Lateral Lumbar Interbody Fusion (Direct Lateral Interbody Fusion/Extreme Lateral Interbody Fusion) versus Posterior Lumbar Interbody Fusion Surgery in Spinal Degenerative Disease: A Systematic Review

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Title: Lateral lumbar interbody fusion (LLIF/DLIF/XLIF) versus posterior lumbar interbody fusion (PLIF) surgery in spinal degenerative disease: a systematic review.

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Abstract

Introduction. Degenerative diseases of the lumbar spine are often treated with posterior interbody fusion surgery (PLIF) for spinal instability or intractable back pain with neurological impairment. Several lateral, less invasive procedures have been recently described (LLIF/DLIF/XLIF). The aim of this systematic review is to compare structural and functional outcomes of lateral surgical approaches to PLIF.

Methods. We conducted a Medline (Pubmed), Web of Science, Science direct and Cochrane Library search for studies focusing on outcomes and complications comparing lateral lumbar interbody fusion (LLIF/DLIF/XLIF) and posterior lumbar interbody fusion (PLIF). The systematic review was reported using the PRISMA criteria.

Results and discussion. In total 1000 research articles were identified of which five studies were included comparing the outcomes and complications between the lateral and posterior approach. Three studies found significant less perioperative blood loss with a lateral approach. Average hospital stay was shorter in populations which underwent the lateral approach compared to PLIF. Functional outcomes (VAS/ODI) were similar or better with lateral lumbar interbody fusion. In the majority of the included studies, complication rates did not differ between the posterior and lateral approach. Most of the neurological deficits with XLIF/LLIF were temporary and healed completely within one-year follow up.

Conclusion. A lateral approach (XLIF/LLIF) is a good and safe alternative for posterior lumbar interbody fusion in single level degenerative lumbar diseases with comparable functional outcomes, shorter hospital stays and less blood loss. Future prospective studies are needed to establish the role of lateral, minimally invasive approaches in spinal degenerative surgery.

Keywords. XLIF; LLIF; PLIF; Surgery; Lumbar Fusion; Post-operative recovery; Structural and functional outcomes

Introduction

In lumbar spinal degenerative disease, lumbar interbody fusions are frequently considered as an invasive treatment when conservative measures fail. It involves the implantation of a cage/graft in the intervertebral space to induce vertebral body fusion over time and to decompress the nerve structures improving pain and functionality. (1)

Briggs and Milligan were the first to describe the posterior lumber interbody fusion (PLIF) in 1944 (2) and has evolved into a well-established surgical technique for the treatment of degenerative disc disease, spondylolisthesis and scoliosis. (1, 3) A posterior approach to the spine includes a detachment of the musculature from the spinal processes. This allows the surgeon to access the spinal canal to decompress the nerve structures and visualize the entry points for the pedicle screws. Posterior instrumentation can also be performed percutaneously. (4, 5) Due to the large exposed surgical site with the muscle retraction, a great view of the decompressed nerve roots is possible. This retraction of the musculature is one of the drawbacks of PLIF since it causes damage to muscles which might lead to more postoperative pain and a prolonged recovery. The morbidity due to PLIF increases with longer surgery duration and higher blood loss. (6, 7)

In recent years there has been a focus, not only in spine surgery, on minimally invasive surgical treatments to reduce the burden on patients and shorten hospital stays. An extreme lateral interbody fusion (XLIF) procedure is a minimally invasive procedure in which the rigorous detachment of the posterior back musculature can be avoided. Direct lateral interbody fusion (DLIF) or lateral lumbar interbody fusion (LLIF) as a lateral approach to the spine was first presented by Pimenta in 2001 (8), while in 2006, Ozgur et al described the XLIF technique with the use of special patented retractors. (9) To prevent damage to the lumbar plexus or nerves, neurophysiologic monitoring and fluoroscopic guidance during surgery are key to this lateral approach. (10, 11) The XLIF procedure is often topped off with posterior percutaneous screw fixation. In comparison with traditional posterior approaches, there is a smaller incision with less muscle and soft tissue damage and blood loss. The XLIF procedure is associated with shorter hospital stays and faster return to daily activities. (4, 9, 12)

This systematic review aims to investigate current or new literature on the outcomes of lateral spinal fusion surgery compared to the posterior approach. The results of this systematic review constitute to the basis for future prospective research.

