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ORIGINAL ARTICLE

Visceral, vascular, and wound complications following over 13,000 lateral interbody fusions: a survey study and literature review

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Abstract

Purpose Minimally invasive lateral interbody fusion (MIS-LIF) has become a popular less invasive treatment option for degenerative spinal disease, deformity, and trauma. While MIS-LIF offers several advantages over traditional anterior and posterior approaches, the procedure is not without risk. The purpose of this study was to evaluate the incidence of visceral, vascular, and wound complications following MIS-LIF performed by experienced surgeons.

Methods A survey was conducted by experienced (more than 100 case experience) MIS-LIF surgeons active in the society of lateral access surgery (SOLAS) to collect data on wound infections and visceral and vascular injuries. Of 77 spine surgeons surveyed, 40 (52 %) responded, including 25 (63 %) orthopedic surgeons and 15 (38 %) neurosurgeons, with 20 % practicing at an academic institution and 80 % in community practice.

Results Between 2003 and 2013, 13,004 patients were treated with MIS-LIF by the 40 surgeons who responded to the survey. Of those patients, 0.08 % experienced a visceral complication (bowel injury), 0.10 % experienced a vascular injury, 0.27 % experienced a superficial wound infection, and 0.14 % experienced a deep wound infection.

Conclusion The incidence of surgical site infections and vascular and visceral complications following MIS-LIF in this large series was low and compared favorably with rates for alternative interbody fusion approaches. Although technically demanding, MIS-LIF is a reproducible approach for interbody fusion with a low risk of vascular and visceral complications and infections.

Keywords XLIF · Lateral · Transpsoas · Aorta · Vena cava · Bowel · Infection

Introduction

Spinal interbody fusion has traditionally been performed through open surgical approaches, such as transforaminal lumbar interbody fusion (TLIF), posterior lumbar interbody fusion (PLIF), and anterior lumbar interbody fusion (ALIF) [1–9]. Vascular, visceral, and wound complications in these procedures have been well described and large-series incidences, though varying significantly, have been documented in many studies. The anterior approach is most notably associated with vascular injury (0.3–20 %), though also has elevated rates of ileus (0.6–5 %), bowel injury (1.7 %), and wound complications (0.4–7.1 %) with respect to alternative approaches [8, 10–18]. Posterior approaches to interbody fusion also involve a number of different risks, including high and varying rates of wound infection (3.2–9.5 %) and, while rare, risks of both visceral (1.2 %) and vascular injuries (0.5–3.8 %) [2–7, 9, 19–28].

One alternative to these techniques is the minimally invasive lateral interbody fusion (MIS-LIF) procedure, which utilizes a lateral, retroperitoneal, transpsoas approach to the anterior thoracolumbar spine [29]. MIS-LIF has been described as a less invasive option for the treatment of degenerative spinal disease, deformity, and trauma, offering several potential advantages over traditional posterior approaches, including decreased muscle dissection, decreased postoperative muscle atrophy, and the ability to place a graft spanning a majority of the interbody space

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[30–32]. However, the approach is not without risk and has its own set of challenges due to the unique nature of the approach.

Since the original description of MIS-LIF in 2006, there has been a lack of consistent reporting of complications and, as such, a large variation in reported rates in the literature. In addition, there is a perception in the spine surgery community of potential underreporting of the incidence of major complications related to MIS-LIF. Thus, the purpose of this study was to evaluate the incidence of complications following MIS-LIF performed by experienced surgeons actively engaged in an MIS lateral research society, including visceral (bowel laceration) and vascular complications (great vessel injury), as well as superficial and deep surgical site infections (SSI) in a large series.

