NEUROSURGICAL FOCUS

Neurosurg Focus 39 (4):E4, 2015

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

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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 procedures.[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.

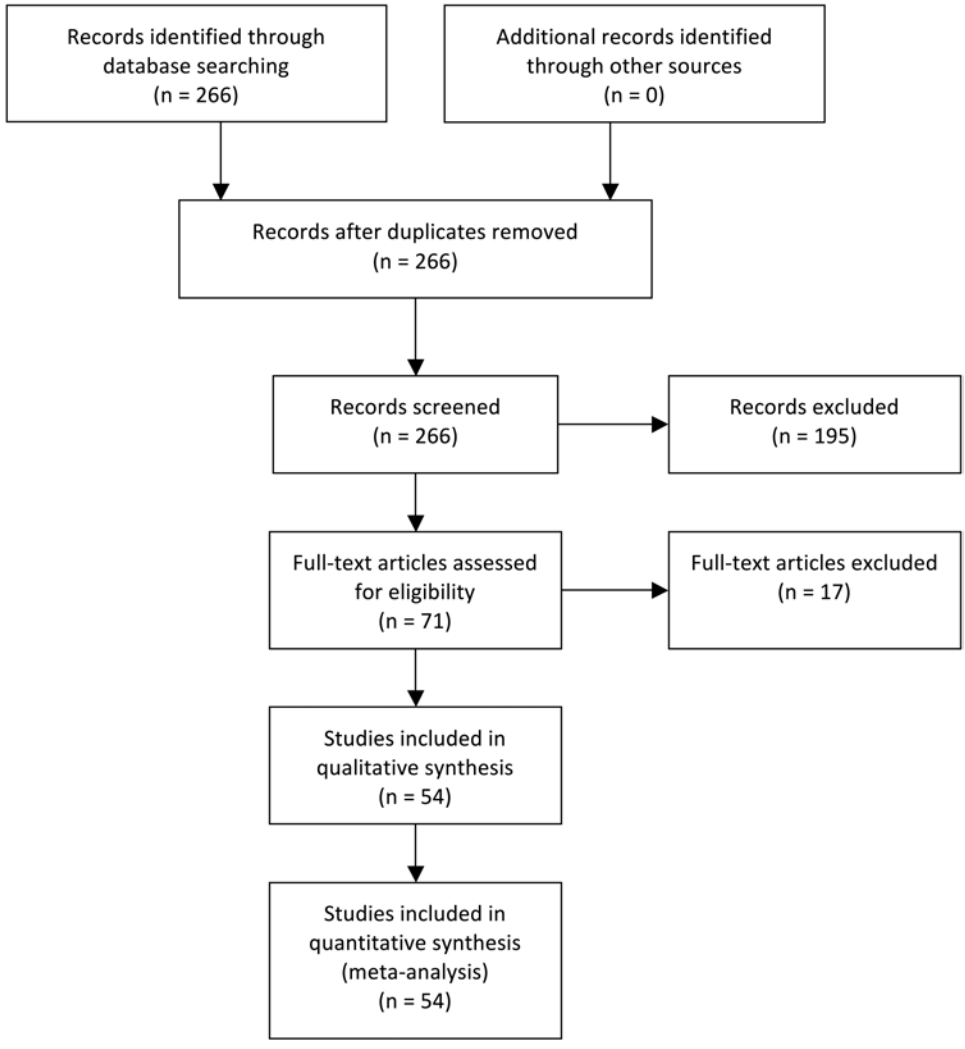

FIG. 1. Flow diagram showing selection of the studies for this systematic review of MI-TLIF.

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 "transpsoas" 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

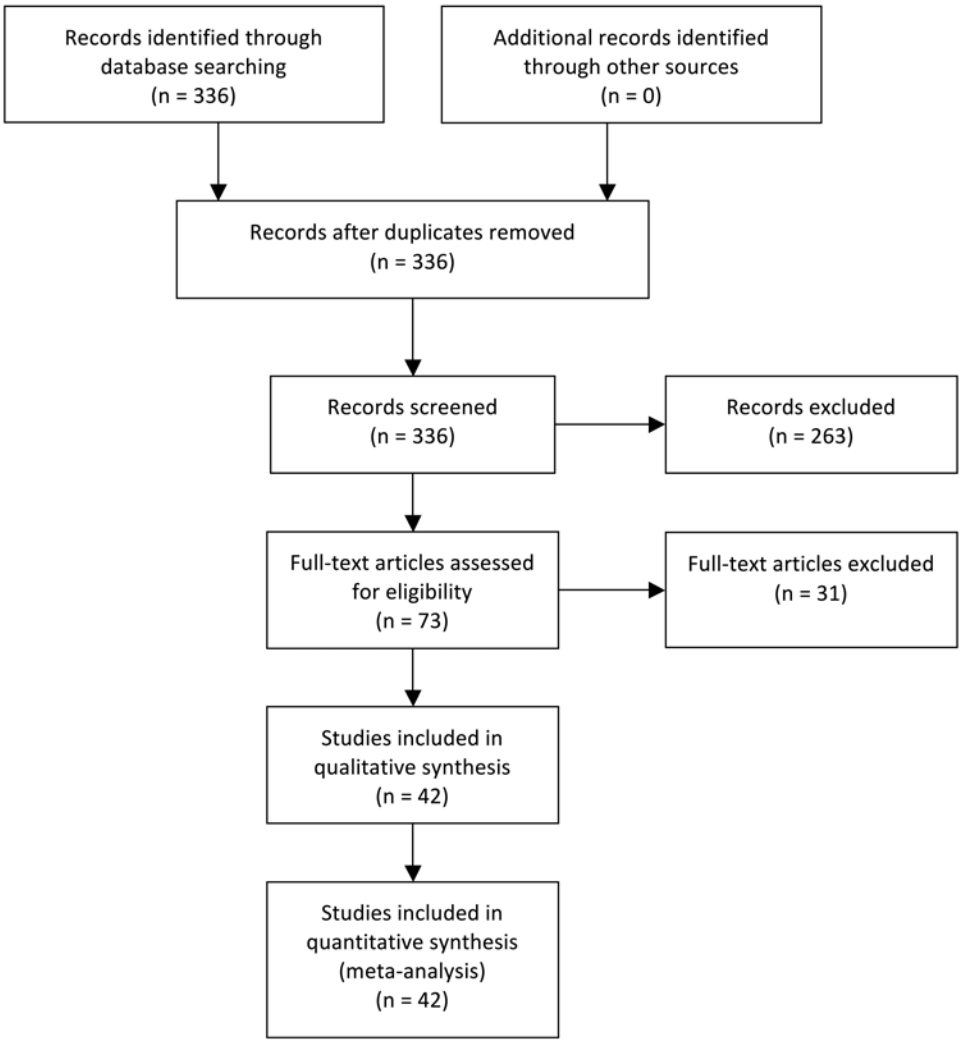

FIG. 2. Flow diagram showing selection of the studies for this systematic review of LLIF.

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 review. 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
Ozgur 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 comparative 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.

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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.

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