Comparison of complication rates of minimally invasive transforaminal lumbar interbody fusion and lateral lumbar interbody fusion: a systematic review of the literature

Jacob R. Joseph, MD, Brandon W. Smith, MD, MS, Frank La Marca, MD, and Paul Park, MD

Department of Neurosurgery, University of Michigan, Ann Arbor, Michigan

OBJECT Minimally invasive transforaminal lumbar interbody fusion (MI-TLIF) and lateral lumbar interbody fusion (LLIF) are 2 currently popular techniques for lumbar arthrodesis. The authors compare the total risk of each procedure, along with other important complication outcomes.

METHODS This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Relevant studies (up to May 2015) that reported complications of either MI-TLIF or LLIF were identified from a search in the PubMed database. The primary outcome was overall risk of complication per patient. Secondary outcomes included risks of sensory deficits, temporary neurological deficit, permanent neurological deficit, intraoperative complications, medical complications, wound complications, hardware failure, subsidence, and reoperation.

RESULTS Fifty-four studies were included for analysis of MI-TLIF, and 42 studies were included for analysis of LLIF. Overall, there were 9714 patients (5454 in the MI-TLIF group and 4260 in the LLIF group) with 13,230 levels fused (6040 in the MI-TLIF group and 7190 in the LLIF group). A total of 1045 complications in the MI-TLIF group and 1339 complications in the LLIF group were reported. The total complication rate per patient was 19.2% in the MI-TLIF group and 31.4% in the LLIF group ($p < 0.0001$). The rate of sensory deficits and temporary neurological deficits, and permanent neurological deficits was 20.16%, 2.22%, and 1.01% for MI-TLIF versus 27.08%, 9.40%, and 2.46% for LLIF, respectively ($p < 0.0001$, $p < 0.0001$, $p = 0.002$, respectively). Rates of intraoperative and wound complications were 3.57% and 1.63% for MI-TLIF compared with 1.93% and 0.80% for LLIF, respectively ($p = 0.0003$ and $p = 0.034$, respectively). No significant differences were noted for medical complications or reoperation.

CONCLUSIONS While there was a higher overall complication rate with LLIF, MI-TLIF and LLIF both have acceptable complication profiles. LLIF had higher rates of sensory as well as temporary and permanent neurological symptoms, although rates of intraoperative and wound complications were less than MI-TLIF. Larger, prospective comparative studies are needed to confirm these findings as the current literature is of relative poor quality.

<http://thejns.org/doi/abs/10.3171/2015.7.FOCUS15278>

KEY WORDS transforaminal lumbar interbody fusion; lateral lumbar interbody fusion; direct lateral interbody fusion; extreme lateral interbody fusion; minimally invasive spine surgery

MINIMALLY invasive surgery (MIS) techniques for lumbar fusion have progressively increased in popularity in recent years. Benefits for MIS procedures have been touted for patients who otherwise would have significant risk for open procedures, such as obese or elderly patients.^{1,41,48} Previous studies have also emphasized its efficacy, with good clinical and radiological outcome, and comparable complications to open pro-

cedures.^{47,96,109} More recently, MIS approaches have been used in progressively more complicated procedures for spinal deformity.^{14,19,65} The issue of the “learning curve” associated with MIS fusion procedures has been extensively discussed in the literature, with a consensus that the procedure is technically demanding, but surmountable.^{45,59,60,79,80,88}

Currently, MIS techniques for transforaminal lumbar

ABBREVIATIONS EMG = electromyography; LLIF = lateral lumbar interbody fusion; MI-TLIF = minimally invasive transforaminal lumbar interbody fusion; MIS = minimally invasive surgery.

SUBMITTED June 1, 2015. **ACCEPTED** July 14, 2015.

INCLUDE WHEN CITING DOI: 10.3171/2015.7.FOCUS15278.

FIG. 1. Flow diagram showing selection of the studies for this systematic review of MI-TLIF.

interbody fusion (MI-TLIF) as well as lateral lumbar interbody fusion (LLIF) are both used for arthrodesis in the lumbar spine. The traditional open TLIF was first described by Harms and Rolinger in 1982.³⁰ MI-TLIF was then popularized by Foley et al. in 2003.²³ LLIF was first described in 2006 by Ozgur et al., though variations existed before then.^{64,106} Advantages of the LLIF procedure include minimal blood loss, decreased postoperative pain, and a more robust discectomy, though direct decompression of the neural elements is not possible through the classic LLIF approach. Conversely, MI-TLIF offers good visualization of neural elements, thus allowing for direct decompression of the posterior elements.²⁷

Complications for MI-TLIF have previously been described in the literature.^{103,107} Most frequent surgical complications include durotomy and malpositioned hardware.²⁶ In contrast, durotomy for LLIF is relatively rare. However, lumbar plexopathies encompassing transient hip flexion weakness and transient sensory deficits are a well-known complication of the retroperitoneal approach to the lumbar spine.⁴ In this study, we perform a systematic

review of the literature, comparing complication rates of LLIF and MI-TLIF procedures.

Methods

Literature Search and Inclusion Criteria

This systematic review was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.⁵⁷

We identified articles published up to May 2015 through search of the PubMed database. The search strategy was used in 2 separate components. The search strategy for publications regarding MI-TLIF was (“TLIF” OR “transforaminal lumbar interbody fusion”) AND (“minimally invasive” OR “MIS”). The search strategy for publications regarding LLIF was “DLIF” OR “XLIF” OR “LLIF” OR “transposas” OR “lateral lumbar interbody fusion” OR “extreme lateral interbody fusion” OR “direct lateral interbody fusion.” In addition, manual checks through the reference lists were performed. Only articles written in the English language were included. We only used studies that

FIG. 2. Flow diagram showing selection of the studies for this systematic review of LLIF.

provided new data on a minimum of 10 patients. Studies that did not specifically mention complications were not included. Publications that were from the same institutions or senior authors were evaluated for any potential overlap in data sets. In these situations, the study with the largest number of patients or largest reported number of complications was included in the study, and the remaining studies were excluded. Publications that combined other fusion procedures in the analysis such as posterior lateral interbody fusion or anterior lumbar interbody fusion were also excluded.