Methods and materials

In 2012 and 2013, all active members of the Society of Lateral Access Surgery (SOLAS) who had performed over 100 MIS-LIF's [extreme lateral interbody fusion (XLIF®, NuVasive, Inc. San Diego, CA, USA)] were contacted by email with a survey on their experience of wound infections and visceral and vascular complications in their MIS-LIF cases. As there are differences in the approach and instrumentation of non-XLIF MIS-LIF procedures, only XLIF cases were analyzed for homogeneity in analysis. Data were included from each surgeon's entire series of MIS-LIF patients starting from their adoption of the procedure. Data collected included duration and extent of their use of the procedure as well as demographic information on the surgeon's practice and setting. Accounting and clinical research records were used to verify the number of patients treated by each respondent and in the case of a discrepancy between the two, the lower number was used. Surgeons were then initially surveyed on three questions:

1. "Did any deep or superficial infections in the XLIF exposure site occur in your patient experience?"
2. "Did any major vascular (great vessel) injuries occur in your patient experience?"
3. "Did any bowel injuries occur in your patient experience?"

If a surgeon reported any of these complications in their experience, additional information including patient demographic and treatment information, a description of the complication, any additional treatment the complication required, and resolution was requested. Survey and follow-up questions are included in Table 1.

A total of 77 SOLAS surgeons who met inclusion criteria were identified and contacted for the survey via email, of which 40 (52 %) responded following multiple reminder emails. These 40 surgeons were composed of 25 (62.5 %) orthopedic surgeons and 15 (37.5 %) neurosurgeons, with 8 (20 %) surgeons practicing at academic institutions and 32 (80 %) in private practice.

Table 1 Survey and follow-up questions for patients with vascular, visceral, or wound complications

Patient information
Gender
Age
Notable comorbidities
Prior surgery? If yes, specify type
Treatment information
Indication for surgery
Levels treated
Single or two-incision approach
Side of approach
Biologic used
Instrumentation used
When did this case occur in your experience? In first 10 cases, 11–50, or >50?
Complication information
When was the complication identified?
How was it treated?
What was the outcome (e.g., resolution)?
How long postoperatively did the outcome occur?

Statistical analysis included the use descriptive statistics for all survey result data. Statistical analyses were performed using JMP v11 (SAS Institute, Cary, NC, USA).

Literature search strategy and criteria

A literature review was performed to assess the incidence of similar complications following other commonly used interbody fusion techniques. The MEDLINE®/PubMed® database was searched for relevant studies from the last 30 years in the English language using MeSH (Medical Subject Headings) keywords related to ALIF (anterior lumbar interbody fusion), TLIF (transforaminal lumbar interbody fusion), PLIF (posterior lumbar interbody fusion), and vascular, visceral, and infection complications. References of all primary studies were also searched for additional references not identified in the initial search (citation pearling).

Results

From 2003 to early 2013, a total of 13,004 XLIF cases were performed between 40 surgeons. In these cases, 35 (0.27 %) superficial lateral wound infections and 18

Table 2 Incidence of complications surveyed from 40 spine surgeons

	$N = 13{,}004$
Lateral wound infections, *n* (%)	
Superficial	35 (0.27 %)
Deep wound infections	18 (0.14 %)
Vascular complications, *n* (%)	13 (0.10 %)
Visceral complications, *n* (%)	11 (0.08 %)

n Number of patients

Table 3 Superficial lateral wound infections

	$N = 12$[a]
Mean age (years)	58.5
Female, *n* (%)	8 (67 %)
Comorbidities, *n* (%)	
None	3 (25 %)
Diabetes mellitus	5 (42 %)
Rheumatoid arthritis	2 (17 %)
Hypertension	2 (17 %)
Treatment, *n* (%)	
Wound washout + antibiotics	8 (67 %)
Oral antibiotics	4 (33 %)
Outcome, *n* (%)	
Full resolution	12 (100 %)

n Number of patients

[a] A total of 35 superficial lateral wound infections were reported and detailed patient data were available for 12 cases

(0.14 %) deep lateral wound infections, as well as 13 (0.10 %) vascular and 11 (0.08 %) bowel injuries were reported per surgeon recall (Table 2).

