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Laminectomy and Foraminotomy Versus Bilateral Fenestration in Symptomatic Lumbar Spinal Canal Stenos is - Comparison of Results by Electrophysiological

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Abstract

Background: Lumbar spinal canal stenos is a progressive degenerative condition predominantly affecting the elderly, with surgery being the definitive treatment in symptomatic cases. Conventional outcome measures such as pain scales and radiological criteria are subjective and prone to inter - observer variability. Electro physiological parameters offer objective, reproducible surrogates of neural decompression adequacy. No prior published study has used nerve conduction parameters to compare these two surgical techniques.

Methods: The prospective comparative study enrolled 78 patients with MRI-proven symptomatic lumbar canal stenos is operated between July 2004 and January 2009. Patients with Spondylolisthesis, sensori motor poly neuropathy, dynamic instability, or requiring reoperation were excluded. Forty-five patients underwent laminectomy with for aminotomy; 33 underwent bilateral fenestration. All patients had bilateral lower limb EMG and nerve conduction studies performed preoperatively and at six-month follow-up. Statistical analysis was performed using both parametric and non-parametric tests in R and MATLAB.

Results: Bilateral fenestration demonstrated significantly greater improvement in combined H-reflex and F-wave latencies compared to laminectomy ($p < 0.01$). H-reflex latency showed statistically superior normalization with fenestration ($p < 0.01$). F-wave latency improvement, while clinically apparent, did not reach statistical significance between the two groups (p

> 0.01). No significant subgroup effects were identified based on age, sex, operative level, or duration of symptoms.

Conclusion: Bilateral fenestration achieves superior or equivalent neural decompression compared to laminectomy, as objectively demonstrated by electrophysiological outcomes. This technique should be considered the preferred surgical approach for symptomatic lumbar canal stenos is, offering adequate decompression while preserving posterior spinal stability.

Keywords: Decompression, H-Reflex, Laminectomy, Lumbar Vertebrae, Spinal Stenosis

Introduction

Lumbar spinal canal stenosis is one of the most prevalent degenerative conditions of the aging spine, characterized by progressive narrowing of the vertebral canal, lateral recesses, or intervertebral foramina, resulting in compression of the thecal sac and caudaequina nerve roots. Its incidence rises sharply beyond the fifth decade of life and disproportionately affects men earlier than women.[1] With the global demographic shift toward an older population, the burden of symptomatic lumbar canal stenos is has grown substantially, making it the most common indication for spinal surgery in patients over 65 years of age.[1,2]

The pathogenesis is rooted in the cumulative degenerative cascade involving the three-joint complex: the intervertebral disc and bilateral apophyseal joints. Repeated axial loading and rotational strain lead to disc height loss, annular bulging, facet joint hypertrophy, osteophyte formation, and thickening of the ligamentumflavum, all of which progressively encroach upon the neural elements.[3] The resulting clinical syndrome which is neuro genic claudication manifests as bilateral lower limb pain, dysesthesias, and weakness precipitated by walking and relieved by sitting or spinal flexion, a hallmark that distinguishes it from vascular claudication. Radiculopathy may coexist when lateral recess or foraminal stenos is compresses individual nerve roots.[2,4]

While conservative management with analgesics, anti-inflammatory agents, neuropathic pain modulators, and physiotherapy offers temporary symptomatic relief, the evidence for sustained benefit is limited. Surgery remains the definitive treatment for patients who fail conservative measures or exhibit neurological deterioration. Two widely practiced surgical strategies have emerged: laminectomy with foraminotomy, which achieves wide central decompression through removal of the spinous process, laminae, and ligamentumflavum, and bilateral fenestration (laminotomy), a less aggressive technique that preserves the spinous process, inter spinous ligaments, and the majority of the laminae, thereby maintaining the posterior tension band of the spine.[5,6,7] The theoretical advantages of bilateral fenestration over laminectomy relate to two well - recognized complications of the latter: postoperative spinal instability and epidural fibrosis.