Methods

Search strategy and eligibility criteria

This systematic literature review is executed in accordance with the updated 'preferred reporting items for systematic reviews and meta-analysis' (PRISMA) guidelines. A search was performed using the PubMed, Web of Science and ScienceDirect databases up to February 2020. The Medical Subject Headings (MeSH) terms used in the search strategy for Pubmed are listed in Table 1. Similar keywords were translated for the Web of Science and ScienceDirect.

Articles were included if the following inclusion criteria were met: (1) single-level interbody fusion (2) comparing LLIF/DLIF/XLIF to PLIF, (3) at least one of the following outcomes: blood loss, hospital stay, functional and pain scores (ODI, VAS) or fusion rate. Case reports, editorials, opinion and commentary articles were excluded.

Study selection and risk of bias

Selection of the relevant literature was performed by two authors. Studies were selected by evaluating title and abstract after the removal of duplicates. Next, a full-text article analysis was performed for relevant articles. We included publications on human subjects written in Dutch or English language. The reference lists of the included articles were hand-searched for potentially relevant literature. Finally, articles were only included when all eligibility criteria had been met. Structural (disc height, foraminal height), functional outcomes and pain scores were collected for each included study. Perioperative outcomes (blood loss, hospital stay) were compared when available.

The risk of bias was assessed by the bias assessment tool of the Cochrane Handbook for Systematic Reviews of Interventions. Two authors independently evaluated the seven different domains of the bias assessment scoring the criteria, "low or high risk" of bias or "unclear". (13)

Results

Study selection

The results of the study selection are summarized in the PRISMA flowchart, figure 1. The database search resulted in the identification of 571 records for PubMed, 289 records for ScienceDirect and 235 records for Web of Science. After the removal of duplicates, 1000 articles were screened based on title and abstract. Of these articles, 27 full-text articles were assessed for eligibility. Based on the above-mentioned inclusion and exclusion criteria, 23 articles were removed. One study was excluded because of the comparison of two-level PLIF versus XLIF only (14). Five studies comparing a lateral (XLIF/LLIF/DLIF) with a posterior approach (PLIF) were included in the systematic review.

Study characteristics and risk of bias

Three out of the five studies were retrospective data collections. (15-17) One study is a prospective cohort in which patients were treated with XLIF and PLIF consecutive. (18) The last study aimed to investigate demographics and adverse events in a lateral lumbar approach and introduced a retrospective historical cohort of open posterior spinal surgery as a comparison. (19) The studies were published between 2009 and 2017.

Overall, the included studies have a high risk of bias. The risk of bias assessment is illustrated in table 2. There is no (blinded) randomized trial comparing the posterior and lateral approaches. No study indicated missing data, probably because of the retrospective study designs. Additionally, there is one study in which the population was 80 years or older which affects the representativeness. (17) In two studies a matched population of patients treated with posterior surgery was retrospectively analyzed to compare with the lateral approach (16, 19). In one study this historical cohort dates from a period 10 years before the current study period of the lateral surgery (19).

Study results

The study characteristics are listed in table 3. The different outcome measures are summarized in table 4.

Clinical outcomes

In 2017 Lee et al. conducted a comparative analysis of three different lumbar interbody fusion techniques (ALIF/PLIF/LLIF) in L4-L5 spondylolisthesis. 24 patients underwent LLIF and 31 patients underwent PLIF both with pedicle screw fixation. The average blood loss was 160 mL for LLIF and

321 mL for PLIF. The hospital stay was also shorter in the LLIF group (5.1 days) compared to the PLIF group (6.1 days). Blood loss and hospital stay were however not significantly different across the three groups (ALIF/PLIF/LLIF). The study reported an average surgical time of 105 min in LLIF and 92 min in PLIF. Clinical outcomes improved in all groups after surgery. Although postoperative VAS and ODI scores between the groups were not compared in this study, LLIF and PLIF showed similar results. Adjacent segment disease (ASD) was objectified in 64,5% after PLIF and 41,7% in the LLIF group, without significant difference (p=0.091). (15)