Data Extraction and Outcome Measures

We extracted the following data from each report: first author name, last author name, date of publication, number of patients, number of levels fused, medical complications, infectious complications, intraoperative complications, reoperations, temporary neurological deficit, permanent neurological deficit, and sensory deficit. In addition, the number of subsidences was recorded for LLIF studies, and the number of hardware failures was recorded

for MI-TLIF procedures. Pain was not considered a complication and was eliminated from this study. Durotomies were considered intraoperative complications. Permanent neurological deficits were defined as motor deficit present at last follow-up. Studies that did not specifically mention the number of levels operated on were presumed to be single-level surgeries. Risk of bias was evaluated for each study at the time of data extraction, and it was noted that there was a risk for publication bias in this present study. Total complication rate was the primary outcome of the study. It was noted that follow-up time was variable between studies, as was specific mention of each category of complication that was recorded. In studies that did not specifically mention each category of complication, but did mention that there were no other complications noted grossly, these variables were presumed to be zero for the primary analysis. Studies that did not make any specific mention of lack of complications were excluded from this analysis. Secondary outcome measures included rates of specific complications such as sensory deficit, temporary neurological deficit, permanent neurological deficit, in-

TABLE 1. MI-TLIF study characteristics and outcomes*

Authors & Year	No. of Patients	No. of Levels	Sensory Deficit	Temporary Neurological Deficit	Permanent Neurological Deficit	Intraop Complication	Medical Complication	Wound Complication	Hardware Failure	Reop
Adogwa et al., 2015	14	14				0		0	0	
Adogwa et al., 2012	40	40			1	1	0	2	1	
Awad et al., 2013	26	26						1		1
Brodano et al., 2013	30	30			0	1			0	0
Cheng et al., 2013	50	50								5
Choi et al., 2013	53	53								4
Deutsch & Musacchio, 2006	34	34		1	0	2		0	1	1
Eckman et al., 2014	1005	1201					12	8		29
Gu et al., 2014	44	88	0	0	0	2		2	0	
Hsiang et al., 2013	40	40	1	1		0			2	2
Jang & Lee, 2005	22	23			0			0		0
Jhala et al., 2014	23	23				0	0	0	2	3
Kang et al., 2014	46	46	0	0	0	5	0	0	2	1
Kim et al., 2012	44	44	1	1	0	0	2	2	1	1
Lau et al., 2011	10	10				1		2	1	
Lau et al., 2013	78	78				3	7	1		
Lee et al., 2014	90	90				1			2	
Lee et al., 2010	20	28				1				
Lee et al., 2012 ⁴⁵	86	99	1					2	2	3
Lee et al., 2012 ⁴⁷	72	72				1	1			
Lin & Chiang, 2014	52	52	4	0	0	2	6	1		0
Lo et al., 2015	36	36				0		0		
Min et al., 2014	30	30		0	0	0	0	0	0	
Nandyala et al., 2014	65	65				5		1	1	7
Niesche et al., 2014	14	14		0	0	0	0	0	0	2
Park et al., 2015 ⁶⁷	124	141	3			1		2	5	7
Park et al., 2011	66	66			0	0	0	1	0	3
Parker et al., 2014	50	50				3		0	2	2
Peng et al., 2009	29	30						2		
Pereira et al., 2015	249	294	1			4	20			1
Perez-Cruet et al., 2014	318	330				1	31	11	1	4
Rouben et al., 2011	169	214								24
Schizas et al., 2009	18	18		2		1			3	2
Schwender et al., 2005	49	49							4	4
Sclafani et al., 2014	98	119				3		4		4
Seng et al., 2013	40	40				1		1		2
Sethi et al., 2009	19	19								3
Shen et al., 2014	65	65	1			3		0		1
Shunwu et al., 2010	32	32				0	1	3	2	
Siemionow et al., 2012	104	104								
Silva et al., 2013	150	168	3		2	8	1	3		2
Singh et al., 2013	573	573	327			23		3	2	49
Sonmez et al., 2013	20	20						0	0	
Starkweather et al., 2008	17	34			0		0	0		
Tender & Serban, 2014	60	60		1		2			1	5
Tian et al., 2014	30	30	1	1				0	0	1

(continued)

TABLE 1. MI-TLIF study characteristics and outcomes* (continued)

Authors & Year	No. of Patients	No. of Levels	Sensory Deficit	Temporary Neurological Deficit	Permanent Neurological Deficit	Intraop Complication	Medical Complication	Wound Complication	Hardware Failure	Reop
Tsahtsarlis & Wood, 2012	34	34	1				1			
Villavicencio et al., 2010	76	95		3	5	1		1	10	7
Wang et al., 2011	25	28				3		0		
Wang & Zhou, 2014	204	204	24	6	4	11	27	5	4	4
Wong et al., 2015	513	594		2	2	32	37	5	11	5
Wong et al., 2014	144	189	12	12		6	8	6	3	12
Xia et al., 2015	66	66					6			
Yoo et al., 2015	88	88								0

* Cells that are blank represent complications that were not mentioned in the studies.

traoperative complication, medical complications, wound complication, hardware failure, subsidence, and reoperation. In the analysis of secondary outcome measures, studies that did not make specific mention of each complication were excluded.

Statistical Analysis

Demographic data and other noncomparative data were generated utilizing simple descriptive statistics. Comparative univariate outcomes were evaluated for differences utilizing t-test, z-test, contingency tables, and Pearson's chi-square. Statistical analysis was performed using SPSS Statistics 22. Statistical significance was defined at a level of $p < 0.05$.

Results

Study Selection

For the review of MI-TLIF complications, 266 studies were identified through database searching. No additional studies were found manually. All studies had abstracts screened and assessed for eligibility. Seventy-one studies were deemed to be eligible and underwent full-text review. Seventeen studies were excluded after full-text review. Reasons for exclusion included lack of complication outcomes, reused data sets from other publications, study samples smaller than 10 persons, studies with mixed data sets of MI-TLIF and other fusion techniques that were not separated in the results of the study, and patient selection limited to those only with complications. Studies that did not use tubular retractors but used a "mini-open" procedure were excluded. A total of 54 studies, consisting of prospective cohorts, retrospective cohorts, and case series, were included in the study. The search flow diagram is shown in Fig. 1.

For review of the LLIF complications, 336 studies were identified through database searching. No additional studies were found manually. All studies had abstracts screened and were assessed for eligibility. Seventy-three studies were deemed to be eligible and underwent full-text review. Thirty-one studies were excluded after full-text re-

view. Reasons for exclusion included lack of complication outcomes, reused data sets from other publications, study samples of fewer than 10 persons, studies with mixed data sets of LLIF and other fusion techniques that were not separated in the results of the study, patient selection limited to those only with complications, and studies that involved the thoracic spine or thoracolumbar junction. A total of 42 studies, consisting of prospective cohorts, retrospective cohorts, and case series, were included in the study. The search flow diagram is shown in Fig. 2.