Laminectomy disrupts the posterior stabilizing elements, potentially transferring compressive forces to the remaining spinal structures and predisposing to iatrogenic spondylolisthesis. Additionally, the larger raw bony surface exposed after laminectomy promotes fibroblast ingrowth from the paraspinal musculature, forming a laminectomy membrane that may engulf the dura and nerve roots, causing restenosis and failed back syndrome in a reported 6–8% of patients. Fenestration, by limiting bone removal, theoretically reduces both risks.[8,9]

Despite this Patho physiological reasoning, direct comparative evidence between the two techniques has remained elusive. Studies in the literature have relied on qualitative pain scales, patient-reported outcome questionnaires, and radiological measurements; all of which carry inherent limitations. Pain scales are subjective and influenced by psychological factors and general health status. Radiological assessments of decompression are prone to inter-observer variability and do not directly reflect the functional recovery of compressed neural tissue. What has been conspicuously absent from the published literature is an objective, quantifiable, and reproducible measure of the adequacy of neural decompression that is independent of patient-reported symptoms.[10,11] Electrophysiological parameters, specifically H-reflex latency and F-wave latency derived from nerve conduction studies fulfill this requirement precisely.

These measures assess the functional integrity of the proximal motor and sensori motor pathways of the lower limb nerve roots, the very structures compressed in lumbar canal stenos is. They are objective, standardized, and directly reflective of neuro physiological recovery following surgical decompression.[12,13]

The present study was designed to prospectively compare the outcomes of laminectomy with foraminotomy versus bilateral fenestration in patients with symptomatic lumbar canal stenos is, using preoperative and postoperative H-reflex and F-wave latency measurements as primary outcome measures. To the best of the authors' knowledge, this represents the first study in published literature to employ nerve conduction parameters for the objective comparison of these two established surgical techniques.

Materials and Methods

Study Design and Setting

This was a prospective comparative study conducted at the National Neurosciences Centre, Kolkata (Peerless Hospital Campus), over a period of approximately four and a half years from July 2004 to January 2009. The study was approved by the institutional authority and all patients provided informed consent prior to enrollment.

Patient Selection

A total of 78 patients with symptomatic lumbar spinal canal stenos is were enrolled. Diagnosis was established on clinical grounds and confirmed by MRI of the lumbar spine. Plain radiographs of the lumbar spine including Antero posterior, lateral, and dynamic flexion-extension views were obtained preoperatively in all patients.

Inclusion criteria required the presence of neuro genic claudication, either alone or in combination with radiculopathy, with corresponding MRI-confirmed lumbar canal stenos is. Exclusion criteria comprised: radio logically proven spondylolisthesis or dynamic instability on flexion-extension views; coexistent sensori motor poly neuropathy on nerve conduction studies; cases requiring reoperation for degenerative lumbar disease; vascular claudication from peripheral vascular pathology; and patients presenting with isolated radiculopathy without neuro genic claudication despite radiological evidence of canal narrowing.

Surgical Groups

The decision regarding surgical technique was made by the operating surgeon based on the patient's clinical presentation and MRI findings. The surgeon was blinded to the preoperative electrophysiological results at the time of surgical planning. Forty-five patients underwent laminectomy with for aminotomy, and 33 patients underwent bilateral fenestration (laminotomy). All surgeries were performed under general anesthesia in the prone position on a Wilson's frame. Intraoperative level localization was performed using a C-arm portable image intensifier both before skin incision and after bilateral laminar exposure. All bone work was executed under an operating microscope using a high-speed drill.

Laminectomy involved removal of the spinous process, inter spinous ligament, and bilateral laminae, preserving the facet joints and capsules.

The underlying ligamentumflavum was excised to the lateral extent of the canal. Discectomy was performed under the microscope where anterior compression warranted it. Bilateral fenestration involved creation of two laterally placed bony windows by drilling portions of the laminae above and below the affected level, preserving the spinous process, supra- and inter spinous ligaments, and the medial laminar arch. In both procedures, the medial aspect of the inferior articular facet of the superior vertebra was drilled as required by the degree of lateral recess compression.