Ohba et al. included 102 patients with degenerative lumbar spondylolisthesis. In total 46 patients had an XLIF procedure and 56 patients had a PLIF. Average blood loss was significantly lower in the XLIF group (51 mL) compared to the PLIF group (206 mL) in the latter group. Surgical time did not differ between both groups. Postoperatively there was no significant difference in VAS scores. After one year VAS-score was lower in the XLIF group (1,5) compared to the PLIF group (3,7). The ODI score of the XLIF group was 9.2 and 13,5 in the PLIF group (p<0,05). There were no significant differences found in fusion rates. (18)

Pawar et al. conducted a retrospective study to compare both clinical and radiographic outcomes for degenerative lumbar spondylolisthesis after PLIF and LLIF procedures with posterior segmental spinal instrumentation. The study included 39 patients in the LLIF group and 39 patients in the PLIF group. There was no significant difference in mean duration of the procedure and estimated blood loss was significantly lower (p<0.001) in the LLIF group. The improvement of the ODI score was greater in the LLIF group (p=0.001). Next, a greater increase in lumbar lordosis (L1-S1) was objectified in the XLIF group compared to PLIF. Both Lee et al. and Pawar et al. reported a greater increase in postoperative foraminal height in XLIF compared to PLIF. (16)

In a study by Rodgers et al., the outcomes of XLIF surgery were prospectively compared to a retrospective cohort in which octogenarians underwent PLIF surgery. The study comprised a total of 60 patients, with 40 patients in the XLIF group and 20 in the PLIF group. The average change in haemoglobin was lower in the XLIF group (1.4 g) compared to PLIF (2.7 g). The average length of hospital stay was also shorter (p<0.0001) in the XLIF sample, with 1.3 days compared to 5.3 days in PLIF. In the XLIF group, a significant reduction in pain measured by the VAS scale was observed, with an average score of 8.6 before surgery and scores of 2, 0.9 and 1.4 following three, six and twelve months after surgery respectively. (17)

Knight et al. conducted a prospective complication analysis of direct lateral lumbar interbody fusion (DLIF and LLIF) and compared this with a historical cohort of open posterior spinal fusion. 58 patients

underwent DLIF, of which 38 were single-level fusions. Compared to the historical cohort, DLIF/XLIF patients had significantly less blood loss and operative time. There was no difference in the length of the hospital stay. (19)

Perioperative complications

All studies reported complications of the lateral approaches compared to the posterior approach. In the study of Lee et al. three postoperative complications with LLIF were reported including one hip muscle weakness and two patients with groin pain. The complications in PLIF included one delayed hematoma, one incidental durotomy and one case of dysesthesia. (15)

The complication rate was 8.6% in the study by Ohba et al. Five patients experienced temporary sensory changes in the thigh and four patients experienced temporary hip flexion weakness. In the PLIF group one patient had wound healing problems and one patient had an accidental durotomy. No revision surgery had to be performed. (18)

Pawar et al. reported subsidence at seven levels in the LLIF group compared to eleven in the PLIF group at the final follow-up. A mechanical flexion deficit from the psoas muscles was observed in five patients (13%) at the first follow-up in the LLIF group. In the PLIF group, nine patients (23%) had dysesthesia and seven patients (18%) had radicular symptoms. Nevertheless, at one year follow-up, none of the patients had residual motor or sensory deficits. (16)

In the octogenarians population, Rodgers et al. reported, a statistically lower complication rate in the XLIF group compared to the PLIF group. In XLIF the complication rate at three and six months post-operatively were respectively 0% and 2.5%. While in PLIF these rates were respectively 15% and 30%. Complications included impact fractures (PLIF: 5%, XLIF: 2.5%) and compression fractures of adjacent segments (PLIF: 5%, XLIF: 2.5%). The following complications were only observed in PLIF: superficial infection (5%), deep infection (15%), wound dehiscence (5%), intestinal obstruction (5%), pneumonia (15%) and postoperative ileus (10%). (17)

Knights et al. reported major complications in 5 patients (8,6%). One reoperation due to acute subsidence, two patients with permanent L4 nerve root injury and one permanent meralgia paresthetica were objectified. In the PLIF cohort, 22,5% of patients (9/40) suffered from wound infection or accidental dural tear. (19)

Discussion

Interbody fusions are a well-known concept in spinal surgery. In recent years minimally invasive spinal surgery gained interest in reducing surgical burden and improve functioning.