Study Characteristics and Outcomes

The relevant characteristics for each included study are summarized in Table 1 and Table 2, respectively, for MI-TLIF and LLIF. Primary outcome (total complications) and secondary outcomes are shown in Table 3. A total of 9714 patients (5454 in the MI-TLIF group and 4260 in the LLIF group) were included in the study. A total of 13,230 levels were fused, with 6040 in the MI-TLIF group and 7190 in the LLIF group. On average, there were 1.11 levels fused in the MI-TLIF patients compared with 1.69 levels fused in the LLIF patients ($p < 0.001$). The primary outcome of total complications showed 1045 in the MI-TLIF group and 1339 in the LLIF group. The total complication rate per patient was 19.2% in the MI-TLIF group, and 31.4% in the LLIF group ($p < 0.001$).

Significant differences for specific complications were observed between LLIF and MI-TLIF (Table 3). There were statistically more sensory deficits ($p < 0.0001$) as well as temporary ($p < 0.0001$) and permanent neurological ($p < 0.0001$) deficits per patient with LLIF. Conversely, there were more intraoperative ($p = 0.0003$) and wound ($p = 0.034$) complications with MI-TLIF. No significant differences in medical complications ($p = 0.201$) or reoperation ($p = 0.29$) were found. Intraoperative complications included occurrences such as durotomies, hardware or k-wire fractures, anterior longitudinal ligament rupture (unintentional during LLIF), abdominal wall paresis, vertebral body fractures bowel injuries, and vascular injuries. Medical complications included arrhythmias, deep venous thrombosis or pulmonary embolisms, urinary retention,

TABLE 2. LLIF study characteristics and outcomes*

Authors & Year	No. of Patients	No. of Levels	Sensory Deficit	Temporary Neurological Deficit	Permanent Neurological Deficit	Intraop Complication	Medical Complication	Wound Complication	Subsidence	Reop
Pimenta et al., 2013	30	30		4					5	4
Malham et al., 2014	52	79	3		1					4
Yuan et al., 2014	34	34	15			1	3			
Caputo et al., 2012	30	127				4	2	1		1
Formica et al., 2014	39	41	16	10	0			1		
Kotwal et al., 2015	118	237	13	20			9	1	34	4
Nemani et al., 2014	117	239							4	12
Lykissas et al., 2014	451	919	97	18	30					
Alimi et al., 2014	90	145	4	2	0	0				13
Kepler et al., 2011	13	13	1	3					2	
Aichmair et al., 2013	293	559	231	64	6					
Kim et al., 2014	163	229	13	23		1		1		
Khajavi et al., 2015	160	197	22	20		9	1	1	0	0
McAfee et al., 2013	25	64		20	2	1			0	1
Grimm et al., 2014	108	193	19		1		2			3
Tempel et al., 2015	335	712				2			29	2
Cahill et al., 2012	118	201		1	1		5			
Moller et al., 2011	53	102	13	19	0	1				
Wang et al., 2014	21	25	0	0	0	0				1
Sofianos et al., 2012	45	71	8	5	5					
Rodgers et al., 2011	600	741		4	0	0	23	2	2	8
Elowitz et al., 2011	25	31	25							
Uribe et al., 2015	323	507		13						
Castro et al., 2014	35	107			0	3			10	3
Marchi et al., 2013	74	98	14	11	0				57	10
Ozgun et al., 2010	62	113			0	1	11			
Rodgers et al., 2012 ⁷⁶	63	80			0		1			
Rodgers et al., 2012 ⁷⁵	44	49								
Knight et al., 2009	58	79	10	1	3	2	2		1	1
Sharma et al., 2011	43	87	13	15	2	4			18	
Castellvi et al., 2014	44	117	0	0	0	0	0			
Malham et al., 2012	30	43	5		1	2			4	3
Tender & Serban, 2013	26	26	1	6	0			2		
Ahmadian et al., 2013 ⁵	31	31	7	0	0	1				0
Le et al., 2012	140	238							20	
Ahmadian et al., 2015	59	96	10	12	0	0	6	0	18	1
Dakwar et al., 2010	25	76	3			1	1		1	
Rhee et al., 2015	38	38				0	1		1	
Wolfla et al., 2002	25	38	2		1	0	3			
Cummock et al., 2011	59	101	37	5	9	4	3	1		2
Waddell et al., 2014	21	54	3	2	0	3	0			3
Tohmeh et al., 2014	140	223				2	1			6

* Cells that are blank represent complications that were not mentioned in the studies.

TABLE 3. Comparison of total and specific complications between MI-TLIF and LLIF

Complication	MI-TLIF			LLIF			p Value
	No. of Patients	No. of Events	Rate/Patient	No. of Patients	No. of Events	Rate/Patient	
Total complications	5454	1045	19.2%	4260	1339	31.4%	<0.0001
Sensory deficit	1885	380	20.16%	2160	585	27.08%	<0.0001
Neurological deficit							
Temporary	1349	30	2.22%	2957	278	9.40%	<0.0001
Permanent	1382	14	1.01%	2525	62	2.46%	0.002
Intraop complication	3587	128	3.57%	2181	42	1.93%	0.0003
Medical complication	3197	160	5.00%	1762	74	4.20%	0.201
Wound complication	4243	69	1.63%	1254	10	0.80%	0.034
Hardware failure	2887	63	2.18%				
Subsidence				1900	206	10.84%	
Reop	4693	201	4.28%	2193	82	3.74%	0.29

ileus, rhabdomyolysis, acute altered mental status, pneumonia, respiratory failure, and other infections (excluding surgical site infections). Reasons for reoperation included wound debridement, epidural hematoma, psoas hematoma, adjacent-segment disease, revision of misplaced screws, new neurological deficits, hardware failure, and pseudarthrosis. Wound complications included superficial and deep infections, seromas, and hematomas.

Discussion

This systematic review of all studies defining complications in both MI-TLIF and LLIF procedures demonstrates that both procedures have an acceptable complication profile. Although LLIF did have an overall significantly higher complication rate per patient as compared with MI-TLIF (31.4% vs 19.2%), analysis of specific complications were not uniformly in favor of MI-TLIF.

