REVIEW

Back Muscle Injury During Posterior Lumbar Spine Surgeries: Minimally Invasive Versus Open Approaches. A Review of the Literature

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Abstract

Background data: **The use of less-invasive procedures during surgery for thoracolumbar and lumbar problems has grown in importance. Mini-open or minimally invasive procedures lessen intraoperative bleeding and postoperative back pain compared with open techniques. Uncertainty persists on whether minimally invasive surgeries cause less paraspinal muscle injury than open surgery. According to some reports, compared with open surgery, minimally invasive surgeries might result in less muscle atrophy and fat infiltration.**

Purpose: **This study aimed to find whether minimally invasive posterior lumbar spine surgery can lessen paraspinal muscle damage, restrict alterations in muscular structure and function, and improve functional outcomes.**

Study design: **A literature review was performed.**

Patients and methods: **A cross-referencing and extramanual search of the literature in PubMed and MEDLINE, the Cochrane Library databases, and Google Scholar search was conducted. Studies comparing traditional open surgery with minimally invasive or percutaneous procedures were included. In total, 40 studies comparing both techniques were found and analyzed. The muscle state assessment was extended up to 2 years in human studies.**

Results: **A total of 11 studies were conducted on experimental animals, and the remaining studies were either case−control studies, case series, or comparative studies comparing the size of the multifidus muscle between patients with various lumbar spine disorders treated either conventionally or using minimally invasive techniques.**

Conclusion: **Even though the degree of evidence is relatively weak, the present study revealed that the minimally invasive posterior spinal techniques have some advantages over the open techniques, such as less damage to the multifidus muscle, which is supported by the literature review. The association between changes in muscular structure and pain, strength, and quality of life needs to be better understood via research. These investigations ought to focus on the surgical approach (2022ESJ257).**

Keywords: Functional outcome, Minimally invasive, Open, Paraspinal muscle, Percutaneous

Introduction

Surgery combining cylindrical retractor blades, sleeves, or tubes with a muscle-dilating or muscle-splitting approach was described as minimally invasive. Open (conventional) spine surgeries were described as being performed using a method that involves raising or removing the paraspinal muscles to reach the spine, regardless of the length of the midline incision [1].

In recent years, minimally invasive spine surgery (MISS) techniques have become increasingly common among surgeons. On the backside of the spine, there is a collection of muscles connected to the posterior portions of the spine. The most important

Received 5 January 2022; accepted 29 March 2022.
Available online 1 April 2022

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Online ISSN: 2314 - 8969; Print ISSN: 2314 - 8950; *esj.researchcommons.org*

https://doi.org/10.57055/2314-8969.1259

muscles of the lumbar spine include the multifidus, which stabilizes and rotates the lumbar spine, and the longissimus, which begins in the middle of the lumbar spine and continues up to the transverse process. Therefore, during spine surgery employing the posterior approach, the surgeon must detach and retract these muscles to create a surgical access corridor [2].

The capacity to perform spinal decompression and fusion without detachment of the back muscles from their attachments in the posterior vertebral column, reducing pressure on the muscles with special low-profile retractors, and constricting the operating space are all made possible by an increasing number of different surgical techniques and tools [2,3].

The paraspinal musculature is dissected and retracted in the conventional method. Compression of the back muscles by retractors increases the intramuscular pressure to levels that impedes the local blood flow of the muscles, resulting in ischemia, atrophy, and denervation [4–13]. However, minimally invasive techniques reduce the time that muscles, nerves, and arteries are retracted and the risk of paraspinal muscles detaching [13–17]. Following MIS, serum enzyme levels were dramatically reduced, especially creatine kinase, and a less systemic inflammatory response was noted [14,18–21]. Capillary perfusion is inhibited after open spinal surgery, leading to the degradation of muscle fibers and altered cell metabolism [22,23]. Interstitial edema, sarcolemma disintegration, and mitochondrial changes that suggest muscle fiber necrosis are also brought on by the pressure of retraction [24,25] The muscle fiber cross-section atrophy [measured by computed tomography (CT) scan or MRI)] is the outcome of altered muscle use following injury and surgery because of recovery, discomfort, impairments in motor ability, or other causes. Previous studies that compared minimally invasive and conventional procedures measured the invasiveness of the surgery directly using the length of the surgical incisions, whereas other studies employed indirect metrics like blood loss intraoperatively or creatine phosphokinase (CPK) levels postoperatively. Meanwhile, all these techniques failed to account for the amount of muscle tissue that must be removed from the spine and dissected to create the required surgical corridor [26–28]. It is still unclear if minimally invasive thoracolumbar and lumbar spine surgery can reduce paraspinal muscle damage with an impact on clinical outcomes compared with conventional surgery. This study was intended to summarize and discuss the relevant research.

Patients and methods

A review of the literature was done in the PubMed and MEDLINE, Cochrane databases, and Google Scholar search by cross-referencing and further manual search to compare the evidence of altered lumbar back muscle structure and function following minimally invasive or conventional posterior lumbar surgical techniques from January 1971 to April 2022.

The primary inclusion criteria were studies comparing conventional or minimally invasive and percutaneous posterior surgical techniques regarding back muscle damage. Regarding the back muscles, imaging and histochemical methods and clinical or functional outcomes were considered. Only articles in the English language were included in the study.

