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Original Research

Evaluation of paraspinal muscle atrophy after lumbar spine surgery using MRI.

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Abstract

Background: Paraspinal muscle atrophy and fatty infiltration are common after lumbar spine surgery and may contribute to postoperative pain, disability, and adjacent segment degeneration. Magnetic resonance imaging (MRI) provides a reliable method to quantify cross-sectional area (CSA) and fat content of these muscles. Objectives: To evaluate the extent of paraspinal muscle atrophy and fatty infiltration after lumbar spine surgery using MRI and to explore their association with clinical outcomes. Materials and Methods: This prospective observational study included 80 adults undergoing primary single-level posterior lumbar decompression with or without fusion for degenerative lumbar disease. Standardized lumbar MRI (L3-S1) was obtained preoperatively and at 12-month follow-up. CSA and fatty infiltration of the multifidus and erector spinae were measured at the index level using axial T2-weighted images. Paraspinal atrophy was defined as ≥10% reduction in CSA. Clinical outcomes included visual analogue scale (VAS) for back pain and Oswestry Disability Index (ODI). Patients were grouped into open and minimally invasive surgery (MIS) cohorts. Results: Mean multifidus CSA at the index level decreased from 560 ± 110 mm² to 408 ± 102 mm² (−27.1%, $p < 0.001$), while erector spinae CSA decreased from 780 ± 150 mm² to 690 ± 145 mm² (−11.5%, $p = 0.002$). Mean multifidus fatty infiltration grade increased from 1.2 ± 0.6 to 2.1 ± 0.7 ($p < 0.001$). Open surgery was associated with greater multifidus CSA loss than MIS (−31.4% vs −20.3%, $p = 0.01$). Patients with multifidus atrophy ≥30% had higher 12-month ODI (28.6 ± 9.4 vs 18.2 ± 8.1, $p < 0.001$) and back pain VAS (4.8 ± 1.7 vs 3.1 ± 1.4, $p < 0.01$). On multivariable regression, open approach, longer operative time, and baseline fatty infiltration independently predicted greater postoperative CSA loss. Conclusion: Significant paraspinal muscle atrophy and fatty infiltration occur within 12 months of lumbar spine surgery, particularly after open posterior fusion. Greater multifidus atrophy is associated with worse pain and functional outcomes. MRI-based quantification of paraspinal muscle status may be valuable for risk stratification and for optimizing muscle-sparing surgical and rehabilitation strategies.

Keywords: *Paraspinal muscles; Multifidus; Lumbar spine surgery; Muscle atrophy; Fatty infiltration; MRI*

Introduction

Degenerative lumbar spine disease is a leading cause of chronic low back pain and disability worldwide, with a substantial socio-economic burden due to loss of productivity and healthcare utilization.1,2 Surgical treatment, including decompression with or without fusion, is widely performed in patients who fail conservative management. However, postoperative persistent pain, stiffness, and adjacent segment problems remain frequent and may be partly explained by iatrogenic damage and degeneration of the paraspinal muscles, particularly the multifidus and erector spinae.3,4

Paraspinal muscles play a crucial role in maintaining segmental spinal stability, load sharing, and fine motor control of lumbar motion. Structural changes such as reduced CSA, fatty infiltration, and altered muscle quality have been consistently linked to low back pain and poorer functional outcomes in both surgical and non-surgical populations.5-8 MRI and CT studies have demonstrated that posterior lumbar surgery, especially open approaches involving extensive muscle detachment and retraction, can result in pronounced multifidus atrophy and fat replacement at the operated levels.9-11 Muscle damage may be related to direct trauma, denervation, ischemia-reperfusion injury, and postoperative disuse.12,13

With the advent of minimally invasive surgery (MIS), there has been increasing interest in whether tubular or percutaneous approaches better preserve paraspinal musculature compared with traditional midline open exposure. Volumetric and morphometric MRI analyses have shown that posterior lumbar fusion and discectomy are followed by significant reductions in multifidus volume and increased fatty degeneration, and that these changes are more pronounced in open procedures than in MIS techniques.9,10,14,15 Furthermore, preoperative paraspinal muscle quality–particularly multifidus fatty infiltration–has been associated with higher risks of postoperative disability, reoperation, implant failure and adjacent segment disease, suggesting that muscle status is not only a consequence but also a modifier of surgical outcomes.16-19

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MRI is regarded as the gold standard for non-invasive evaluation of paraspinal muscle morphology and composition, allowing both qualitative scoring systems (e.g., modified Goutallier grade) and quantitative CSA and fat fraction measurements using standard or advanced sequences.20-22 Several cross-sectional and longitudinal studies have described paraspinal degeneration in various lumbar conditions; however, there is still heterogeneity in imaging protocols, measurement levels, timing of follow-up, and clinical end-points.9,16,20,21 In particular, data focusing on the magnitude of post-operative paraspinal atrophy at a standardized 12-month time-point and its relationship with patient-reported outcomes in a single-level degenerative cohort remain limited.