Postoperative Rehabilitation

All patients were mobilized postoperatively with a lumbar corset. Claudication distance was recorded and monitored at each follow-up visit.

Electrophysiological Assessment

All patients underwent bilateral lower limb electromyography (EMG) and nerve conduction velocity (NCV) studies, including H-reflex and F-wave latency measurements, both preoperatively and at six-month follow-up. H-reflex upper limit of normal was taken as 35 ms, and F-wave upper limit as 61 ms. Patients with baseline sensorimotor polyneuropathy were excluded to ensure the validity of these measurements as indicators of root-level pathology.

Statistical Analysis

Pre- and postoperative electrophysiological data were compared within and between the two surgical groups. Both parametric (paired and unpaired t-tests) and non-parametric (Wilcox on signed-rank and Mann-Whitney U) tests were applied to account for data distribution. Subgroup analyses were performed for age, sex, symptom duration, and level of stenos is. All statistical analyses were conducted using R and MATLAB software. A p-value of less than 0.01 was considered statistically significant.

Results

A total of 78 patients with MRI-proven symptomatic lumbar canal stenos is were enrolled in this study. Of these, 45 patients underwent laminectomy with foraminotomy and 33 patients underwent bilateral fenestration.

The demographic and clinical characteristics of the two groups are summarized in Table 1. No statistically significant difference was observed between the two groups with respect to age, sex distribution, symptom duration, or a level of stenos is, confirming baseline comparability.

Table 1: Baseline Demographic and Clinical Characteristics of the Study Population

Characteristic	Laminectomy Group (n = 45)	Fenestration Group (n = 33)	p-value
Mean age (years ± SD)	56.4 ± 9.8	54.9 ± 10.3	0.52 (NS)
Sex: Male / Female	31 / 14	22 / 11	0.81 (NS)
Mean symptom duration (months ± SD)	18.6 ± 12.4	17.2 ± 11.9	0.61 (NS)
Single-level stenos is	28 (62.2%)	22 (66.7%)	0.68 (NS)

Multi-level stenos is	17 (37.8%)	11 (33.3%)	0.68 (NS)
Neuro genic claudication alone	18 (40.0%)	13 (39.4%)	0.96 (NS)
Claudication with radiculopathy	27 (60.0%)	20 (60.6%)	0.96 (NS)

NS = Not significant; SD = Standard deviation

Distribution of Stenos is Levels

The distribution of steno tic levels in the overall study population is presented in Table 2. The L4–L5 level was the most commonly affected single level, followed by L5–S1. Among multilevel cases, L4–L5–S1 was the predominant combination.

Table 2: Distribution of Levels of Stenos is (n = 78)

Level of Stenos is	Number of Patients	Percentage (%)
Single-level	50	64.1
L3–L4	2	4.0
L4–L5	33	66.0
L5–S1	15	30.0
Multi-level	28	35.9
L3–L4–L5	5	17.9
L4–L5–S1	18	64.3
L3–L4–L5–S1	5	17.9
Total	78	100

Preoperative Electrophysiological Parameters

Preoperative H-reflex and F-wave latency values in both groups are summarized in Table 3. No statistically significant intergroup difference was found in baseline electrophysiological parameters, confirming the comparability of the two groups prior to surgical intervention.

Table 3: Preoperative H-Reflex and F-Wave Latencies in Both Groups

Parameter	Laminectomy Group (mean ± SD, ms)	Fenestration Group (mean ± SD, ms)	p-value
H-reflex latency — Right	36.8 ± 3.2	37.1 ± 3.5	0.69 (NS)
H-reflex latency — Left	37.0 ± 3.4	36.6 ± 3.1	0.59 (NS)
F-wave latency — Right	63.4 ± 4.1	62.9 ± 3.8	0.57 (NS)
F-wave latency — Left	63.1 ± 4.3	63.5 ± 4.0	0.64 (NS)
H-reflex abnormal (>35 ms)	38 (84.4%)	28 (84.8%)	0.96 (NS)
F-wave abnormal (>61 ms)	34 (75.6%)	25 (75.8%)	0.98 (NS)

Upper limit of normal: H-reflex = 35 ms; F-wave = 61 ms; NS = Not significant

Postoperative Electrophysiological Parameters

At six-month follow-up, both groups demonstrated improvement in H-reflex and F-wave latencies. The postoperative values and within-group changes are presented in Table 4. Both groups showed statistically significant improvement from their respective preoperative baselines ($p<0.01$).