The most significant differences in complications were noted in sensory deficits (27.08% for LLIF and 20.16% for MI-TLIF) and temporary neurological deficit (9.40% for LLIF and 2.22% for MI-TLIF). There was, however, significant heterogeneity in individual reports of these conditions. Aichmair et al. reported sensory deficits in 78.8% of patients and transient neurological deficits in 21.8% of patients with LLIF.⁶ Other studies have suggested that transient thigh numbness and mild hip flexion weakness are a result of the surgical technique of LLIF and should not be considered a complication.⁷⁴ Most reports showed these deficits to be temporary and not morbid, although Lykissas et al. did note a 6.7% rate of permanent neurological deficit.⁵¹ To combat this, Uribe et al. suggested the use of triggered electromyography (EMG) during the procedure as well as minimizing psoas retraction time.^{99,100} The present study was not able to distinguish if a lower rate of complication exists in procedures that used EMG. Intraoperative EMG has also routinely been used in MI-TLIF with mixed results.^{9,25} Bindal and Ghosh evaluated 25 consecutive patients undergoing MI-TLIF and based on EMG redirected the trajectory of the pedicle access needle in 76.2% of the screw placements.⁹ However, there was no comparative group. Conversely, in a retrospective compar-

ative study of 73 patients who underwent MI-TLIF with neurophysiological monitoring to 39 patients who had no monitoring, no significant difference in malpositioning of screws were identified.²⁵

LLIF did show a significantly lower risk of intraoperative complications (1.93% for LLIF vs 3.57% for MI-TLIF). This was likely due to a decrease in the incidence of durotomies. There were reports, however, of bowel injury and vascular injury, as well as a case of aortic thrombosis during LLIF.^{52,106,112} Reports of intraoperative complications in the MI-TLIF group were variable, ranging from 0% to 10.8%.³⁴ Reoperation rates were not significantly different between MI-TLIF and LLIF groups (4.28% vs 3.74%). These data, however, could be affected by the relative youth of the LLIF procedure, with overall shorter follow-up times. Subsidence rates were extremely variable in the LLIF group, with reports as high as 58.2%.⁵⁴ Overall, this study found a subsidence rate of 10.8%. Clinical significance is not known at this time for minor subsidence. Wound complications had relatively low rates in both LLIF and MI-TLIF, although LLIF was significantly lower (0.80% for LLIF and 1.63% for MI-TLIF). The overall low wound complication rate for either approach is likely related to the small incisions associated with MIS procedures. A unique complication associated with LLIF was abdominal paresis, which has been well described in previous studies.^{55,102}

Overall, medical complications were not excessive with a 4.20% rate in LLIF patients and 5.00% in MI-TLIF patients. These rates did not differ significantly and may reflect the decreased blood loss and exposure-related morbidity of minimally invasive approaches.

There are several limitations to this study. The quality of data available is relatively poor, with a predominance of noncomparative retrospective studies. There were no randomized controlled trials or prospective comparative studies. Given the quality of studies, there is likely publication and selection bias, which could undermine the validity of the present study. There is also a measurement bias, as the studies differed in their definition and reporting of complications. Surgical techniques are variable among the included studies. For example, some studies for LLIF used

stand-alone lateral cages, while others supplemented with posterior fixation. In addition, studies for MI-TLIF varied between unilateral and bilateral pedicle fixation. The follow-up time was variable among studies as well, which could affect reports of reoperation rates. In addition, the MI-TLIF group tended toward fewer levels being fused (1.11 levels for MI-TLIF vs 1.69 levels for LLIF), which suggests that the cases were less complex than in the LLIF group. Finally, several studies did not make specific mention of certain complications. In this study, it was assumed that those complications were not present rather than not reported for the primary outcome analysis. This is a potential source of bias. However, for the secondary outcomes analyses, these studies were eliminated and so would not have impacted the results.

Conclusions

MI-TLIF and LLIF both have acceptable complication profiles, although overall, there was a higher rate of complications per patient with LLIF. In regard to specific complications, LLIF had higher rates of sensory as well as temporary and permanent neurological symptoms, although rates of intraoperative and wound complications were less than those for MI-TLIF. Large, prospective comparative and ideally randomized studies are needed to confirm these findings as the current literature is of relatively poor quality.