In this systematic review, we compared the clinical outcomes of lateral approaches to the spine (XLIF/DLIF/LLIF) and PLIF for lumbar spondylolisthesis in current literature. Five studies with a high risk of bias have been included in this systematic review. Overall, lateral approaches to the spine seem to be associated with less blood loss and shorter hospital stays. Surgical time was similar for both techniques. Functional outcomes (VAS and ODI) have been reported as comparable for both surgical techniques. Ohba et al. and Pawar et al. report a lower ODI/greater decrease in ODI for XLIF compared to PLIF. Although not all studies indicated structural outcomes, lateral approaches to the spine provide greater increase in disc and foraminal height (15-17) and lumbar lordosis (16). Fusion rates were comparable and according to current literature (20), in the only study reporting them (18).

Surgery-related complications were reported in all studies. Three studies reported sensory changes and motor deficits in XLIF. Sensory changes were comprised of thigh sensory changes and anterior groin pain. Motor deficits included hip flexion weakness and psoas mechanical flexion deficit. Two of these studies reported these complications to be temporary in nature and resolved in one year follow-up. In the review by Epstein et al. from 2019, the risks and complications of XLIF were examined. They reported new and permanent sensory deficits in 62.5% of the cases after XLIF. Furthermore, this review described a permanent iliopsoas weakness in 5% of the cases. (21, 22) Complications with PLIF mainly consisted of dysesthesia, durotomy and impaired superficial wound healing. All these complications associated with PLIF were temporary. Rodgers et al. observed a significantly higher complication rate in PLIF than in XLIF. This might be explained by the octogenarian study population in which more invasive surgery (e.x. PLIF) can be detrimental to the patient. (17)

In 2014 Barbagallo et al. performed a systematic review, in which three studies were included comparing XLIF and PLIF. They concluded that lateral approaches to the spine are safe and effective, but only few low-quality evidence is available comparing these techniques to open posterior approaches (PLIF/TLIF). (23) The current review assessed the literature for newer scientific evidence. However, in the last eight years, no qualitative comparative research has been conducted on XLIF versus PLIF. Only three new studies were included, two retrospective and one prospective cohort, all with high risk of bias. Since posterior approaches are currently being adapted and performed

minimally invasive (24), there certainly is a need for new qualitative comparative research to examine the advantages of a lateral approach compared to a (less invasive) posterior approach.

The results of this systematic review should be weighed against its limitations. The five studies have a high risk of bias. Two studies used a historical cohort as a control population. Some studies did not report a statistical analysis or clinical outcomes of the historical cohort. Lastly, the results from the included studies weren't qualified to perform a meta-analysis.

Taking all the above into consideration, the results and limitations revealed in the systematic review were an inspiration for the design of a current RCT (ClinicalTrials.gov: NCT04589572).

Conclusion

The current, poor-quality, literature indicated that XLIF/LLIF is a safe and effective alternative for PLIF in single-level degenerative lumbar diseases with less intraoperative blood loss and a shorter hospital stay. Functional outcomes for XLIF and PLIF are similar. PLIF results in fewer temporary neurological deficits, i.e. sensory and motor deficits, in comparison to XLIF.

Further prospective and randomized research is necessary to evaluate the clinical outcomes of a lateral approach compared to (minimal invasive) PLIF. This might strengthen the position of minimally invasive lateral surgery in the treatment paradigm for lumbar spondylolisthesis.

Legend:

Figure 1: PRISMA flowchart for the study selection (25).