Table 4: Postoperative H-Reflex and F-Wave Latencies at Six-Month Follow-Up

Parameter	Laminectomy Group (mean ± SD, ms)	Fenestration Group (mean ± SD, ms)	p-value (within group)
H-reflex latency — Right	34.9 ± 2.8	33.1 ± 2.4	< 0.01 (both)
H-reflex latency — Left	35.2 ± 2.9	32.8 ± 2.3	< 0.01 (both)
F-wave latency — Right	61.8 ± 3.6	60.9 ± 3.2	< 0.01 (both)
F-wave latency — Left	61.5 ± 3.7	60.7 ± 3.1	< 0.01 (both)
H-reflex normalized (≤35 ms)	24 (53.3%)	26 (78.8%)	< 0.01
F-wave normalized (≤61 ms)	21 (46.7%)	18 (54.5%)	0.48 (NS)

Intergroup Comparison of Electrophysiological Improvement

The mean pre-to-postoperative change (delta) in H-reflex and F-wave latencies between the two surgical groups is presented in Table 5. The fenestration group demonstrated significantly greater reduction in H-reflex latency compared to the laminectomy group ($p<0.01$). The difference in F-wave latency reduction between the two groups, however, did not reach statistical significance ($p>0.01$).

Table 5: Comparison of Mean Change (Δ) in Electrophysiological Parameters Between Groups

Parameter	Δ Laminectomy Group (mean ± SD, ms)	Δ Fenestration Group (mean ± SD, ms)	p-value (intergroup)
Δ H-reflex — Right	1.9 ± 1.1	4.0 ± 1.6	< 0.01*
Δ H-reflex — Left	1.8 ± 1.2	3.8 ± 1.5	< 0.01*
Δ F-wave — Right	1.6 ± 1.0	2.0 ± 1.2	0.09 (NS)
Δ F-wave — Left	1.6 ± 1.1	2.8 ± 1.3	0.07 (NS)
Combined Δ (H + F)	6.9 ± 3.1	12.6 ± 4.2	**< 0.01***

Δ = mean preoperative minus postoperative latency; statistically significant at 1% level (both parametric and non-parametric tests)*

Subgroup Analysis

Subgroup analysis was performed to assess the influence of age, sex, symptom duration, and stenos is level on electrophysiological outcomes. As shown in Table 6, none of these variables demonstrated a statistically significant effect on the degree of electrophysiological improvement in either group.

Table 6: Subgroup Analysis (Factors Influencing Electrophysiological Outcome)

Subgroup Variable	Category	Δ H-reflex (ms)	Δ F-wave (ms)	p-value
Age	≤ 55 years	2.9 ± 1.4	1.9 ± 1.1	0.43 (NS)
	> 55 years	2.7 ± 1.5	1.7 ± 1.0	0.51 (NS)
Sex	Male	2.8 ± 1.3	1.8 ± 1.0	0.38 (NS)

	Female	2.6 ± 1.4	1.7 ± 1.1	0.41 (NS)
Symptom duration	≤ 12 months	3.1 ± 1.6	2.0 ± 1.2	0.29 (NS)
	> 12 months	2.5 ± 1.3	1.6 ± 0.9	0.33 (NS)
Stenos is level	Single-level	2.9 ± 1.4	1.9 ± 1.1	0.47 (NS)
	Multi-level	2.7 ± 1.5	1.8 ± 1.0	0.52 (NS)

NS = Not significant at 1% level

Summary of Electrophysiological Normalization Rates

Table 7 summarizes the proportions of patients achieving normalization of H-reflex and F-wave latencies at six months, stratified by surgical group. Fenestration achieved significantly higher H-reflex normalization rates compared to laminectomy, reinforcing the primary finding of the study.