In total, 1756 studies on the participant were found. It included conventional posterior spinal procedures such as discectomy, lumbar interbody fusion, or posterior lumbar interbody fixation, and/or fusion for traumatic or degenerative illnesses. Minimally invasive or percutaneous surgical methods included the use of endoscopy or tube retractors, intermuscular splitting, or a spinous process splitting technique. The lumbar multifidus muscle was to be preserved using all these surgical techniques.

Results

After eliminating duplicate research, the computerized search turned up a total of 227 studies. After examining titles and abstracts, it was determined that 40 papers were to be included (Fig. 1).

Study characteristics

A total of 11 studies were conducted on experimental animals. The remaining studies were either case–control studies, case series, or comparative studies assessing the size of the multifidus muscle or the paraspinal muscle group in different patients with various lumbar spine disorders who underwent either minimally invasive or conventional treatment.

Imaging assessment of paraspinal muscles

Quantitative analysis of MRI or CT images, using computer analysis with specialized software, was used in numerous studies to examine how posterior lumbar operations affected the paraspinal

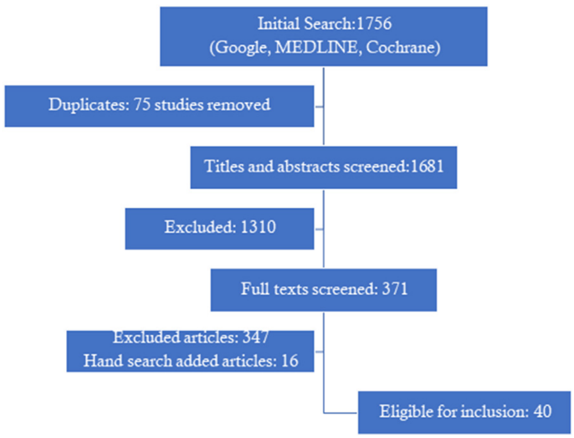

Fig. 1. Flowchart outlining the literature review process.

muscles [18,27,28]. Numerous studies used cross-sectional area measurement using T1-weighted images obtained in the axial plane to accomplish two-dimensional analysis [29,30]. Through a straightforward assessment of the image, the volume of the paraspinal muscles was also calculated [31] (Table 1).

For symptomatic herniated discs, Hellinger et al. [38], found variations in multifidus atrophy and fatty replacement between microsurgery and endoscopic discectomy. Relative cross-sectional area (rCSA) data from MRI taken at 4 days after surgery revealed lessened trauma and a much lower mean surgical defect zone in the endoscopic group (17 vs. 41%) against the group that underwent microsurgery. Postoperatively, there were no noticeable variations in the rCSA for the multifidus replaced with fatty tissue between the interlaminar endoscopic (20%) and microsurgical (22%) groups. In the axial T2-weighted MRI performed 1 year after surgery, compared with endoscopy (6%), the defect zone, including scar formations, was much larger following microsurgical treatments (62%). Following microsurgery and endoscopy, the mean rCSA decreased by 2 and 23%, respectively, owing to the fatty replacement of the muscles adjacent to the spine.

Motosuneya et al. [37], used MRI to compare the cross-sectional area of the back muscles before and after five different surgical procedures, including anterior lumbar interbody fusion, posterior lumbar interbody fusion (PLIF), posterolateral lumbar fusion (PLF), laminectomy or fenestration, and Love's nucleotomy for degenerative conditions. Postoperatively, the anterior lumbar interbody fusion group's back muscle cross-sectional area decreased from 69.015.7 to 64.514.8 cm^2 ($P = 0.028$). The ratio of atrophy was 0.94 ± 0.10. Back muscles in the PLIF group had a postoperative decrease in the

Table 1. Degree of muscle damage (in percentage) assessed by clinical imaging in the open versus minimal access posterior lumbar spine approaches.

References	Approach	Paraspinal muscle change after surgery
An et al. [32]	LE-ULBD	SL: MF (+2%); ES (+6.5%) ML: MF (+1.5%); ES (+1.2%)
Bresnahan et al. [4]	Lumbar decompression	Open: adjacent level (−5.4%); MEDS: adjacent level (+9.9%); no difference between sides
Cho et al. [31]	PLIF	MF (−34%), ES (−9%)
Fan et al. [14]	PLIF and bilateral LPSF	Open: operative level (−36.8%) adjacent level and (−29.3%); mini-open: operative level (−12.2%) and adjacent level (−8.5%)
Gille et al. [33]	Decompression and bilateral LPSF	Open: (1) with cholinergic blockade: superior level (−2%) and inferior level (−24%); (2) without cholinergic blockade: superior level (−6%) and inferior level (−30%)
He et al. [34]	OLIF and OLIF + PPSF	OLIF: MF (+8.5%); ES (+1.7%) OLIF + PPSF: MF (−25%); ES (−19%)
Hyun et al. [35]	TLIF and bilateral LPSF	Midline TLIF and LPSF: adjacent level (−21%); contralateral PIA for LPSF: adjacent level (−5%)
Kim et al. [36]	LPSF	Open: adjacent level (−30.35%); percutaneous: adjacent level (−3.68%)
Motosuneya et al. [37]	ALIF, PLIF, PLF, lam, Love's	Open, operative level: ALIF (−6%); PLIF (−12%); PLF (−16%); LAM (−6%); Love (−4%); control (−2%)
Suwa et al. [28]	Open PLF and laminectomy	Open: single laminectomy (−2.5 to −3.4%); multiple laminectomy (−6.5); PLF (−7 to −19.4%)
Tsutsumimoto et al. [20]	PLIF and bilateral LPSF	Open: adjacent level (−26 to −38%); mini-open: adjacent level (−3 to −15%)
Ortega-Porcayo et al. [17]	MI-TLIF and unilateral LPSF	Superior level (+4.06%); inferior level (−3.3%)