References

- Adogwa O, Carr K, Thompson P, Hoang K, Darlington T, Perez E, et al: A prospective, multi-institutional comparative effectiveness study of lumbar spine surgery in morbidly obese patients: does minimally invasive transforaminal lumbar interbody fusion result in superior outcomes? **World Neurosurg** 83:860–866, 2015
- Adogwa O, Johnson K, Min ET, Issar N, Carr KR, Huang K, et al: Extent of intraoperative muscle dissection does not affect long-term outcomes after minimally invasive surgery versus open-transforaminal lumbar interbody fusion surgery: A prospective longitudinal cohort study. **Surg Neurol Int** 3 (Suppl 5):S355–S361, 2012
- Ahmadian A, Bach K, Bolinger B, Malham GM, Okonkwo DO, Kanter AS, et al: Stand-alone minimally invasive lateral lumbar interbody fusion: multicenter clinical outcomes. **J Clin Neurosci** 22:740–746, 2015
- Ahmadian A, Deukmedjian AR, Abel N, Dakwar E, Uribe JS: Analysis of lumbar plexopathies and nerve injury after lateral retroperitoneal transposas approach: diagnostic standardization. **J Neurosurg Spine** 18:289–297, 2013
- Ahmadian A, Verma S, Mundis GM Jr, Oskouian RJ Jr, Smith DA, Uribe JS: Minimally invasive lateral retroperitoneal transposas interbody fusion for L4-5 spondylolisthesis: clinical outcomes. **J Neurosurg Spine** 19:314–320, 2013
- Aichmair A, Lykissas MG, Girardi FP, Sama AA, Lebl DR, Taher F, et al: An institutional six-year trend analysis of the neurological outcome after lateral lumbar interbody fusion: a 6-year trend analysis of a single institution. **Spine (Phila Pa 1976)** 38:E1483–E1490, 2013
- Alimi M, Hofstetter CP, Cong GT, Tsiouris AJ, James AR, Paulo D, et al: Radiological and clinical outcomes following extreme lateral interbody fusion. **J Neurosurg Spine** 20:623–635, 2014
- Awad BI, Lubelski D, Shin JH, Carmody MA, Hoh DJ, Mroz TE, et al: Bilateral Pedicle Screw Fixation versus Unilateral Pedicle and Contralateral Facet Screws for Minimally Invasive Transforaminal Lumbar Interbody Fusion: Clinical Outcomes and Cost Analysis. **Global Spine J** 3:225–230, 2013
- Bindal RK, Ghosh S: Intraoperative electromyography monitoring in minimally invasive transforaminal lumbar interbody fusion. **J Neurosurg Spine** 6:126–132, 2007
- Brodano GB, Martikos K, Lolli F, Gasbarrini A, Cioni A, Bandiera S, et al: Transforaminal lumbar interbody fusion in degenerative disc disease and spondylolisthesis grade I: minimally invasive versus open surgery. **J Spinal Disord Tech** [epub ahead of print], 2013
- Cahill KS, Martinez JL, Wang MY, Vanni S, Levi AD: Motor nerve injuries following the minimally invasive lateral transposas approach. **J Neurosurg Spine** 17:227–231, 2012
- Caputo AM, Michael KW, Chapman TM Jr, Massey GM, Howes CR, Isaacs RE, et al: Clinical outcomes of extreme lateral interbody fusion in the treatment of adult degenerative scoliosis. **ScientificWorldJournal** 2012:680643, 2012
- Castellvi AE, Nienke TW, Marulanda GA, Murtagh RD, Santoni BG: Indirect decompression of lumbar stenosis with transposas interbody cages and percutaneous posterior instrumentation. **Clin Orthop Relat Res** 472:1784–1791, 2014
- Castro C, Oliveira L, Amaral R, Marchi L, Pimenta L: Is the lateral transposas approach feasible for the treatment of adult degenerative scoliosis? **Clin Orthop Relat Res** 472:1776–1783, 2014
- Cheng JS, Park P, Le H, Reisner L, Chou D, Mummaneni PV: Short-term and long-term outcomes of minimally invasive and open transforaminal lumbar interbody fusions: is there a difference? **Neurosurg Focus** 35(2):E6, 2013
- Choi UY, Park JY, Kim KH, Kuh SU, Chin DK, Kim KS, et al: Unilateral versus bilateral percutaneous pedicle screw fixation in minimally invasive transforaminal lumbar interbody fusion. **Neurosurg Focus** 35(2):E11, 2013
- Cummock MD, Vanni S, Levi AD, Yu Y, Wang MY: An analysis of postoperative thigh symptoms after minimally invasive transposas lumbar interbody fusion. **J Neurosurg Spine** 15:11–18, 2011
- Dakwar E, Cardona RF, Smith DA, Uribe JS: Early outcomes and safety of the minimally invasive, lateral retroperitoneal transposas approach for adult degenerative scoliosis. **Neurosurg Focus** 28(3):E8, 2010
- Dangelmajer S, Zadnik PL, Rodriguez ST, Gokaslan ZL, Sciubba DM: Minimally invasive spine surgery for adult degenerative lumbar scoliosis. **Neurosurg Focus** 36(5):E7, 2014
- Deutsch H, Musacchio MJ Jr: Minimally invasive transforaminal lumbar interbody fusion with unilateral pedicle screw fixation. **Neurosurg Focus** 20(3):E10, 2006
- Eckman WW, Hester L, McMillen M: Same-day discharge after minimally invasive transforaminal lumbar interbody fusion: a series of 808 cases. **Clin Orthop Relat Res** 472:1806–1812, 2014
- Elowitz EH, Yanni DS, Chwajol M, Starke RM, Perin NI: Evaluation of indirect decompression of the lumbar spinal canal following minimally invasive lateral transposas interbody fusion: radiographic and outcome analysis. **Minim Invasive Neurosurg** 54:201–206, 2011
- Foley KT, Holly LT, Schwender JD: Minimally invasive lumbar fusion. **Spine (Phila Pa 1976)** 28 (15 Suppl):S26–S35, 2003
- Formica M, Berjano P, Cavagnaro L, Zanirato A, Piazzolla A, Formica C: Extreme lateral approach to the spine in degenerative and post traumatic lumbar diseases: selection process, results and complications. **Eur Spine J** 23 (Suppl 6):684–692, 2014