Wound infections

Of the 35 (0.27 %) reported superficial wound infections, detailed patient data were available for 12 (34.3 %) cases. In these 12 cases, mean age was 58.5 years and 67 % were female (Table 3). Notable baseline comorbidities included diabetes mellitus in five patients, rheumatoid arthritis in two patients, and hypertension in one patient. Five patients had undergone previous spinal surgery, four of which were prior fusion procedures and one was a prior laminectomy. All patients were treated with antibiotics, with all but one being administered orally. Drainage was employed in eight cases. All 12 patients with detailed case information experienced full resolution without further sequelae.

A total of 18 (0.14 %) deep lateral-incision wound infections were reported in the survey and case details were available for 13 (72.2 %). Mean age of these 13 patients was 66.1 years and 38 % were female (Table 4). Notable baseline comorbidities in these patients included diabetes mellitus in three patients, hypertension in three patients, and colon disease in one. Prior lumbar spine surgery had been performed in nine patients, including four fusions and five laminectomies. In one patient, preoperative diagnosis was discitis at the level to be treated. Two of these patients were questionable for inclusion as one had an existing deep wound infection revised with MIS-LIF (prior implant was infected, which resolved following MIS-LIF) and a second patient had prior methicillin-resistant Staphylococcus aureus (MRSA) from a previous L4-S1 PLIF, with the infection persistent at the adjacent L3-4 level when treated with interbody fusion.

Table 4 Deep lateral wound infections

	$N = 13$[a]
Mean age (years)	66.1
Female, *n* (%)	5 (38 %)
Comorbidities, *n* (%)	
None	6 (46 %)
Diabetes mellitus	3 (23 %)
Hypertension	3 (23 %)
Colon disease	1 (8 %)
Surgical information, *n* (%)	
Single incision approach	9 (69 %)
Two incision approach	4 (31 %)
Left side approach	11 (85 %)
Right side approach	2 (15 %)
Surgeon experience, *n* (%)	
1–10 cases	0 (0 %)
11–50 cases	2 (15 %)
>50 cases	11 (85 %)
Treatment, *n* (%)	
Hardware revision	8 (62 %)
Wound washout + antibiotics	4 (31 %)
Intravenous antibiotics only	1 (8 %)
Outcome, *n* (%)	
Unknown	2 (15 %)
Lymphedema/permanent motor deficit	1 (8 %)
Full resolution	10 (77 %)

n Number of patients

[a] A total of 18 deep wound infections were reported and detailed patient data were available for 13 cases

Treatment for these 13 reported deep wound infections included revision surgery in 8 patients, drainage followed by administration of antibiotics in 4 patients, and intravenous antibiotics alone in 1 patient. Ten patients experienced full resolution, two patients had unknown postoperative status due to loss to follow-up, and one patient had developed lymphedema and had persistent, infection-related bilateral motor deficits at 11 months postoperative.

Vascular and visceral injuries

Of the 13 (0.10 %) reported vascular injuries, detailed patient data were available for 10 (76.9 %) cases. In these 10 cases, mean age was 54.6 years and 60 % were female (Table 5). Three patients had no relevant preoperative medical comorbidities, four had diabetes mellitus, two had coronary artery disease, one had peripheral vascular disease, and one had hypertension. Four patients had undergone previous spinal surgery, three of which were prior ALIF procedures and one was a prior laminectomy. Three of the ten reported "great vessel" injuries were described as "small" or "segmental" vessel injuries, bringing the great vessel injury rate to 0.08 % (10 cases) in this survey. A hemostatic matrix (Floseal®, Baxter, Inc. Deerfield, IL, USA) and surgical packing were used in five patients with the other five treated with primary surgical repair. Of these 10 cases, there were no mortalities and their postoperative outcomes were classified as "fully resolved."