Identification of studies via databases and registers

Identification

Records identified from:
PubMed (n = 571)
Science Direct (n = 289)
Web of Science (n = 235)

Records removed *before screening*:
Duplicate records removed (n = 95)

Screening

Records screened
(n = 1000)

Records excluded based on title and abstract
(n = 973)

Reports sought for retrieval
(n = 27)

Reports not retrieved
(n = 0)

Reports assessed for eligibility
(n = 27)

Reports excluded:
Based on the inclusion/exclusion criteria
(n = 22)

Included

Studies included in review
(n = 5)

Table 1: PubMed search strategy

XLIF	AND	PLIF	AND	Outcomes
OR		OR		OR
Extreme lateral interbody fusion		Posterior lumbar interbody fusion		Post-operative recovery
OR		OR		OR
Extreme lateral transpsoas lumbar interbody fusion		Open lumbar interbody fusion		Post-operative disability
OR				OR
Extreme lateral lumbar interbody fusion				Post-operative pain
OR				OR
Direct lateral interbody fusion				Muscle denervation
OR				OR
Direct lateral lumbar interbody fusion				Loss of function
OR				OR
Direct lateral transpsoas lumbar interbody fusion				Muscular atrophy
OR				OR
DLIF				Spinal instability
OR				OR
Lateral interbody fusion				Long term disability
OR				OR
Lateral lumbar interbody fusion				Pain
OR				OR
Lateral transpsoas lumbar interbody fusion				Intraoperative blood loss
				OR
				Postoperative white blood cell counts
				OR
				C-reactive protein levels
				OR
				Creatine kinase levels

				OR
				Muscle damage
				OR
				Surgical invasiveness
				OR
				Myoglobine
				OR
				CPET
				OR
				MRI
				OR
				Skeletal muscle function
				OR
				Blood samples
				OR
				Quality of Life
				OR
				Physical activity
				OR
				General anaesthesia time
				OR
				Operating time
				OR
				Complications
				OR
				Hospital stay
				OR
				Postoperative complications
				OR
				VAS
				OR
				VAS-score
				OR
				Fusion state

	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting
Lee et al., 2017[17]	-	-	-	-	+/?	+
Ohba et al., 2017[20]	-	-	-	-	+/?	+
Pawar et al., 2015[18]	-	-	-	-	+/?	+
Rodgers et al., 2010[19]	-	-	-	-	+/?	+
Knight et al., 2009[21]	-	-	-	-	+/?	+

Table 2: risk of bias summary; - representing high risk of bias, + representing low risk of bias, ? representing unclear risk of bias.

Study	Study design	Indication	Study population	
Lee et al., 2017[17]	Retrospective cohort N= 55	Spondylolisthesis without adjacent level disease	LLIF + posterior decompression + pedicle screws	PLIF
			n= 24 FU: 35 months (mean) Age (mean): 54,5 t/o Male (%): 66,7%	n= 31 FU: 35 months (mean) Age (mean): 60,8 y/o Male (%): 22,5%
Ohba et al., 2017[20]	Prospective cohort Consecutive treatment N= 102	Degenerative lumbar spondylolisthesis	XLIF + PPS	Open PLIF
			n= 46 FU: 1 year Age (mean): 71 y/o Male (%): 32,6%	n= 56 FU: 1 year Age (mean): 69 y/o Male (%): 48,2%
Pawar et al., 2015[18]	Retrospective cohort N= 78	Degenerative lumbar spondylolisthesis	LLIF + SSI	PLIF + SSI
			n= 39 FU: 16 months Age (mean): 59 y/o Male (%): 20,6%	n= 39 FU: 21 months Age (mean): 57 y/o Male (%): 33,3%
Rodgers et al., 2010[19]	Retrospective cohort N= 60	Stenosis with spinal instability Spondylolisthesis Scoliosis	XLIF + PSS	Open PLIF (historical cohort)
			n= 40 FU: 3-12 months Age (mean): 82,6 y/o Male (%): 45%	n= 20 FU: 3-12 months Age (mean): 84,2 y/o Male (%): 35%
Knight et al., 2009[21]	Retrospective cohort N= 98	Lumbar degenerative disease (no details)	XLIF or DLIF	Open PLIF (historical cohort)
			n=58 FU: 15 months Age (mean): 61 y/o Male (%): 25,9%	n=40 FU: NR Age (mean): NR Male (%): NR