ALIF, anterior lumbar interbody fusion; ES, erector spinae; LAM, laminectomy; Lam, laminectomy; LE-ULBD, lumbar endoscopic unilateral laminotomy with bilateral decompression; Love, Love's method for a lumbar nucleotomy; LPSF, lumbar pedicle screw fixation; MEDS, microendoscopic decompression of stenosis; MF, multifidus; MI, minimally invasive; ML, multiple levels; OLIF, oblique lateral interbody fusion; PIA, paramedian interfascial approach; PLF, posterolateral fusion lumbar spine; PLIF, posterior lumbar interbody fusion; PPSF, percutaneous pedicle screw fixation; SL, single level; TDR, total disk replacement; TLIF, transforaminal lumbar interbody fusion.

cross-sectional area from 64.0 ± 9.4 to 56.7 ± 11.7 cm^2 ($P = 0.002$). The atrophy ratio was 0.88 ± 0.10. The back muscle cross-sectional area decreased from 63.2 ± 16.0 to 52.4 ± 12.7 cm^2 in the PLF group postoperatively ($P = 0.003$). The atrophy ratio was 0.84 ± 0.13. Back muscles in the laminectomy group had a postoperative cross-sectional area reduction from 62.9 ± 8.5 to 59.0 ± 10.3 cm^2 (nonsignificant difference). The atrophy ratio was 0.94 ± 0.13. Cross-sectional areas in the Love's nucleotomy group did not significantly differ before or after surgery. It was 0.96 ± 0.06 in favor of atrophy.

For both groups, there was no discernible difference in the paraspinal muscles' functional cross-sectional area (FCSA) in the 6-month follow-up MRI, according to An et al. [32], who assessed paraspinal muscles changes after unilateral laminotomy with bilateral decompression following a single-stage and multiple-stage lumbar endoscopic laminotomies (LE-ULBD). The single-level LE-ULBD group's fatty infiltration of the paraspinal muscles considerably decreased from 0.77 to 0.59, but not for the multilevel LE-ULBD group ($P = 0.320$). He et al. [34], evaluated the differences between oblique lateral interbody fusion (OLIF) and ordinary OLIF [with percutaneous pedicle screws fixation (PPSF)]. At 2 years, the multifidus and erector spinae FCSA and fat infiltration percentage in the OLIF group did not change (FCSA: multifidus, from 8.59 ± 1.76 to 9.39 ± 1.74 cm^2, $P = 0.072$, and erector spinae, from 13.32 ± 1.59 to 13.55 ± 1.31 cm^2, $P = 0.533$) (multifidus and erector spinae FCSA decreased in the OLIF + PPSF group: multifidus, from 7.72 ± 2.69 to 5.67 ± 1.71 cm^2, $P < 0.001$, and erector spinae, from 12.60 ± 2.04 to 10.15 ± 1.82 cm^2, $P < 0.001$). FIB increased in erector spinae from 11.93 ± 3.22 to 22.60 ± 4.99% ($P < 0.001$) and in multifidus from 16.13 ± 7.01% to 49.38 ± 20.54% ($P < 0.001$). At 24 months, the two groups had substantial differences in FCSA and fat infiltration percentage (all $P < 0.001$).

Hyun et al. [35], compared the paramedian interfascial approach (PIA) with the traditional midline technique to see whether the lumbar fusion procedure resulted in the least amount of postoperative back muscle atrophy (MA). The cross-sectional area, thickness, and width of the multifidus muscle were measured using CT both before and after surgery. Postoperative paraspinal MA was significantly more prevalent on the MA side than on the PIA side (−21.7 and −4.8%, respectively, $P < 0.01$). They concluded that the PIA for lumbar fusion successfully protected the paraspinal muscle (Table 2).

Enzymatic assessment of paraspinal muscles injury

The length of pressure time is proportional to the severity of back muscle injury. According to Kawaguchi et al. [15] following surgery, the CPK-MM isoenzyme activity increased, peaked 1 day later, and then recovered to normal after 1 week.

Kim et al. [36], assessed the effects of three different surgical procedures on the atrophy of the paraspinal muscles: modified bilateral decompression with hemilaminectomy, modified bilateral decompression with spinous process splitting, and unilateral paraspinal dissection from the spinous process with the cutting of the spinous process. They measured the levels of CPK, hemoglobin, and C-reactive protein (CRP) both before surgery and on the first postoperative day. The three groups did not statistically differ in their CRP and hemoglobin levels. Compared with group 1, group 2 and group 3 had significantly lower postoperative elevations of CPK. Compared with group 1 and group 2, group 3 showed much less atrophic alterations in the paraspinal muscle. Therefore, they concluded that modified bilateral decompression via spinous process splitting is a less intrusive, effective way of treating posterior spinal elements, resulting in decreased muscle injury. It also encourages the preservation of the paraspinal muscle.