A total of 11 (0.08 %) visceral (bowel) injuries were reported in the survey and case details were available for 10 (90.9 %). Mean age in these 10 patients was 59.0 years and all were female (Table 6). Comorbidities were common, with each patient having at least one major preoperative comorbid factor, though comorbidities were available for two patients. Notable preoperative comorbid factors included prior renal failure, lupus, multiple sclerosis, gallbladder disease, chronic constipation, megacolon, prior sigmoid colectomy, diverticulosis, preoperative constipation in a high narcotic user, prior caesarian sections (two in one patient), and hepatitis C.

Treatment reported for these bowel injuries included a laparotomy in six patients (washout, debridement, colectomy), a colostomy in three patients, and treatment was unknown in one patient. One patient had postoperative nausea and vomited with a CT showing free air. However, findings from laparoscopic exploration were negative for bowel perforation and the gallbladder was subsequently removed (patient had pre-existing gallbladder disease), leading to complete resolution of symptoms. Four injuries were identified intraoperatively and the remaining were identified in the early postoperative period (one on postoperative day (POD) 2, three on POD 3, one on POD 5, and one listed simply as "postoperative" identification). Of the 10 patients, five patients experienced full recovery, one patient had a preserved colostomy, one patient (colon repair breakdown) was subsequently lost to follow-up, one patient died from complications related to sepsis, and two patients were lost to follow-up.

Table 5 Vascular complications

	$N = 10^{a}$
Mean age (years)	54.6
Female, *n* (%)	6 (60 %)
Comorbidities, *n* (%)	
None	3 (30 %)
Diabetes mellitus	4 (40 %)
Coronary artery disease	2 (20 %)
Peripheral vascular disease	1 (10 %)
Hypertension	1 (10 %)
Surgical information, *n* (%)	
Single incision approach	8 (80 %)
Two incision approach	2 (20 %)
Left side approach	7 (70 %)
Right side approach	3 (30 %)
Surgeon experience, *n* (%)	
1–10 cases	1 (10 %)
11–50 cases	3 (30 %)
>50 cases	6 (60 %)
Treatment, *n* (%)	
Flowseal®/packing	5 (50 %)
Primary surgical repair	5 (50 %)
Outcome, *n* (%)	
Full resolution	10 (100 %)

n Number of patients

[a] A total of 13 vascular injuries were reported and detailed patient data were available for 10 cases. Injuries from 7 surgeons; 3 of the complications described as "small or segmental (non-great) vessel injuries"

Literature search

An initial search of the literature revealed 117 articles concerning ALIF complications and 156 articles on TLIF/PLIF complications. 201 were excluded following review of title and abstract due to relevancy. Of the remaining 72, 31 were excluded following full text review. In all, 41 articles, including retrospective reviews, randomized controlled trials, case series, observational and cohort studies, and case–control studies, were used for literature review (Tables 7, 8).

Discussion

Minimally invasive lateral interbody fusion (MIS-LIF) was developed to minimize the approach-related risk and surgical morbidity associated with conventional, open anterior and posterior approaches. MIS-LIF has become an increasingly popular means of interbody fusion as it does not require an access surgeon or dissection/resection of the

Table 6 Visceral complications

	$N = 10^{a}$
Mean age (years)	59.0
Female, *n* (%)	10 (100 %)
Surgical information, *n* (%)	
Single incision approach	7 (70 %)
Two incision approach	3 (30 %)
Left side approach	7 (78 %)
Right side approach	2 (22 %)
Surgeon experience, *n* (%)	
1–10 cases	0 (0 %)
11–50 cases	3 (30 %)
>50 cases	7 (70 %)
Treatment, *n* (%)	
Laparotomy	5 (50 %)
Colostomy	3 (30 %)
Colon repair breakdown (lost to follow-up)	1 (10 %)
Unknown	1 (10 %)
Outcome, *n* (%)	
Unknown	3 (30 %)
Preserved colostomy	1 (10 %)
Death (sepsis)	1 (10 %)
Full resolution	5 (50 %)

n Number of patients

[a] A total of 11 visceral injuries were reported and detailed patient data were available for 10 cases