25. Garces J, Berry JF, Valle-Giler EP, Sulaiman WA: Intraoperative neurophysiological monitoring for minimally invasive 1- and 2-level transforaminal lumbar interbody fusion: does it improve patient outcome? **Ochsner J** 14:57–61, 2014
26. Goldstein CL, Macwan K, Sundararajan K, Rampersaud YR: Comparative outcomes of minimally invasive surgery for posterior lumbar fusion: a systematic review. **Clin Orthop Relat Res** 472:1727–1737, 2014
27. Graham RB, Wong AP, Liu JC: Minimally invasive lateral transposas approach to the lumbar spine: pitfalls and complication avoidance. **Neurosurg Clin N Am** 25:219–231, 2014
28. Grimm BD, Leas DP, Poletti SC, Johnson DR II: Postoperative complications within the first year after extreme lateral interbody fusion: experience of the first 108 patients. **J Spinal Disord Tech** [epub ahead of print], 2014
29. Gu G, Zhang H, Fan G, He S, Cai X, Shen X, et al: Comparison of minimally invasive versus open transforaminal lumbar interbody fusion in two-level degenerative lumbar disease. **Int Orthop** 38:817–824, 2014
30. Harms J, Rolinger H: [A one-stager procedure in operative treatment of spondylolistheses: dorsal traction-reposition and anterior fusion (author's transl)]. **Z Orthop Ihre Grenzgeb** 120:343–347, 1982 (Ger)
31. Hsiang J, Yu K, He Y: Minimally invasive one-level lumbar decompression and fusion surgery with posterior instrumentation using a combination of pedicle screw fixation and transpedicular facet screw construct. **Surg Neurol Int** 4:125, 2013
32. Jang JS, Lee SH: Minimally invasive transforaminal lumbar interbody fusion with ipsilateral pedicle screw and contralateral facet screw fixation. **J Neurosurg Spine** 3:218–223, 2005
33. Jhala A, Singh D, Mistry M: Minimally invasive transforaminal lumbar interbody fusion: Results of 23 consecutive cases. **Indian J Orthop** 48:562–567, 2014
34. Kang MS, Park JY, Kim KH, Kuh SU, Chin DK, Kim KS, et al: Minimally invasive transforaminal lumbar interbody fusion with unilateral pedicle screw fixation: comparison between primary and revision surgery. **BioMed Res Int** 2014:919248, 2014
35. Kepler CK, Sharma AK, Huang RC: Lateral transposas interbody fusion (LTIF) with plate fixation and unilateral pedicle screws: a preliminary report. **J Spinal Disord Tech** 24:363–367, 2011
36. Khajavi K, Shen A, Lagina M, Hutchison A: Comparison of clinical outcomes following minimally invasive lateral interbody fusion stratified by preoperative diagnosis. **Eur Spine J** 24 (Suppl 3):322–330, 2015
37. Kim JS, Jung B, Lee SH: Instrumented minimally invasive spinal-transforaminal lumbar interbody fusion (MIS-TLIF); minimum 5-years follow-up with clinical and radiologic outcomes. **J Spinal Disord Tech** [epub ahead of print], 2012
38. Kim SJ, Lee YS, Kim YB, Park SW, Hung VT: Clinical and radiological outcomes of a new cage for direct lateral lumbar interbody fusion. **Korean J Spine** 11:145–151, 2014
39. Knight RQ, Schwagler P, Hanscom D, Roh J: Direct lateral lumbar interbody fusion for degenerative conditions: early complication profile. **J Spinal Disord Tech** 22:34–37, 2009
40. Kotwal S, Kawaguchi S, Lebl D, Hughes A, Huang R, Sama A, et al: Minimally invasive lateral lumbar interbody fusion: clinical and radiographic outcome at a minimum 2-year follow-up. **J Spinal Disord Tech** 28:119–125, 2015
41. Lau D, Khan A, Terman SW, Yee T, La Marca F, Park P: Comparison of perioperative outcomes following open versus minimally invasive transforaminal lumbar interbody fusion in obese patients. **Neurosurg Focus** 35(2):E10, 2013
42. Lau D, Lee JG, Han SJ, Lu DC, Chou D: Complications and perioperative factors associated with learning the technique of minimally invasive transforaminal lumbar interbody fusion (TLIF). **J Clin Neurosci** 18:624–627, 2011
43. Le TV, Baaj AA, Dakwar E, Burkett CJ, Murray G, Smith DA, et al: Subsidence of polyetheretherketone intervertebral cages in minimally invasive lateral retroperitoneal transposas lumbar interbody fusion. **Spine (Phila Pa 1976)** 37:1268–1273, 2012
44. Lee CK, Park JY, Zhang HY: Minimally invasive transforaminal lumbar interbody fusion using a single interbody cage and a tubular retraction system: technical tips, and perioperative, radiologic and clinical outcomes. **J Korean Neurosurg Soc** 48:219–224, 2010
45. Lee JC, Jang HD, Shin BJ: Learning curve and clinical outcomes of minimally invasive transforaminal lumbar interbody fusion: our experience in 86 consecutive cases. **Spine (Phila Pa 1976)** 37:1548–1557, 2012
46. Lee KH, Yeo W, Soeharno H, Yue WM: Learning curve of a complex surgical technique: minimally invasive transforaminal lumbar interbody fusion (MIS TLIF). **J Spinal Disord Tech** 27:E234–E240, 2014
47. Lee KH, Yue WM, Yeo W, Soeharno H, Tan SB: Clinical and radiological outcomes of open versus minimally invasive transforaminal lumbar interbody fusion. **Eur Spine J** 21:2265–2270, 2012
48. Lee P, Fessler RG: Perioperative and postoperative complications of single-level minimally invasive transforaminal lumbar interbody fusion in elderly adults. **J Clin Neurosci** 19:111–114, 2012
49. Lin JH, Chiang YH: Unilateral approach for bilateral foramen decompression in minimally invasive transforaminal interbody fusion. **World Neurosurg** 82:891–896, 2014
50. Lo WL, Lin CM, Yeh YS, Su YK, Tseng YY, Yang ST, et al: Comparing miniopen and minimally invasive transforaminal interbody fusion in single-level lumbar degeneration. **BioMed Res Int** 2015:168384, 2015
51. Lykissas MG, Aichmair A, Hughes AP, Sama AA, Lebl DR, Taher F, et al: Nerve injury after lateral lumbar interbody fusion: a review of 919 treated levels with identification of risk factors. **Spine J** 14:749–758, 2014
52. Malham GM, Ellis NJ, Parker RM, Seex KA: Clinical outcome and fusion rates after the first 30 extreme lateral interbody fusions. **ScientificWorldJournal** 2012:246989, 2012
53. Malham GM, Parker RM, Goss B, Blecher CM, Ballok ZE: Indirect foraminal decompression is independent of metabolically active facet arthropathy in extreme lateral interbody fusion. **Spine (Phila Pa 1976)** 39:E1303–E1310, 2014
54. Marchi L, Abdala N, Oliveira L, Amaral R, Coutinho E, Pimenta L: Radiographic and clinical evaluation of cage subsidence after stand-alone lateral interbody fusion. **J Neurosurg Spine** 19:110–118, 2013
55. McAfee PC, Shucosky E, Chotikul L, Salari B, Chen L, Jerrens D: Multilevel extreme lateral interbody fusion (XLIF) and osteotomies for 3-dimensional severe deformity: 25 consecutive cases. **Int J Spine Surg** 7:e8–e19, 2013
56. Min SH, Yoo JS, Lee JY: Usefulness of Contralateral Indirect Decompression through Minimally Invasive Unilateral Transforaminal Lumbar Interbody Fusion. **Asian Spine J** 8:453–461, 2014
57. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, et al: Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. **Syst Rev** 4:1, 2015
58. Moller DJ, Slimack NP, Acosta FL Jr, Koski TR, Fessler RG, Liu JC: Minimally invasive lateral lumbar interbody fusion and transposas approach-related morbidity. **Neurosurg Focus** 31(4):E4, 2011
59. Nandyala SV, Fineberg SJ, Pelton M, Singh K: Minimally