In the postoperative period, Matějka et al. [39], compared the blood levels of creatine kinase and myoglobin between conventional and mini-invasive stabilization of thoracolumbar spine fractures. They found that the median increase in the values of both enzymes is more in the mini-invasive method than that in the conventional method, contradicting the hypothesis that levels of creatine kinase and myoglobin enzymes increase significantly in open stabilization. Statistically, however, they were more common in minimally invasive procedures.

Suwa et al. [28] associated the CPK level and paraspinal muscle thickness in three groups: single interlaminar level procedures (SL), multiple interlaminar level procedures (ML), and posterolateral fusion procedures (PLF). As they found a significantly stronger association in the PLF group than that in the SL or ML groups between the postoperative elevation of serum CPK level and a decrease in paraspinal muscle thickness, they concluded that PLF is the most invasive procedure of the paraspinal muscles.

To treat L4−L5 spondylolisthesis, Am Park et al. [40], examined tissue injury markers following percutaneous screw fixation and screw insertion through the paraspinal muscle sparing approach. In the paraspinal muscle sparing group, serum levels

Table 2. Degree of fat infiltration assessed by clinical imaging in open and minimally invasive posterior lumbar spine approaches.

References	Approach	Degree of fat infiltration
Putzier et al. [9]	TLIF	Index segment: 1 week: MF: 15.7% Longs.: 10.1% 12 months: MF: 19.3% Longs.: 41.2%
		Adjacent segment: 1 week: MF: 8.9% Longs.: 4.9% 12 months: MF: 10.5% Longs.: 6.8%
	PLIF	Index segment: 1 week: MF: 16.7% Longs.: 10.7% 12 months: MF: 58.6% Longs.: 46.8%
		Adjacent segment: 1 week: MF: 9.4% Longs.: 6.4% 12 months: MF: 11.8% Longs.: 7.9%
Ntilikina et al. [7]	Open surgery	ROI-fat, subcutaneous: 497.1 ± 61.2 Ratio ROI-CSA/ROI-fat: 0.4 ± 0.1 (0.1–0.8)
	Percutaneous	ROI-fat, subcutaneous: 483.9 ± 69.5 Ratio ROI-CSA/ROI-fat: 0.3 ± 0.1 (0.1–0.6)
An et al. [32]	ESLD	Single-level: preoperative: 16.95–39.83% Six-month follow-up: 11.86–52.54%
		Multilevel: Preoperative: 28.95–97.37% Six-month follow-up: 26.32–100%
He et al. [34]	OLIF	MF: preop: 15.91, 2 years postop: 14.38 ES: preop: 11.63, 2 years postop: 11.22
	OLIF + PPSF	MF: preop: 16.13, 2 years postop: 49.38 ES: preop: 11.93, 2 years postop: 22.60
Hellinger et al. [38]	IVD microsurgery	Fatty replacement of the paraspinal muscles: 23.6%
	Endoscopy	2.1%

Values are presented as median. Between 1 week and 12 months, all differences were significant ($P < 0.003$).
Values of ROIs are expressed in pixels as the mean.
CSA, cross-sectional area; ES, erector spinae, Longs, longissimus muscle; ESLD, endoscopic stenosis lumbar decompression; IVD, intervertebral disc; MF, multifidus; OLIF, oblique lateral interbody fusion; PLIF, posterior lumbar interbody fusion; PPSF, percutaneous pedicle screw fixation; ROIs, regions of interest.
P value was insignificant in the two groups. *P* value was significant in both groups 2 years postoperatively (<0.001).

of CK-MM, troponin C type 2 fast (TNNC2), and IL-1Ra dramatically increased on postoperative days 1 and 3 and then decreased to preoperative levels on postoperative day 7. Regarding IL-8 levels, there was no difference between the two groups. They concluded that the best minimally invasive treatment for reducing muscle damage caused by L4–L5 spondylolisthesis is the percutaneous screw fixation surgery.

Experimental studies of paraspinal muscles

Kawaguchi et al. [15], investigated the link between intramuscular pressure or blood flow during posterior lumbar surgery and postoperative back muscle injury in pigs by measuring the contact pressure between the retractor blade and muscle tissue. They found that the contact pressure decreased over time. At 5 mm lateral to the retractor, the intramuscular pressure was significantly higher (114 ± 31 mmHg) than that at 10 and 20 mm lateral to the retractor. Additionally, when the retractor was released at 5 and 20 mm lateral to the retractor, the blood flow drastically decreased during surgery and only partially recovered. Blood flow at 5 mm was much lower than that at 20 mm throughout the procedure. The muscular damage was worse around the retractor blade 3 h after surgery.

Gejo et al. [41], compared the histopathological findings in rats with the MRI of damage to rat back muscle. Three groups of rats were created: the sham operation group, the 1-h retraction group, and the 2-h retraction group. Before surgery and 2, 7, and 21 days postoperatively, multifidus muscles' histology and MRI were analyzed. Only in the 2-h retraction group, they discovered that the multifidus muscles' strong signal intensity on T2-MRI persisted 21 days following surgery. Histologically, the regeneration of the multifidus muscles was finished in the 1-h retraction group 21 days after surgery, whereas the 2-h retraction group's regenerated muscle fibers had a short diameter and a significant extracellular fluid gap. Therefore, they reasoned that in circumstances of lengthy surgery, the postoperative multifidus muscles' high signal on T2-MRI may suggest a lack of complete muscle regeneration linked to denervated alterations.

