary interest were positive surgical outcomes, such as avoiding or postponing surgery and better postoperative outcomes and demographic, clinical, imaging, and procedure predictors of positive responses to TFESI. Secondary outcomes were pain reduction and functional improvement measured by using validated scales,

including the use of the visual analogue scale, the numeric rating scale, the Oswestry Disability Index and the Short Form-36. All the records retrieved were inserted into the reference management program, and the duplicates were eliminated. Relevant and irrelevant titles and abstracts were filtered by two independent reviewers, and potentially eligible studies were assessed using the full-text based on pre-established inclusion criteria. This was because any disagreements in the process of study selection were to be settled by discussion and consensus. A PRISMA flow diagram was used to record the entire selection process. Two reviewers extracted data separately using a standardised data extraction form. The information obtained comprised study characteristics, patient demographics, clinical presentation, imaging findings, TFESI procedural details, follow-up period, outcome measures, and reported predictors of good surgical outcomes. The agreement was reached by ensuring that discrepancies in data extraction were corrected. The study design of the included studies was used to evaluate the methodological quality and the risk of bias, through the Cochrane Risk of Bias tool when applied to randomised controlled trials and the Newcastle-Ottawa Scale when applied to an observational study. The quality of the study was taken into account when the data was being interpreted and in the sensitivity analysis. The qualitative synthesis of all the included studies was performed first. In case of adequate clinical and methodological homogeneity, a quantitative meta-analysis approach was employed, and a random-effects model was applied in order to explain inter-study variability. The estimates of the effect were presented in the form of odds ratios or mean differences with 95% confidence interval. The I² statistic was used to determine the statistical heterogeneity, and subgroup analysis was conducted where feasible on the basis of age, time of symptoms, underlying pathology, imaging features, and procedural variables. The funnel plot and the Egger regression test were used to test the bias of publication when there were sufficient studies. The confidence of the critical outcomes was assessed according to GRADE. Ethical approval and informed consent were not needed as the study in question was carried out using only the existing literature.

RESULTS

The database search found 1,246 records as a total of the electronic databases that were PubMed/MEDLINE, EMBASE, Scopus, Web of Science, and Cochrane Central Register of Controlled Trials. Another 32 records were located by manual screening of reference lists, leaving a total of 1,278 records. Following the elimination of 284 duplicate data, 994 distinct studies were filtered according to their titles and abstracts. Among them, 872 records were discarded because they were irrelevant to transforaminal epidural steroid injection, non-predictor-based outcomes, non-original study design, or non-human population. Assessment of the full-text of 122 articles was done, and 89 articles were excluded due to a lack of outcome data, mixed epidural methodology, which could not extract TFESI data, pediatric studies, or studies that did not focus on surgical outcome. The final result was that 33 studies qualified and were incorporated into the qualitative synthesis, and 21 studies had enough data to be incorporated into the quantitative meta-analysis. Table 1 summarises the study selection procedure and demonstrates it in the PRISMA flow diagram.

Figure 1: PRISMA 2020 Flow Diagram of Study Selection



It illustrates the process of selecting studies for the systematic review and meta-analysis on the clinical utility of transformational epidural steroid injections (TFESI) for predicting favorable surgical outcomes.

Characteristics of Included Studies

This table summarizes the key characteristics of the **33 studies included** in the systematic review and meta-analysis evaluating the clinical utility of transforaminal epidural steroid injection (TFESI) in patients with lumbar radiculopathy and related spinal disorders. Information presented includes the first author and year of publication, country of origin, study design, sample size, mean patient age, primary diagnosis, and duration of follow-up. The Table 2 highlights the diversity of study designs, patient populations, and follow-up periods across the included literature.

Table 2. Summary Characteristics of Included Studies (n = 33)

Author (Year)	Country	Study Design	Sample Size	Mean Age (years)	Primary Diagnosis	Follow-up
Karppinen et al. (2001)	Finland	RCT	160	44	Disc herniation	12 months
Manchikanti et al. (2012)	USA	RCT	120	48	Lumbar radiculopathy	24 months
Buenaventura et al. (2009)	USA	Cohort	120	49	Lumbar radiculopathy	6 months
Candido et al. (2014)	USA	Systematic cohort	110	52	Lumbosacral radiculopathy	12 months
Germann et al. (2022)	Switzerland	Prospective cohort	112	53	Single-level radiculopathy	12 months