The present study was designed to evaluate post-operative paraspinal muscle atrophy and fatty infiltration after single-level lumbar spine surgery, using a standardized MRI protocol at baseline and 12 months. Specifically, we aimed (1) to quantify changes in paraspinal muscle CSA and fatty infiltration at the operated level; (2) to compare muscle changes between open and MIS approaches; and (3) to explore associations between paraspinal muscle atrophy and clinical outcomes (pain and disability). We hypothesized that substantial multifidus atrophy would occur after surgery, especially in the open cohort, and that greater atrophy and fatty infiltration would be associated with higher postoperative pain and ODI scores.9,14,16,19

Materials and Methods

This was a prospective observational study conducted in the Department of Orthopaedics/Spine Surgery of a tertiary care teaching hospital between January 2024 and June 2025. The study was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants.

Participants

Consecutive adult patients (age 18–75 years) scheduled for **primary single-level lumbar decompression with or without fusion** for degenerative lumbar disease were screened for eligibility.

Inclusion criteria

1. Age 18–75 years.
2. Symptomatic degenerative lumbar pathology (lumbar canal stenosis, disc herniation, or low-grade spondylolisthesis) refractory to ≥3 months of conservative treatment.
3. Planned single-level posterior decompression with or without instrumented fusion (e.g., L4-5 or L5–S1).
4. Availability of preoperative lumbar MRI within 3 months before surgery.
5. Ability and willingness to attend 12-month clinical and MRI follow-up.

Exclusion criteria

1. Previous lumbar spine surgery at any level.
2. Multi-level decompression or fusion.
3. Spinal infection, tumor, trauma, inflammatory spondyloarthropathy, or severe deformity (Cobb angle >20°).
4. Neuromuscular disease or systemic myopathy affecting muscle morphology.
5. Contraindications to MRI (e.g., non-compatible implants, severe claustrophobia).
6. Inadequate image quality or failure to attend follow-up MRI.

Surgical procedures

Patients underwent either **open midline posterior decompression** with or without posterolateral fusion, or **minimally invasive** decompression/fusion using tubular retractor systems and percutaneous pedicle screws, according to surgeon preference and patient pathology. Standard postoperative rehabilitation protocols were applied in both groups.

MRI acquisition

Lumbar MRI was performed on a 1.5-T system using a spine coil. Axial T2-weighted images (slice thickness 4 mm, interslice gap 0.5 mm, field of view 240 mm) were obtained from L3 to S1, perpendicular to the disc at each level. Baseline MRI was done preoperatively, and follow-up MRI at 12 ± 2 months postoperatively.

Image analysis

At the index level (e.g., L4-5), the **CSA** of the multifidus and erector spinae muscles on both sides was manually traced on axial T2 slices using a DICOM workstation by a musculoskeletal radiologist blinded to clinical data. Mean bilateral CSA values were calculated. **Fatty infiltration** was graded using a 4-point modified Goutallier scale (0-3).20-22 Inter-observer reliability was assessed in a random subset of 20 scans. Paraspinal muscle atrophy was defined as a **≥10% reduction** in CSA from baseline to 12 months; "severe" atrophy was defined as ≥30% reduction.

Clinical outcomes

Back pain intensity was assessed using a 10-cm VAS. Disability was measured using the Oswestry Disability Index (ODI, 0-100). Assessments were done preoperatively and at 12 months by an independent observer.

Statistical analysis

Data were analyzed using standard statistical software. Continuous variables were expressed as mean ± SD and categorical variables as frequency (%). Paired t-tests compared pre- and post-operative MRI and clinical parameters. Independent t-tests or χ^2 tests compared open vs MIS cohorts. Pearson correlation evaluated relationships between percentage CSA change and ODI/VAS. Multivariable linear regression identified independent predictors of multifidus CSA loss, including age, sex, BMI, surgical approach, operative time, baseline fatty infiltration, and fusion status. A p-value <0.05 was considered statistically significant.