In Lehman's comparison between conventional and PPSF in a sheep, he discovered considerably less blood loss and more evenly distributed serum levels of total CPK, a marker for muscle injury in the percutaneous group. Other factors such as intracompartmental pressure, blood flow, and monitoring of the EMG at various times did not show any appreciable variations. Based on the findings, he concluded that percutaneous screw fixation has some benefits; however, it should be stated that a softly open technique would not be able to identify any significant functional deficiencies in the muscle [42].

Kawaguchi et al. [16], looked into the effectiveness of intermittent retractor release during surgery to stop severe muscle damage in rats. Three groups were used to compare postoperative results: continuous 2-h retraction of the back muscle, release after 1 h of retraction for 5 min, and release after every 40-min period of retraction for 5 min. They discovered that group 1 had the most severe postoperative back muscle deterioration. Compared with group 2 and group 3, group 1 had a considerably higher concentration of CPK-MM. One week following surgery, group 1's regenerated fibers had a smaller diameter than those of group 2 and group 3. Group 1 had the highest rate of neurogenic muscle injury. They concluded that the release of retraction for 5 min after 40 min or an hour after retraction during posterior lumbar spine surgery was useful in preventing significant back muscle damage following surgery.

To determine whether minimally invasive lumbar spinal fusion caused less paraspinal muscle damage than traditional open posterior fusion, Stevens et al. [27], used an ultra-miniature pressure transducer to measure the intramuscular pressure produced by a minimally invasive and standard open retractor in cadavers. The results showed that the intramuscular pressure measurement for the minimally invasive retractor was 1.4 compared with 4.7 kPa for the open retractor ($P < 0.001$). Only upon initial expansion did the minimally invasive retractor produce a momentary maximum intramuscular pressure. Throughout the use of the open retractor, the maximum intramuscular pressure remained constant. On MRI, the muscular edema in the open and minimally invasive groups showed observable differences. The average T2 relaxation time at the fusion level was 47 ms in the minimally invasive group and 90 ms in the open group ($P = 0.013$).

Using finite element analysis models, Kumaran et al. [43], analyzed the biomechanics of the paraspinal muscles' reduction in cross-sectional area (CSA) on the neighboring segments after TLIF utilizing open and minimally invasive methods. They discovered an increased range of motion at the superior level in the TLIF model compared with the intact model. The quadratus lumborum and multifidus showed the greatest changes in scale among the paraspinal muscles. Similarly, CSA decreased, but intervertebral disc pressures and stresses at the annulus at the higher level increased. Therefore, they concluded that reduction of CSA during the TLIF procedure may result in neighboring area modifications in the spinal stresses and the possibility for persistent back discomfort in the postoperative period. As a result, patients may benefit from minimally invasive methods.

Functional results of paraspinal muscles

Linzer et al. [44], measured myoglobin, creatine kinase, IL-6, CRP, and the degree of low back discomfort and radicular manifestations during one-level micro-PLIF and open PLIF surgeries. They concluded that both procedures produced a similar amount of myonecrosis. The systemic inflammatory response was dramatically reduced in the micro-PLIF approach, according to the examination of IL-6 and CRP levels. The small PLIF approach temporarily reduces postoperative pain early postoperatively. The myoglobin levels between the study groups did not differ significantly and thus did not establish the superiority of any strategies. The open PLIF and small PLIF groups' muscle protein levels and visual analog scale (VAS) scores for back pain were compared statistically, but no moderate or significant correlations between the two variables were found. Additionally, there was no discernible link between muscle protein levels and the VAS for leg discomfort.

Kim et al. [26], contrasted percutaneous pedicle screw insertion (PPF) with open pedicle screw insertion (OPF) in terms of postoperative multifidus MA and trunk muscle strength. They discovered a considerable reduction in the OPF group's multifidus muscle's CSA. In the PPF group, however, there was no statistically significant variation in the preoperative and follow-up MRI results. Clinical outcomes, such as the patient's opinion of the surgical outcome and the patient's pain score and JOA score, did not significantly differ between the two groups.

Comparing the open PLIF versus XLIF besides PPS, Ohba et al. [45], assessed the invasiveness and tolerability of each procedure. One year after surgery, the XLIF/PPS group had considerably lower Oswestry Disability Index (ODI) and VAS scores (lumbar) than the PLIF group. They claimed that from postoperative days 2–7, the XLIF/PPS group's performance recovery was much greater than that of the PLIF group.

Peng et al. [46], compared the efficiency of MISS with open surgery for patients with lumbar canal stenosis. They observed that patients with lumbar canal stenosis treated with MISS had shorter wounds and shorter hospital admissions than those treated with conventional open surgery (COS). Results indicated that MISS outperformed COS in terms of ODI and inflammatory score improvement for patients with lumbar spinal stenosis. Compared with the COS group, MISS for people with lumbar spinal stenosis demonstrated improved VAS for back and leg pain.