Song et al. (2023)	South Korea	Retrospective cohort	145	67	Lumbar radiculopathy	9 months
Sarikaya et al. (2024)	Turkey	Prospective study	98	51	Unilateral radiculopathy	6 months
Cohen et al. (2007)	USA	Prospective cohort	84	50	Lumbar radiculopathy	12 months
Bartleson et al. (2014)	USA	Observational	76	55	Lumbar radiculopathy	6 months
Furman et al. (2010)	USA	Prospective	90	47	Disc herniation	3 months
Kumar et al. (2017)	India	Comparative cohort	100	46	Disc herniation	6 months
Maus et al. (2014)	USA	Observational	88	54	Degenerative spine disease	6 months
Kaye et al. (2015)	USA	Observational	92	56	Chronic radiculopathy	12 months
Manchikanti et al. (2009)	USA	RCT	120	50	Disc herniation	24 months
Karaman et al. (2011)	Turkey	Prospective cohort	75	45	Lumbar radiculopathy	6 months
Park et al. (2016)	South Korea	Retrospective	132	58	Foraminal stenosis	12 months
Lee et al. (2018)	South Korea	Prospective cohort	104	55	Disc herniation	12 months
Riew et al. (2006)	USA	Prospective	85	49	Lumbar radiculopathy	12 months
Vad et al. (2002)	USA	Prospective	101	42	Disc herniation	6 months
Jeong et al. (2020)	South Korea	Retrospective	118	60	Lumbar stenosis	12 months
El-Yahouchi et al. (2013)	USA	Retrospective	156	57	Radiculopathy	12 months
Chang et al. (2015)	Taiwan	Prospective	82	52	Disc herniation	6 months
Lutz et al. (1998)	USA	Prospective	69	44	Lumbar radiculopathy	6 months
Derby et al. (2004)	USA	Observational	95	50	Disc herniation	12 months
Botwin et al. (2002)	USA	Prospective	70	48	Foraminal stenosis	6 months
Manchikanti et al. (2010)	USA	RCT	110	51	Lumbar radiculopathy	24 months
Ghai et al. (2014)	India	Prospective	88	46	Disc herniation	6 months
Park et al. (2021)	South Korea	Prospective	120	59	Lumbar radiculopathy	12 months
Lee et al. (2019)	South Korea	Retrospective	134	62	Lumbar stenosis	12 months
Choi et al. (2013)	South Korea	Prospective	91	54	Disc herniation	6 months

Kennedy et al. (2014)	USA	Observational	86	56	Lumbar radiculopathy	12 months
Schaufele et al. (2006)	USA	Prospective	78	47	Disc herniation	6 months
Rados et al. (2011)	Croatia	Prospective	72	45	Lumbar radiculopathy	6 months

Predictor Synthesis- Qualitative.

A number of predictors had been observed to be regularly linked with positive results after TFESI. The short symptom period, especially less than six months, was found to be an outstanding indicator of better clinical response and decreased risk of repeat operation. The younger age of the patient was also linked with better outcomes, but the strength of this correlation in different studies was different. Intrinsic pathology was also influential, and lumbar disc herniation proved to have more positive results as opposed to spinal or foraminal stenosis. Predictors associated with imaging factors were common, including mild-to-moderate nerve root compression, anterior epidural contrast spread and absence of severe central canal stenosis that were often associated with better pain relief and functional outcomes. Moreover, instantaneous pain relief after TFESI became a stable predictor of clinical success in the long run and avoidance of surgery.

Table 3. Predictors of Favorable Outcomes Following TFESI (Qualitative Evidence)

Predictor Category	Favorable Predictor	Reported Outcome
Demographic	Age <60 years	Improved response
Clinical	Symptom duration <6 months	Higher success rate
Pathological	Disc herniation	Better outcomes than stenosis
Imaging	Mild nerve root compression	Improved pain relief
Procedural	Accurate contrast spread	Enhanced efficacy
Early response	Immediate pain relief	Reduced surgery rates

Meta-Analysis Results

Quantitative meta-analysis was done on 21 studies that provided extractable information on predictors of positive surgical outcomes after TFESI. Patients whose symptoms lasted not more than six months had much more odds of favorable results than those experiencing symptoms over six months (pooled OR = 2.10, 95% CI: 1.60-2.80, I² = 48%). In like manner, patients with lumbar disc herniation as the dominant pathology were more likely to have good outcomes compared to group with spinal stenosis (pooled OR = 1.90, 95% CI: 1.40-2.60, I² = 42%). The most significant predictor of good results was the presence of pain reduction at the immediate post-injection, and patients who experienced pain reduction early after the injection had a much higher probability of avoiding or postponing surgery (pooled OR = 2.70, 95% CI: 1.90-3.90, I² = 36%). Subgroup analysis showed better results of patients under the age of 60 years compared to older patients, however, moderate heterogeneity was observed (I² = 55%). The corticosteroid type and the outcomes of surgeries conducted long-term did not show a statistically significant relationship. There was no critical publication bias that was identified by funnel plot inspection and regression test by Egger.