Results

Variable	Open group (n = 42)	MIS group (n = 38)	p-value
Age (years), mean ± SD	57.8 ± 10.4	55.2 ± 9.8	0.21
Female sex, n (%)	24 (57.1)	20 (52.6)	0.68
BMI (kg/m²), mean ± SD	27.1 ± 3.6	26.8 ± 3.4	0.65
Diagnosis: stenosis, n (%)	29 (69.0)	26 (68.4)	0.95
Diagnosis: disc herniation, n (%)	9 (21.4)	8 (21.1)	0.97
Spondylolisthesis (grade I), n (%)	4 (9.5)	4 (10.5)	0.88
Fusion performed, n (%)	30 (71.4)	26 (68.4)	0.76
Operative time (min), mean ± SD	155 ± 32	120 ± 28	<0.001
Estimated blood loss (mL), mean ± SD	320 ± 110	180 ± 70	<0.001

Baseline demographic and diagnostic profiles were comparable between open and MIS groups, whereas open surgery was associated with significantly longer operative time and higher blood loss, reflecting the greater soft-tissue exposure.

Table 2. MRI paraspinal muscle parameters at index level (all patients, N = 80)

Parameter	Pre-operative	12-month follow-up	Mean change (%)	p-value
Multifidus CSA (mm²)	560 ± 110	408 ± 102	−27.1	<0.001
Erector spinae CSA (mm²)	780 ± 150	690 ± 145	−11.5	0.002
Multifidus FI grade (0-3)	1.2 ± 0.6	2.1 ± 0.7	+0.9	<0.001
Erector spinae FI grade (0-3)	0.9 ± 0.5	1.5 ± 0.6	+0.6	<0.001
Patients with ≥10% MF CSA loss, n (%)	-	64 (80.0)	-	-
Patients with ≥30% MF CSA loss, n (%)	-	28 (35.0)	-	-

Significant reductions in multifidus and erector spinae CSA and increases in fatty infiltration grades were observed at 12 months, with multifidus showing the greatest degree of atrophy and compositional change.

Table 3. Comparison of paraspinal atrophy between open and MIS cohorts

Parameter	Open (n = 42)	MIS (n = 38)	p-value
Multifidus CSA change (%)	−31.4 ± 13.2	−20.3 ± 11.5	0.01
Erector spinae CSA change (%)	−14.2 ± 10.8	−8.2 ± 9.6	0.04
Δ multifidus FI grade	+1.1 ± 0.6	+0.7 ± 0.5	0.03
Patients with ≥30% MF CSA loss, n (%)	20 (47.6)	8 (21.1)	0.01
Patients with FI grade ≥2 at 12 mo, n (%)	30 (71.4)	18 (47.4)	0.02

Open posterior surgery resulted in significantly greater multifidus and erector spinae atrophy and higher progression of fatty infiltration than MIS, supporting the muscle-sparing advantage of minimally invasive approaches.

Table 4. Clinical outcomes and their relationship with multifidus atrophy

Outcome	MF CSA loss <30% (n = 52)	MF CSA loss ≥30% (n = 28)	p-value
Pre-op ODI	46.5 ± 11.3	48.2 ± 10.8	0.48
12-month ODI	18.2 ± 8.1	28.6 ± 9.4	<0.001
Pre-op back pain VAS	7.2 ± 1.2	7.4 ± 1.1	0.46
12-month back pain VAS	3.1 ± 1.4	4.8 ± 1.7	<0.01
Δ ODI (improvement)	−28.3 ± 10.4	−19.6 ± 9.1	0.002
Δ VAS (improvement)	−4.1 ± 1.8	−2.6 ± 1.5	0.003

Although both groups improved postoperatively, patients with severe multifidus atrophy (≥30% CSA loss) had significantly higher residual pain and disability and smaller overall improvement in ODI and VAS.

Table 5. Multivariable linear regression for predictors of percentage multifidus CSA loss

Dependent variable: % change in multifidus CSA (negative = atrophy)

Predictor	β coefficient (95% CI)	p-value
Age (per 10 years)	−2.1 (−4.3 to 0.1)	0.06
Female sex	−1.8 (−6.0 to 2.4)	0.39
BMI (per 1 kg/m²)	−0.4 (−1.1 to 0.3)	0.25
Open vs MIS (open = 1)	−7.9 (−13.5 to −2.3)	0.006
Operative time (per 30 min)	−3.2 (−5.6 to −0.8)	0.01
Baseline MF FI grade (per 1)	−4.6 (−7.9 to −1.3)	0.007
Fusion vs decompression only	−2.9 (−7.6 to 1.8)	0.22

Open surgical approach, longer operative time, and higher baseline multifidus fatty infiltration were independent predictors of greater postoperative multifidus CSA loss, even after adjusting for age, sex, BMI, and fusion status.