- invasive transforaminal lumbar interbody fusion: one surgeon's learning curve. **Spine J** 14:1460–1465, 2014
60. Neal CJ, Rosner MK: Resident learning curve for minimal-access transforaminal lumbar interbody fusion in a military training program. **Neurosurg Focus** 28(5):E21, 2010
 61. Nemani VM, Aichmair A, Taher F, Lebl DR, Hughes AP, Sama AA, et al: Rate of revision surgery after stand-alone lateral lumbar interbody fusion for lumbar spinal stenosis. **Spine (Phila Pa 1976)** 39:E326–E331, 2014
 62. Niesche M, Juratli TA, Sitoci KH, Neidel J, Daubner D, Schackert G, et al: Percutaneous pedicle screw and rod fixation with TLIF in a series of 14 patients with recurrent lumbar disc herniation. **Clin Neurol Neurosurg** 124:25–31, 2014
 63. Ozgur BM, Agarwal V, Nail E, Pimenta L: Two-year clinical and radiographic success of minimally invasive lateral transpoas approach for the treatment of degenerative lumbar conditions. **SAS J** 4:41–46, 2010
 64. Ozgur BM, Aryan HE, Pimenta L, Taylor WR: Extreme Lateral Interbody Fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion. **Spine J** 6:435–443, 2006
 65. Park P, Wang MY, Lafage V, Nguyen S, Ziewacz J, Okonkwo DO, et al: Comparison of two minimally invasive surgery strategies to treat adult spinal deformity. **J Neurosurg Spine** 22:374–380, 2015
 66. Park Y, Ha JW, Lee YT, Oh HC, Yoo JH, Kim HB: Surgical outcomes of minimally invasive transforaminal lumbar interbody fusion for the treatment of spondylolisthesis and degenerative segmental instability. **Asian Spine J** 5:228–236, 2011
 67. Park Y, Lee SB, Seok SO, Jo BW, Ha JW: Perioperative surgical complications and learning curve associated with minimally invasive transforaminal lumbar interbody fusion: a single-institute experience. **Clin Orthop Surg** 7:91–96, 2015
 68. Parker SL, Mendenhall SK, Shau DN, Zuckerman SL, Godil SS, Cheng JS, et al: Minimally invasive versus open transforaminal lumbar interbody fusion for degenerative spondylolisthesis: comparative effectiveness and cost-utility analysis. **World Neurosurg** 82:230–238, 2014
 69. Peng CW, Yue WM, Poh SY, Yeo W, Tan SB: Clinical and radiological outcomes of minimally invasive versus open transforaminal lumbar interbody fusion. **Spine (Phila Pa 1976)** 34:1385–1389, 2009
 70. Pereira P, Buzek D, Franke J, Senker W, Kosmala A, Hubbe U, et al: Surgical data and early postoperative outcomes after minimally invasive lumbar interbody fusion: results of a prospective, multicenter, observational data-monitored study. **PLoS One** 10:e0122312, 2015
 71. Perez-Cruet MJ, Hussain NS, White GZ, Begun EM, Collins RA, Fahim DK, et al: Quality-of-life outcomes with minimally invasive transforaminal lumbar interbody fusion based on long-term analysis of 304 consecutive patients. **Spine (Phila Pa 1976)** 39:E191–E198, 2014
 72. Pimenta L, Marchi L, Oliveira L, Coutinho E, Amaral R: A prospective, randomized, controlled trial comparing radiographic and clinical outcomes between stand-alone lateral interbody lumbar fusion with either silicate calcium phosphate or rh-BMP2. **J Neurol Surg A Cent Eur Neurosurg** 74:343–350, 2013
 73. Rhee JW, Petteys RJ, Anaizi AN, Sandhu FA, Voyadzis JM: Prospective evaluation of 1-year outcomes in single-level percutaneous lumbar transfacet screw fixation in the lateral decubitus position following lateral transpoas interbody fusion. **Eur Spine J** [epub ahead of print], 2015
 74. Rodgers WB, Gerber EJ, Patterson J: Intraoperative and early postoperative complications in extreme lateral interbody fusion: an analysis of 600 cases. **Spine (Phila Pa 1976)** 36:26–32, 2011
 75. Rodgers WB, Gerber EJ, Rodgers JA: Clinical and radiographic outcomes of extreme lateral approach to interbody fusion with β -tricalcium phosphate and hydroxyapatite composite for lumbar degenerative conditions. **Int J Spine Surg** 6:24–28, 2012
 76. Rodgers WB, Lehmen JA, Gerber EJ, Rodgers JA: Grade 2 spondylolisthesis at L4-5 treated by XLIF: safety and midterm results in the “worst case scenario”. **ScientificWorldJournal** 2012:356712, 2012
 77. Rouben D, Casnellie M, Ferguson M: Long-term durability of minimal invasive posterior transforaminal lumbar interbody fusion: a clinical and radiographic follow-up. **J Spinal Disord Tech** 24:288–296, 2011
 78. Schizas C, Tzinieris N, Tsiridis E, Kosmopoulos V: Minimally invasive versus open transforaminal lumbar interbody fusion: evaluating initial experience. **Int Orthop** 33:1683–1688, 2009
 79. Schwender JD, Holly LT, Rouben DP, Foley KT: Minimally invasive transforaminal lumbar interbody fusion (TLIF): technical feasibility and initial results. **J Spinal Disord Tech** 18 (Suppl):S1–S6, 2005
 80. Sclafani JA, Kim CW: Complications associated with the initial learning curve of minimally invasive spine surgery: a systematic review. **Clin Orthop Relat Res** 472:1711–1717, 2014
 81. Sclafani JA, Raiszadeh K, Raiszadeh R, Kim P, Doerr T, Siddiqi F, et al: Validation and analysis of a multi-site MIS Prospective Registry through sub-analysis of an MIS TLIF Subgroup. **Int J Spine Surg** 1:8, 2014
 82. Seng C, Siddiqui MA, Wong KP, Zhang K, Yeo W, Tan SB, et al: Five-year outcomes of minimally invasive versus open transforaminal lumbar interbody fusion: a matched-pair comparison study. **Spine (Phila Pa 1976)** 38:2049–2055, 2013
 83. Sethi A, Lee S, Vaidya R: Transforaminal lumbar interbody fusion using unilateral pedicle screws and a translaminal screw. **Eur Spine J** 18:430–434, 2009
 84. Sharma AK, Kepler CK, Girardi FP, Cammisa FP, Huang RC, Sama AA: Lateral lumbar interbody fusion: clinical and radiographic outcomes at 1 year: a preliminary report. **J Spinal Disord Tech** 24:242–250, 2011
 85. Shen X, Zhang H, Gu X, Gu G, Zhou X, He S: Unilateral versus bilateral pedicle screw instrumentation for single-level minimally invasive transforaminal lumbar interbody fusion. **J Clin Neurosci** 21:1612–1616, 2014
 86. Shunwu F, Xing Z, Fengdong Z, Xiangqian F: Minimally invasive transforaminal lumbar interbody fusion for the treatment of degenerative lumbar diseases. **Spine (Phila Pa 1976)** 35:1615–1620, 2010
 87. Siemionow K, Pelton MA, Hoskins JA, Singh K: Predictive factors of hospital stay in patients undergoing minimally invasive transforaminal lumbar interbody fusion and instrumentation. **Spine (Phila Pa 1976)** 37:2046–2054, 2012
 88. Silva PS, Pereira P, Monteiro P, Silva PA, Vaz R: Learning curve and complications of minimally invasive transforaminal lumbar interbody fusion. **Neurosurg Focus** 35(2):E7, 2013
 89. Singh K, Nandyala SV, Marquez-Lara A, Cha TD, Khan SN, Fineberg SJ, et al: Clinical sequelae after rhBMP-2 use in a minimally invasive transforaminal lumbar interbody fusion. **Spine J** 13:1118–1125, 2013
 90. Sofianos DA, Briseño MR, Abrams J, Patel AA: Complications of the lateral transpoas approach for lumbar interbody arthrodesis: a case series and literature review. **Clin Orthop Relat Res** 470:1621–1632, 2012
 91. Sonmez E, Coven I, Sahinturk F, Yilmaz C, Caner H: Unilateral percutaneous pedicle screw instrumentation with minimally invasive TLIF for the treatment of recurrent lumbar disk disease: 2 years follow-up. **Turk Neurosurg** 23:372–378, 2013