Tsutsumimoto et al. [20], examined the paraspinal muscle injury and radiological characteristics following mini-open and traditional open PLIF in a study of degenerative lumbar spondylolisthesis (PLIF). Regarding the rate of improvement in the Japanese Orthopedic Association score, segmental lordotic angle, and rate of fusion, they discovered no statistically significant differences between the two groups. Following surgery, the percentage of vertebral slip significantly decreased in both groups. Compared with open PLIF, mini-open PLIF caused significantly less multifidus (MF) atrophy and more T2-signal intensity in the MF muscle.

To ascertain whether a minimally invasive approach for one-level instrumented PLIF reduced undesirable changes in the multifidus muscle compared with a conventional open approach, Fan et al. [14], examined associations between muscle injury during surgery (CK levels), clinical outcome, and changes in the multifidus muscle. Decreased postoperative back pain ($P < 0.001$) and ODI scores ($P = 0.001$) were experienced by the minimally invasive group. Multifidus atrophy was reduced in the minimally invasive group, with mean CSA declines of 12.2% at the operative and 8.5% at the surrounding levels, compared with 36.8 and 29.3%, respectively, in the typical open group ($P < 0.001$). The increase in the multifidus: psoas T2 signal intensity ratio was significantly less pronounced in the minimally invasive group, with values increasing by 10.6% at the operative and 8.3% at the neighboring levels as opposed to 34.4 and 22.7%, respectively, in the conventional open group ($P < 0.001$). These differences in multifidus CSA and T2 signal intensity ratio were all significantly ($P < 0.01$) correlated with postoperative creatinine kinase levels, VAS scores, and ODI scores. The minimally invasive technique produced less functional impairment, less postoperative back pain, and less modification in the multifidus than the standard open technique. The surgical muscular injury was strongly associated with long-term multifidus MA and lipid infiltration. These degenerative changes in multifidus were strongly associated with long-term clinical prognosis.

Jang et al. [47], evaluated and compared the safety and efficacy of the paraspinal muscle-sparing method and percutaneous screw fixation for treating L5–S1 spondylolisthesis. Clinical outcomes were assessed for back and leg pain following surgery using the Low Back Outcome Score and VAS. The results of subjective patients were also evaluated six months after surgery using modified MacNab's grading criteria. Patients in both groups demonstrated a significant improvement in Low Back Outcome Score 6 months following surgery. They concluded that the percutaneous screw fixation surgery is the preferred minimally invasive method for lowering low back pain related to L5–S1 spondylolisthesis.

Makia et al. [48], contrasted the transmuscular method to the usual strategy for fixing the lumbar spine and discovered that the conventional group had a higher VAS for back pain postoperatively than the transmuscular group ($P < 0.001$).

Putzier et al. [9], evaluated multifidus muscle (MF) and longissimus muscle (LS) volume atrophy and fatty degeneration with single-level minimally invasive transforaminal lumbar interbody fusion (mi-TLIF) against conventional midline approach-based PLIF (coPLIF) of L4/L5 or L5/S1. They found that although LS damage at the index segment was equal in both groups (3% more fat content increase in the coPLIF group vs. the mi-TLIF group, $P = 0.032$), MF atrophy and degeneration were higher ($P < 001$) in the coPLIF group. Although restricted in both muscles, muscular atrophy and increased fatty infiltration in the neighboring segment were comparable in both groups. There were no changes in the groups' ODI and VAS scores, which both increased ($P < 001$).

Discussion

The paraspinal muscles may suffer irreparable injury and dysfunction as a result of posterior spinal surgery. Minimally invasive procedures have focused on reducing muscle injury by using retractor mechanisms that lower intramuscular pressure, result in less muscle stripping, and cause less denervation [49].

This analysis examined the possibility that less-invasive treatment for posterior lumbar spine problems could lessen paraspinal muscle damage and improve functional outcomes. Overall, the current research shows that, compared with conventional techniques, MIS causes less severe injury to the multifidus muscle.

All imaging investigations showed that conventional spinal surgery caused more atrophic alterations in the muscle's shape. After conventional surgery, the MRI T2 signal increased. This was caused by bigger capillaries that contained more blood and extracellular fluid or by fibrous and fatty infiltrations. Postoperative edema develops shortly after muscular denervation when muscle fibers age, blood volume rises, and extracellular fluid levels rise. Thus, fatty and fibrous infiltrations are signs of more long-lasting neurogenic muscle alterations [23,50–52].

The quantity of tissue that must be dissected and moved to create a big enough surgical corridor means that measuring the size of the surgical incision alone does not sufficiently convey the degree of invasiveness of the procedure. Increased skin incision length may reduce paraspinal muscle damage because it relieves pressure caused by the use of self-retaining retractors during surgery [15,43,53].

The multifidus muscle (MF), which serves as the primary lumbar spine stabilizer, is situated in the paravertebral muscles' most medial area [54–56]. Muscle size loss and an increase in fat deposition are the two primary imaging indicators of muscle degeneration [57]. The only nerves that supply the MF are those in the medial rami of the dorsal ramus; unlike other back muscles, the MF does not receive intersegmental nerve input. MF denervation happened as a result of the intraoperative nerve injury to the medial rami of the dorsal ramus. Retraction pressure, operating time, and operational field size have all been connected to postlumbar surgery ischemia alterations in the back muscles. The muscle signal intensity was found by Tonomura et al. [58] to be at the same level as the preoperative signal intensity 12–18 months after minimally invasive interlaminar decompression, even though an irreversible change in paravertebral muscle signal intensity was typically observed after posterior lumbar surgery.