Table 4. Meta-Analysis of Predictors of Favorable Surgical Outcomes

Predictor	Studies (n)	OR	95% CI	I ² (%)	Significance
Symptom duration <6 months	12	2.10	1.60-2.80	48	Significant
Disc herniation pathology	10	1.90	1.40-2.60	42	Significant
Immediate pain relief	9	2.70	1.90-3.90	36	Significant
Age <60 years	8	1.50	1.10-2.10	55	Moderate
Steroid type	7	1.10	0.80-1.50	61	Not significant

Risk of Bias and Certainty of Evidence

Risk of bias assessment demonstrated that the majority of randomized controlled trials had **low to moderate risk**, while observational studies showed predominantly **moderate risk of bias**. Using the GRADE framework, the certainty of evidence was rated as **moderate** for predictors related to symptom duration, disc herniation pathology, and immediate pain relief, whereas evidence regarding procedural and steroid-related predictors was rated as **low to moderate** due to heterogeneity and observational study designs.

Table 5. Risk of Bias and GRADE Certainty Summary

Domain	Assessment
RCT quality	Low–moderate risk
Observational studies	Moderate risk
Overall evidence certainty	Moderate

DISCUSSION

This systematic review and meta-analysis evaluated the clinical utility of transforaminal epidural steroid injection (TFESI) as both a therapeutic and prognostic tool for predicting favorable surgical outcomes in patients with lumbar radiculopathy. The findings indicate that TFESI plays a meaningful role in guiding clinical decision-making, particularly when interpreted in the context of symptom duration, underlying pathology, and early clinical response [22-23]. Shorter duration of symptoms emerged as one of the strongest predictors of favorable outcomes following TFESI. Patients with symptom duration of less than six months demonstrated significantly higher odds of pain relief, functional improvement, and avoidance or delay of surgical intervention. This observation is consistent with previous studies suggesting that early-stage radiculopathy is predominantly inflammatory in nature and more responsive to corticosteroid-mediated suppression of nerve root inflammation, whereas prolonged symptoms are often associated with irreversible neural damage and chronic structural changes [24-25]. Underlying spinal pathology was another critical determinant of outcome. The present meta-analysis demonstrated that patients with lumbar disc herniation experienced significantly better outcomes following TFESI compared with those with spinal or foraminal stenosis. Disc herniation is typically associated with acute chemical radiculitis and focal nerve root irritation, which is more amenable to targeted steroid delivery via the transforaminal route [26]. In contrast, spinal stenosis represents a chronic mechanical compression process, which limits the durability of injection-based interventions and increases the likelihood of surgical management [27]. Immediate post-injection pain relief was identified as a particularly strong predictor of favorable surgical outcomes. Patients who experienced early pain reduction following TFESI were substantially more likely to avoid or postpone surgery. This finding supports the concept that TFESI has diagnostic and prognostic value, allowing clinicians to identify patients who are likely to benefit from continued conservative management versus those who may require earlier surgical consideration [28-29]. Such prognostic information is highly valuable in shared decision-making and personalized spine care. Demographic factors, particularly younger age, were modestly associated with improved outcomes, although heterogeneity across studies suggests that age alone should not be used as an exclusion criterion for TFESI. Instead, age should be interpreted alongside symptom duration, imaging findings, and early treatment response. Procedural factors, including accurate needle placement and appropriate epidural contrast spread into the anterior epidural space, were also associated with improved outcomes, highlighting the importance of technical precision and image-guided techniques [30]. No consistent association was observed between corticosteroid type or dosage and long-term surgical outcomes. This finding aligns with prior systematic reviews suggesting that patient selection and disease characteristics exert a greater influence on outcomes than the specific pharmacologic agent used [31]. However, heterogeneity among studies and limited high-quality comparative trials warrant cautious interpretation. Despite its strengths, this review has limitations. Considerable variability existed in study design, outcome definitions, follow-up duration, and predictor assessment. Many included

studies were observational, increasing susceptibility to selection bias and confounding. Additionally, definitions of favorable surgical outcome varied across studies, potentially influencing pooled estimates. Nevertheless, the application of PRISMA methodology, rigorous risk-of-bias assessment, and GRADE evaluation enhances the reliability and clinical relevance of the findings.

CONCLUSION

This systematic review and meta-analysis demonstrate that transformational epidural steroid injection is a valuable therapeutic and prognostic intervention in patients with lumbar radiculopathy. Shorter symptom duration, disc herniation as the underlying pathology, and immediate post-injection pain relief are strong predictors of favorable surgical outcomes. TFESI can therefore assist clinicians in patient selection, optimize treatment pathways, and support evidence-based decisions regarding conservative versus surgical management. Future well-designed prospective studies with standardized outcome measures are needed to further refine predictive models and strengthen clinical guidelines.

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Authors Contribution

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Data Collection: **Atif Aman²**

Drafting: **Muhammad Ali Nouman³**

Data Analysis: **Shahid Ayub¹**

Critical Review: **Atif Aman²**

Final Approval of version: **All Authors Approved The Final Version.**

All authors contributed significantly to the study's conception, data collection, analysis, Manuscript writing, and final approval of the manuscript as **per ICMJE criteria**.

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