Table 7: Rates of Electrophysiological Normalization at Six-Month Follow-Up

Outcome Measure	Laminectomy Group (n = 45)	Fenestration Group (n = 33)	p-value
H-reflex normalized	24 (53.3%)	26 (78.8%)	< 0.01*
H-reflex remained abnormal	21 (46.7%)	7 (21.2%)	< 0.01*
F-wave normalized	21 (46.7%)	18 (54.5%)	0.48 (NS)
F-wave remained abnormal	24 (53.3%)	15 (45.5%)	0.48 (NS)
Both H + F normalized	17 (37.8%)	16 (48.5%)	0.32 (NS)
Either H or F normalized	28 (62.2%)	28 (84.8%)	**< 0.01***

*Statistically significant at 1% level; NS = Not significant

Discussion

Lumbar spinal canal stenosis is a progressive degenerative condition predominantly affecting the elderly, characterized by neuro genic claudication resulting from compression of caudaequina nerve roots. Surgical decompression remains the definitive treatment in symptomatic patients who fail conservative management. While both techniques are widely practiced, a direct objective comparison of the adequacy of neural decompression achieved by each has been conspicuously absent from the literature. Conventional outcome measures such as pain scales and radiological parameters carry inherent subjectivity.[7,11]

Electrophysiological parameters being objective, reproducible, and directly reflective of proximal nerve root functional integrity, were therefore employed as primary outcome measures in the present prospective comparative study of 78 patients. The present study demonstrated that both surgical techniques produced statistically significant improvements in electro physiological parameters from baseline. Bilateral fenestration achieved significantly greater improvement in H-reflex latency compared to laminectomy ($p<0.01$), with H-reflex normalization rates of 78.8% versus 53.3% respectively. The difference in F-wave latency improvement between the two groups, while clinically apparent, did not attain statistical significance ($p>0.01$). The superior H-reflex normalization in the fenestration group is postulated to reflect less restrained lateral recess decompression; the intact posterior tension band in fenestration alleviates the surgeon's concern for postoperative instability, permitting more aggressive decompression of the lateral recess and foramen where the nerve root exits.

These findings resonate strongly with the meta-analysis by Zhang Y et al, which pooled 14 randomized controlled trials comprising 1,106 participants and demonstrated that bilateral laminotomy was significantly superior to conventional laminectomy in functional recovery [MD: −2.94; 95% CI −4.12 to −1.76], with a tenfold lower risk of iatrogenic instability [RR: 0.11; 95% CI 0.02 to 0.59] and a significantly higher good-to-excellent recovery rate [RR: 1.31; 95% CI 1.03 to 1.67.[14]

From an Indian perspective, Kariya AD et al studied 50 patients with degenerative lumbar canal stenosis who underwent decompressive laminectomy and reported a significant improvement in ODI score from a baseline of 71.2 ± 6.4 to 21 ± 15.6 at six-month follow-up ($p < 0.05$), confirming the efficacy of laminectomy in improving functional outcomes.[15] However, the single-arm design of that study precluded a comparative assessment of fenestration which is a limitation directly addressed by the present study.

From South India, Vyasa K et al prospectively studied 30 patients undergoing lumbar fenestration Discectomy and reported that 53.3% achieved minimal disability postoperatively, mean VAS improved from 6.40 preoperatively to 1.40 at 12 weeks, and the complication rate was a low 3.3%.[16] The low complication profile and rapid functional recovery following fenestration in that South Indian cohort are concordant with the results of the present study.

The electrophysiological methodology of the present study was further contextualized by Kaur M et al, who evaluated electro diagnostic parameters in 51 patients of lumbar canal stenos is in India and found significantly reduced motor and sensory nerve conduction velocities with increasing severity of stenos is ($p < 0.01$), while latency and amplitude changes were non-significant.[17] This finding affirms the selection of H-reflex and F-wave latencies, more sensitive proximal root-level electrophysiological indicators as outcome parameters in the present study.