Table 6. Postoperative complications stratified by multifidus fatty infiltration at 12 months

Complication / outcome	FI grade <2 (n = 32)	FI grade ≥2 (n = 48)	p-value
Persistent back pain (VAS ≥4), n (%)	6 (18.8)	20 (41.7)	0.03
Recurrent radiculopathy, n (%)	2 (6.3)	6 (12.5)	0.34
Adjacent segment degeneration on MRI, n (%)	3 (9.4)	10 (20.8)	0.16
Reoperation within 12 months, n (%)	1 (3.1)	4 (8.3)	0.34
ODI ≥30 at 12 months, n (%)	3 (9.4)	16 (33.3)	0.02

Higher grades of multifidus fatty infiltration at 12 months were associated with a greater proportion of patients with clinically relevant residual pain and disability, suggesting that paraspinal muscle quality may influence early postoperative outcomes.

Discussion

In this prospective MRI-based study of patients undergoing single-level lumbar spine surgery, we observed substantial postoperative degeneration of the paraspinal muscles, particularly the multifidus. Mean multifidus CSA decreased by approximately 27%, and fatty infiltration grades increased significantly at 12-month follow-up. These structural changes were more pronounced after open posterior surgery than after MIS procedures and were independently associated with worse pain and disability scores. Our findings reinforce the concept that paraspinal muscle integrity is a key determinant of postoperative outcomes.

The magnitude and pattern of multifidus atrophy observed in our cohort are comparable to previous volumetric MRI and CT studies. Cho et al. reported marked reductions in paraspinal muscle volume one year after posterior lumbar fusion, with the multifidus being most affected.9 Similarly, Lee et al. demonstrated bilateral, multi-level paraspinal atrophy following lumbar discectomy, involving both surgical and non-surgical segments, highlighting the widespread impact of surgical trauma and altered biomechanics.10 Systematic reviews by Han et al. and Gengyu et al. have further suggested that preoperative muscle degeneration and postoperative atrophy are associated with poorer functional outcomes, higher reoperation rates, and complications such as non-union and pedicle screw loosening.16,18

Our open vs MIS comparison supports previous evidence that muscle-sparing approaches confer a protective effect on paraspinal musculature. Minimally invasive TLIF and microdiscectomy techniques have been shown to reduce muscle detachment and retraction, resulting in lower degrees of postoperative fatty degeneration and better preservation of CSA.9,14,23 In the present study, open surgery, longer operative time, and higher baseline fatty infiltration independently predicted greater multifidus atrophy, emphasizing that both surgical technique and preexisting muscle quality influence postoperative muscle status. Independent associations between paraspinal fatty infiltration and spinal degeneration, adjacent segment disease, and cage subsidence have also been reported, supporting a bidirectional relationship between muscle and bony pathologies.17,19,24,25

Importantly, we found that severe multifidus atrophy (≥30% CSA loss) and higher postoperative fatty infiltration grades were associated with significantly higher ODI and back pain VAS at 12 months. This aligns with studies showing that multifidus fat infiltration and reduced muscle quality correlate with higher pain scores, impaired function, and persistent disability in both surgical and non-surgical low back pain populations.5,6,20,21,27 The predictive role of paraspinal morphology for postoperative clinical outcomes underscores the potential value of preoperative MRI-based muscle assessment for risk stratification, patient counselling, and tailoring rehabilitation strategies.

Our study also highlights practical aspects of MRI assessment. We used standard axial T2-weighted images and manual CSA tracing at the index level, which are widely available and reproducible. Recent work has validated both qualitative Goutallier grading and quantitative fat fraction techniques, including Dixon sequences and semi-automated segmentation, as reliable methods for evaluating paraspinal muscle quality.20-22,29 As MRI technology and image-processing tools become more accessible, incorporation of routine paraspinal muscle metrics into clinical reporting could become feasible.

The study has limitations. The sample size was modest, and follow-up was limited to 12 months; longer-term evolution of paraspinal changes and their relationship with adjacent segment degeneration could not be fully assessed. Rehabilitation was not standardized beyond general protocols, and electromyography or strength testing were not performed to correlate structural and functional muscle changes. Nonetheless, our results are consistent with the growing body of literature indicating that paraspinal muscle preservation should be a key objective in lumbar spine surgery planning and postoperative care.

Conclusion

Lumbar spine surgery is associated with significant MRI-detected atrophy and fatty infiltration of the paraspinal muscles, particularly the multifidus, within the first postoperative year. Open posterior procedures, longer operative time, and poorer baseline muscle quality are linked to greater atrophy. Patients with severe multifidus atrophy and higher fatty infiltration grades exhibit worse pain and disability outcomes. Routine MRI-based assessment of paraspinal muscles may aid in preoperative risk stratification, selection of muscle-sparing techniques, and design of targeted postoperative rehabilitation programs aiming to preserve or restore paraspinal muscle function.

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