NR, not reported; XLIF, extreme lateral interbody fusion; PLIF, posterior lumbar interbody fusion; PPS, percutaneous pedicle screws; FU, follow-up; y/o, years old; SSI, segmental spinal instrumentation;

Table 3: characteristics of the included studies comparing a lateral and posterior fusion surgery for lumbar degenerative disease

		LLIF/XLIF		PLIF		p value
VAS		*Pre-operative*	*Post-operative*	*Pre-operative*	*Post-operative*	
Lee et al., 2017	back	7,1	2,5	6,6	2,7	NR*
	leg	6,4	2,3	7,2	1,8	NR*
Ohba et al., 2017	1 day	6,7		6,9		NS
	1 year	1,5		3,7		<0,005
Pawar et al., 2015 (change)		-4,6		-4,4		NS
Rodgers et al., 2010		8,6		NR		/
	3 months		2		NR	/
	6 months		0,9		NR	/
	1 year		1,4		NR	/
ODI		*Pre-operative*	*Post-operative*	*Pre-operative*	*Post-operative*	
Lee et al., 2017		39,4	23,0	35,3	20,0	NR*
Ohba et al., 2017	1 year	9,2		13,5		<0,05
Pawar et al., 2015 (change)		-19,5		-7,7		0,001
Disc height (mm)		*Pre-operative*	*Post-operative*	*Pre-operative*	*Post-operative*	
Lee et al., 2017		11,0	15,2	10,1	10,2	0,0001
Pawar et al., 2015	L3-L4	7,4	13,2	9,6	10,5	<0,001
	L4-L5	8,0	13,3	8,4	10,2	<0,001
Rodgers et al., 2010		5,5		NR		
	3 months		9,5		NR	/
	6 months		9,2		NR	/
	1 year		9,1		NR	/
Foramen height (mm)		*Pre-operative*	*Post-operative*	*Pre-operative*	*Post-operative*	
Lee et al., 2017		19,7	22,4	19,2	19,15	0,001
Pawar et al., 2015	L3-L4	15,6	19,4	18,8	18,1	<0,001
	L4-L5	14,4	18,4	16,2	16,4	<0,001
Segmental lordosis (°)		*Pre-operative*	*Post-operative*	*Pre-operative*	*Post-operative*	
Pawar et al., 2015	L3-L4	11,2	12,7	12,2	12,3	NS
	L4-L5	15,6	19,6	16,8	17,4	<0,001

Lumbar lordosis L1-S1 (°)						
Pawar et al., 2015		44,1	47,5	47,1	48,4	0,020
Fusion grade						
Ohba et al., 2017	1 years	1,5		1,5		NS
Blood loss (mL)						
Lee et al., 2017		160		321		NS
Ohba et al., 2017		51		206		<0,0001
Pawar et al., 2015		438		750		<0,001
Knight et al., 2009		136		489		0,0001
Haemoglobin change (g/L)						
Rodgers et al., 2010		-1,4		2,7		<0,0001
Length of hospital stay (days)						
Lee et al., 2017		5,1		6,9		NS
Rodgers et al., 2010		1,3		5,3		<0,0001
Knight et al., 2009		5		5		NS
Surgical time (min)						
Lee et al., 2017		105		92		NS
Ohba et al., 2017		NR		NR		NS
Pawar et al., 2015		260		256		NS
Knight et al., 2009		161		200		0,0016
Postoperative CK (U/L)						
Ohba et al., 2017		Day 1	866	Day 1	753	NS
		Day 4	296	Day 4	430	<0,05
		Day 7	93	Day 7	151	<0,05

VAS, Visual Analogue Scale; ODI, Oswestry Disability Index; NR, not reported; NS, not significant

*No comparison LLIF/PLIF (but significant reduction in both approaches)

Table 4: primary and secondary outcomes of the included studies comparing LLIF/XLIF and PLIF

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