From the South East Asian literature, Khalid M et al compared modified fenestration versus traditional laminectomy in 50 patients with lumbar disc herniation over 12-month follow-up and reported superior outcomes in the fenestration group, persistent pain in only 48% versus 92% in the laminectomy group, shorter operative time (55.6 vs. 98.2 minutes), markedly reduced blood loss (25–50 ml vs. 150–200 ml), and spinal stability maintained in 75% versus 50% of patients respectively.[18] These results closely mirror the present study's conclusion regarding the superiority of fenestration-type approaches.

At the broader Asian level, Hou Y et al introduced the selective fenestration and axial decompression (SFAD) technique in a retrospective Chinese study of 101 patients and demonstrated equivalent VAS and ODI improvements compared to posterior lumbar interbody fusion, with significantly lower operative time, blood loss, hospital stay, and total complication rates (18.75% vs. 43.40%, $p < 0.05$).[19] Similarly, Lee CW et al compared three lumbar decompression techniques: microscopic, tubular, and full-endoscopic in 270 patients with lumbar canal and lateral recess stenosis and reported comparable VAS and ODI improvements across all groups (overall clinical success rate 89.4%), with minimally invasive approaches demonstrating significantly less postoperative back pain, lower serum

CPK elevation, and shorter hospital stays compared to open microsurgical laminotomy.[20] Both these studies reinforce the clinical principle, validated in the present study, that preservation-oriented surgical approaches achieve decompression equivalent to or better than more destructive techniques.

At the global level, Melcher C et al reported outcomes in 438 consecutive patients with lumbar stenosis who underwent decompressive laminotomy or laminotomy with fusion, noting that claudication resolved in 98% of patients and preoperative VAS scores improved significantly.[21] Notably, the revision surgery rate was 11.8%, the most common late complication being adjacent-level stenos is and instability, findings that highlight the very postoperative risks associated with more extensive decompression that bilateral fenestration is specifically designed to mitigate, as corroborated by the present study.

The present study carries certain limitations that merit acknowledgment. The surgical technique was not randomized, the choice between laminectomy and bilateral fenestration was surgeon-directed based on the patient's clinical profile and MRI findings, introducing potential selection bias. Validated functional outcome instruments such as the Oswestry Disability Index or Visual Analogue Scale were not incorporated as co-primary outcomes, limiting direct comparability with the majority of published studies. The follow-up period of six months, while adequate for electrophysiological assessment of neural recovery, may not capture late complications such as adjacent segment disease, rest enosis, or postoperative spinal instability. The sample size, though sufficient for the primary electrophysiological analysis, restricts the power of subgroup analyses.

Notwithstanding these limitations, the study offers important advantages. To the authors' knowledge, this is the first published study in international literature to employ objective nerve conduction parameters to directly compare the adequacy of neural decompression between laminectomy with foraminotomy and bilateral fenestration in lumbar canal stenosis. The electrophysiological approach eliminates the subjectivity inherent in patient-reported pain scores and the inter-observer variability of radiological measurements, providing a level of objectivity that strengthens the validity of the conclusions. The clinical implication is unambiguous: bilateral fenestration, by preserving the posterior tension band of the spine while achieving superior neural decompression as evidenced by significantly better H-reflex normalization, should be considered the preferred surgical approach for symptomatic lumbar canal stenos is. This is particularly relevant in elderly patients in whom postoperative spinal instability carries heightened morbidity, and in health systems where minimizing surgical access trauma and reducing hospital stay duration are priorities.

Conclusion

The present prospective comparative study demonstrates that bilateral fenestration achieves superior neural decompression compared to laminectomy with foraminotomy in symptomatic lumbar canal stenos is, as objectively evidenced by significantly greater H-reflex latency normalization at six-month follow-up (78.8% vs. 53.3%; $p < 0.01$). F-wave improvement, while clinically apparent, was comparable between groups. No demographic or disease-related subgroup influenced outcomes significantly. Bilateral fenestration, by preserving posterior spinal stability while ensuring adequate decompression, should be adopted as the preferred surgical approach for symptomatic lumbar canal stenos is.

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