Reduced CSA of the spinal muscles and changes in muscular density on CT and MRI have both been reported in the literature [36,59]. According to Keller et al. [60], there was no decrease in spinal muscular CSA following surgery, although muscle density, as measured by CT, was significantly damaged. In contrast, Kim et al. [26] discovered that open pedicle screw fixation led to a decrease in the CSA of spinal muscles after an average follow-up of 20 months, whereas PPS osteosynthesis did not lead to a decrease in CSA.

Multifidus muscle edema levels were assessed using fat-suppressed T2-weighted imaging, whereas fatty infiltration levels were evaluated using T1-weighted imaging. Edema and fatty infiltration both exhibited high signal intensities on T2-weighted imaging, making it challenging to discriminate between them.

Owing to the possibility of separating the contractile and noncontractile (fat and connective tissue) components of muscles on T1 images, Gille et al. [59] highlighted the significance of T1-weighted MRI examination [33]. Additionally, there is a strong link between the length of time that the multifidus muscle retracts during operation at the exposed level and the MRI T2 alterations.

Damage of the back muscle fibers owing to retraction or decrease in blood supply results in elevation of CPK level. A decrease in paraspinal muscle thickness and increased CPK level were found to be highest in conventional open posterior lumbar surgery rather than MIS [28,39,61]. On the contary, a rather unexpected result from other researchers who tested the idea that levels would rise mainly during open stabilization was supporting the reverse. Following surgery and implant removal, creatine kinase and myoglobin levels were more significant in the less-invasive method [39]. These contradictory results may be attributed to different methods of enzyme assessment.

Linzer et al. [44] compared the miniPLIF and open PLIF procedures. On the first postoperative day, he discovered higher myoglobin levels in open PLIF than in miniPLIF. The levels reverted to the baseline on day three following surgery. CK levels increased greater in open PLIF than in miniPLIF on the first day postoperatively. On day 3, higher CK levels persisted; by day 7, they were already normal.

Adogwa et al. [1] only looked at the CK levels in miniTLIF and open TLIF, and he discovered that miniTLIF had higher CK levels than open TLIF. He attributed this phenomenon to iatrogenic postoperative compartment syndrome, which develops when wound drainage is not performed during MIS, raising CK levels, edema, and pressure in the paraspinal muscles. He pointed out that the final outcomes were unaffected by this increase. Additionally, Matějka et al. [39] noted that increased muscular contusion occurs when bolts are inserted through tubes through small incisions because the muscles in this region are more severely impacted than during traditional skeletonization because the tubes violently pierce the entering sites. Although open operations affect the complete range of skeletonization, MIS procedures only cause localized muscle injury at the place of screw insertion.

Any kind of wound can result in severe systemic inflammation and clinical symptoms. Macrophages, in reaction to the stress of surgery, initially release IL-1 and tumor necrosis factor-alpha. Owing to their small amounts or rapid disintegration, these cytokines are not detectable in peripheral blood after surgery, despite being expected to trigger the synthesis of IL-6 and IL-8. In particular, neutrophils aggregate at the sites of inflammation, whereas the proapoptotic cytokine IL-8, produced by endothelial cells, also attracts basophils and lymphocytes to the sites of the early systemic inflammatory reactions. No statistically significant difference in IL-8 blood levels was found in the study by Am Park et al. [40], which compared the percutaneous screw fixation method with the paraspinal muscle sparing method.

Hu demonstrated multifidus muscle injury and atrophy after using the splitting approach for the posterior lumbar spine in a rabbit model, demonstrating that splitting has a significant role in multifidus MA in posterior lumbar spine surgery. He saw muscle regeneration processes, including the formation of fibrous tissue, regenerated muscle fibers, and myofiber fusion, at 3 and 6 weeks after surgery. However, the regenerated muscle fibers and fibrous tissue did not develop and remodel at the 12- and 24-week marks and were replaced by fat tissue. He proposed that denervation and disuse may play a significant role in the multifidus muscle's sluggish regeneration and significant fatty infiltration following a splitting injury [62].

After rat posterior spinal surgery, Yamamoto looked at modifications to the paraspinal muscles' biomechanical characteristics. He concluded that surgical damage elevated the passive stiffness of the multifidus fibers and that posterior lumbar spinal surgery significantly increased the elastic (Young's) modulus of the fiber bundles. The extracellular matrix's increased collagen content is the most likely explanation, and these alterations may be essential for the spine's postoperative compensation [63].

According to Kim and colleagues, minimally invasive posterior spinal operations resulted in significantly better clinical results than COS in terms of hospital stay length, narcotic use, and blood loss [14,20,23,46,64]. In a study by Fan, at a 1-year follow-up, patients with minimally invasive posterior approaches had lower ODI scores and less postoperative back discomfort. Changes in multifidus CSA and creatinine kinase levels were substantially correlated with VAS and ODI scores [14]. However, other studies did not discover any clinically significant variations between open or MIS patients in terms of pain intensity, JOA score, or patient assessment of the procedure's success [26,50]. Pishnamaz and others compared the two groups and concluded that future research should be done with a surgical approach to try to clarify the relationship between changes in quality of life, strength, impairment, and muscular structure, as they could not find a clear correlation [57,65,66].