92. Starkweather AR, Witek-Janusek L, Nockels RP, Peterson J, Mathews HL: The multiple benefits of minimally invasive spinal surgery: results comparing transforaminal lumbar interbody fusion and posterior lumbar fusion. **J Neurosci Nurs** **40**:32–39, 2008
93. Tempel ZJ, Gandhoke GS, Bolinger BD, Okonkwo DO, Kanter AS: Vertebral body fracture following stand-alone lateral lumbar interbody fusion (LLIF): report of two events out of 712 levels. **Eur Spine J** **24** (Suppl 3):409–413, 2015
94. Tender GC, Serban D: Genitofemoral nerve protection during the lateral retroperitoneal transpsoas approach. **Neurosurgery** **73** (2 Suppl Operative):ons192–ons197, 2013
95. Tender GC, Serban D: Minimally invasive transforaminal lumbar interbody fusion: comparison of two techniques. **Chirurgia (Bucur)** **109**:812–821, 2014
96. Tian W, Xu YF, Liu B, Liu YJ, He D, Yuan Q, et al: Computer-assisted minimally invasive transforaminal lumbar interbody fusion may be better than open surgery for treating degenerative lumbar disease. **J Spinal Disord Tech** [epub ahead of print], 2014
97. Tohmeh AG, Khorsand D, Watson B, Zielinski X: Radiographical and clinical evaluation of extreme lateral interbody fusion: effects of cage size and instrumentation type with a minimum of 1-year follow-up. **Spine (Phila Pa 1976)** **39**:E1582–E1591, 2014
98. Tsahtsarlis A, Wood M: Minimally invasive transforaminal lumbar interbody fusion and degenerative lumbar spine disease. **Eur Spine J** **21**:2300–2305, 2012
99. Uribe JS, Isaacs RE, Youssef JA, Khajavi K, Balzer JR, Kanter AS, et al: Can triggered electromyography monitoring throughout retraction predict postoperative symptomatic neuropraxia after XLIF? Results from a prospective multicenter trial. **Eur Spine J** **24** (Suppl 3):378–385, 2015
100. Uribe JS, Vale FL, Dakwar E: Electromyographic monitoring and its anatomical implications in minimally invasive spine surgery. **Spine (Phila Pa 1976)** **35** (26 Suppl):S368–S374, 2010
101. Villavicencio AT, Burneikiene S, Roeca CM, Nelson EL, Mason A: Minimally invasive versus open transforaminal lumbar interbody fusion. **Surg Neurol Int** **1**:12, 2010
102. Waddell B, Briski D, Qadir R, Godoy G, Houston AH, Rudman E, et al: Lateral lumbar interbody fusion for the correction of spondylolisthesis and adult degenerative scoliosis in high-risk patients: early radiographic results and complications. **Ochsner J** **14**:23–31, 2014
103. Wang J, Zhou Y: Perioperative complications related to minimally invasive transforaminal lumbar fusion: evaluation of 204 operations on lumbar instability at single center. **Spine J** **14**:2078–2084, 2014
104. Wang J, Zhou Y, Zhang ZF, Li CQ, Zheng WJ, Liu J: Minimally invasive or open transforaminal lumbar interbody fusion as revision surgery for patients previously treated by open discectomy and decompression of the lumbar spine. **Eur Spine J** **20**:623–628, 2011
105. Wang MY, Vasudevan R, Mindea SA: Minimally invasive lateral interbody fusion for the treatment of rostral adjacent-segment lumbar degenerative stenosis without supplemental pedicle screw fixation. **J Neurosurg Spine** **21**:861–866, 2014
106. Wolfla CE, Maiman DJ, Coufal FJ, Wallace JR: Retroperitoneal lateral lumbar interbody fusion with titanium threaded fusion cages. **J Neurosurg** **96** (1 Suppl):50–55, 2002
107. Wong AP, Smith ZA, Nixon AT, Lawton CD, Dahdaleh NS, Wong RH, et al: Intraoperative and perioperative complications in minimally invasive transforaminal lumbar interbody fusion: a review of 513 patients. **J Neurosurg Spine** **22**:487–495, 2015
108. Wong AP, Smith ZA, Stadler JA III, Hu XY, Yan JZ, Li XF, et al: Minimally invasive transforaminal lumbar interbody fusion (MI-TLIF): surgical technique, long-term 4-year prospective outcomes, and complications compared with an open TLIF cohort. **Neurosurg Clin N Am** **25**:279–304, 2014
109. Wu RH, Fraser JF, Härtl R: Minimal access versus open transforaminal lumbar interbody fusion: meta-analysis of fusion rates. **Spine (Phila Pa 1976)** **35**:2273–2281, 2010
110. Xia XL, Wang HL, Lyu FZ, Wang LX, Ma XS, Jiang JY: Mast Quadrant-assisted minimally invasive modified transforaminal lumbar interbody fusion: single incision versus double incision. **Chin Med J (Engl)** **128**:871–876, 2015
111. Yoo JS, Min SH, Yoon SH: Fusion rate according to mixture ratio and volumes of bone graft in minimally invasive transforaminal lumbar interbody fusion: minimum 2-year follow-up. **Eur J Orthop Surg Traumatol** **25** (Suppl 1):183–189, 2015
112. Yuan PS, Rowshan K, Verma RB, Miller LE, Block JE: Minimally invasive lateral lumbar interbody fusion with direct psoas visualization. **J Orthop Surg** **9**:20, 2014

Disclosure

Dr. Park reports that he is a consultant for Medtronic, Biomet, and Globus and receives a royalty from Globus. Dr. La Marca reports that he is a consultant for Globus and Biomet and receives a royalty from Globus.

Author Contributions

Conception and design: Park. Acquisition of data: Joseph. Analysis and interpretation of data: Joseph, Smith, Park. Drafting the article: Joseph, Smith. Critically revising the article: all authors. Reviewed submitted version of manuscript: Park, Joseph, La Marca. Approved the final version of the manuscript on behalf of all authors: Park. Study supervision: Park.

Correspondence

Paul Park, Department of Neurosurgery, University of Michigan, 1500 E. Medical Center Dr., Rm. 3553 TC, Ann Arbor, MI 48109-5338. email: ppark@med.umich.edu.