Surgical site infection has been linked to MIS. When the fat invasion is excessive, over 29.29%, there is a greater chance of surgical site infection development [67,68].

Although numerous studies have demonstrated that PPSF is a secure and successful procedure, Sudhir described patients who underwent percutaneous posterior thoracolumbar pedicle screw fixation and experienced compartment syndrome affecting the thoracolumbar paraspinal musculature. Damage to either the dorsal branches of the posterior intercostal arteries or the longissimus thoracis was likely the reason for its onset. The surgical maneuver led to acute edema in the tiny fascial region between the middle and posterior layers of the lumbodorsal fascia, which constrained the vascular supply to the muscle and led to ischemia. When compared with open traditional lumbar surgical procedures, the prevalence of nerve root injury following any of the several MIS lumbar surgical techniques was found to be greater [69,70].

According to Fourney et al. [71], the alleged benefits of MIS have not been demonstrated, and the complication rates of minimally invasive and open procedures are not statistically different. According to Lubelski and others [72,73], there are often no clear differences in costs between minimally invasive and open surgery for the lumbar region. However, they pointed out that it is likely that with more extensive data, these cost discrepancies may diminish or vanish and perhaps possibly show superior cost-effectiveness for the open alternatives.

McClelland and Goldstein [74] looked at the best available research contrasting MIS with open spine surgery. The best available evidence did not favor MIS for lumbar disc herniation over open surgery. However, MIS TLIF shows benefits and greater revision/readmission rates. Regardless of patient indication, MIS greatly increases the surgeon's radiation exposure; nevertheless, it is unknown how this may affect patients. These findings could facilitate a well-informed choice between MIS and open spine surgery, especially given the current advertising environment that strongly favors MIS.

This study had some limitations, as some evaluated studies used MRI data, whereas others used CT data for imaging evaluation of back muscle injuries. Not all studies used the same histochemical assessment methods.

Conclusion

Despite some contradictory results in the previous studies, minimally invasive posterior lumbar spine surgery, compared with conventionally open surgery, reduced MA. Mini-invasive procedures considerably decreased the systemic inflammatory response when the biochemical stress responses of open and mini-invasive techniques were compared. Compared with open procedures, percutaneous treatments reduced paraspinal muscle injury and improved postoperative trunk muscle function. Patients may choose the minimally intrusive method because it is linked to less back discomfort and less functional disability.

Conflict of interest

There are no conflicts of interest.

Abbreviations

ALIF	Anterior lumbar interbody fusion
COS	Conventional open surgery
CPK	Creatine phosphokinase
CSA	Cross-sectional area
FCSA	Functional cross-sectional area
FIP	Fat infiltration percentage
IMP	Intramuscular pressure
LAM	Laminectomy or fenestration
LE-ULBD	Lumbar endoscopic laminotomies
Love	Love's nucleotomy
MA	Muscle atrophy
MISS	Minimally invasive spine surgery
ODI	Oswestry Disability Index
OLIF	Oblique lateral interbody fusion
OPF	Open pedicle screw insertion
PLF	Posterolateral lumbar fusion
PLIF	Posterior lumbar interbody fusion
PPF	Percutaneous pedicle screw insertion
PPSF	Percutaneous pedicle screws fixation
rCSA	Relative cross-sectional area
TLIF	Transforaminal interbody fusion
VAS	Visual Analog Scale
XLIF	Extreme lateral interbody fusion.

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الملخص العربى

اصابة عضلات الظهر أثناء العمليات الجراحية للعمود الفقري القطني الخلفي. الجراحات محدودة التدخل مقابل الطرق المفتوحة.
مراجعة تحليلية.

البيانات الخلفية: أصبحت الجراحة محدودة التدخل خيارًا قيمًا في علاج أمراض الفقرات الصدرية والقطنية. وقد لوحظ أن أجهزة التثبيت قصيرة المقطع توفر ضمورًا أقل للعضلات وتسللًا أقل للدهون مقارنة بالجراحة المفتوحة.

الغرض: تناولت هذه المراجعة مسألة ما إذا كانت جراحة العمود الفقري الخلفي محدودة التدخل يمكن أن تقلل من إصابة العضلات الخلفية وتحد من التغيرات في البنية والوظيفة العضلية ، وتؤدي إلى نتائج وظيفية أفضل.

تصميم الدراسة: مراجعة المقالات المنشورة فى هذا المجال.

المرضى و الطرق: بحث المؤلف في المقالات المنشورة في ميدلاين وباحث جوجل العلمى ومكتبة كوكرين. تم تضمين أربعين دراسة مقارنة بين الأساليب الجراحية التقليدية المفتوحة والجراحة محدودة التدخل أوعن طريق الجلد.

النتائج: تدعم مراجعة الأبحاث الافتراض القائل بأن الجراحة محدودة التدخل تحافظ على العضلات لفترة ما بعد الجراحة المبكرة على الرغم من أن مستوى الأدلة لا يزال منخفضًا.

الخلاصه: ارتباط التغييرات في البنية العضلية للألم والقوة والإعاقة ونوعية الحياة تظل غامضة ويجب معالجتها في مزيد من الدراسات مع التركيز على النهج الجراحي.