posterior stabilizing elements, but still provides the ability for indirect foraminal decompression and anterior column realignment through placement of a large interbody cage [29]. These factors have contributed to substantial clinical benefits and high fusion rates in many published studies [29, 33, 34]. Over the last decade, the application of MIS techniques continues to evolve and expand [30, 31, 33, 35–38]. The confluence of commercially available devices, advanced surgeon training, and modern intraoperative imaging and neuromonitoring techniques have accelerated this development. Nonetheless, these approaches are not without risk and have their own set of potential approach-related risks and complications that should be considered [29, 30].

Complication rates of MIS-LIF in the thoracolumbar spine have been described in many studies and are highly variable [39]. As with any operation, there will always be a risk of complications that underscore the importance of a thorough understanding of regional anatomy, and meticulous attention to the surgical technique. Some of the structures at risk for injury during the MIS-LIF approach and procedure include the peritoneum and peritoneal contents, the thoracolumbar nerves and the nerves of the lumbar plexus, and segmental and great vessels. As the lateral approach requires mobilization of the peritoneum for development of the retroperitoneal space and subsequent lateral access, inadequate development of this plane increases the risk of injury to the peritoneum and its contents.

With respect to the great vessels, although it has been shown previously that vascular structures move anteriorly (away from the surgical corridor) once the patient is in the lateral decubitus position, there is still a risk of vascular injury if the retractor is docked too far anterior, or if instrumentation migrates anterior of the disc space (e.g., fluororadiography is not truly orthogonal and/or the patient not in a true lateral position) [29, 40, 41].

As there have been anecdotal reports of vascular and visceral injuries in MIS-LIF, with only a few reports in the literature [42–44], we sought to evaluate the rate of these complications in a large series of MIS-LIF procedures to gain perspective on a representative incidence of such events, rather than to just have individual case reports guiding evidence-based medicine decision making. As such, a survey of experienced MIS-LIF (XLIF) surgeons who were members of a dedicated lateral access research society was undertaken.

While responders to the survey included a mix of geographically diverse neurosurgeons and orthopedic surgeons, all used the same standard MIS-LIF technique [with some slight modifications (e.g., one- versus two-incision approach)] developed by Luiz Pimenta and described by Ozgur et al. [29] under the name XLIF. The authors believe that using a heterogeneous group of surgeons utilizing the same surgical technique, with learning curve experience included in the analysis, improves the validity of this study. While there are over a dozen LIF systems on the market, XLIF® was the first commercially available system, has the most extensive literature support with well over 100 peer-reviewed articles, and is the only literature-validated lateral transpsoas surgical approach [29, 45, 46].

Only surgeons who performed at least 100 MIS-LIF cases were included to mitigate a bias toward only learning curve cases (e.g., not a true incidence); however, all MIS-LIF cases of those surgeons were included in the current study, with further questions about when in their experience the complications occurred. This provides both broad prevalence information as well as insight into potential learning curve challenges. Intuitively, earlier cases performed may have been likely to have a complication due to learning curve associated with technique adoption, though no clear learning curve was apparent from the findings of this study (e.g., most of these complications occurred outside of surgeons' early experiences). This may suggest a departure from earlier minimally invasive procedures (endoscopic approaches), which are associated with extended learning curves with substantial early procedural morbidity [47] and a higher risk of complications in treating more

Table 7 Literature review of vascular, visceral, and wound complications following anterior lumbar interbody fusion (ALIF)

References	Year	Study design	Number of patients/ studies	Procedure	Complication	Incidence (%)
Acosta et al. [71]	2009	Retrospective chart review	73 patients	ALIF	Wound infection	2.8
Baker et al. [10]	1993	Retrospective chart review	102 patients	ALIF	Vascular injury	15.6
Brau et al. [1]	2002	Retrospective cohort study	684 patients	Mini-open ALIF	Arterial injury	0.8
					Death	0.2
					Hernia	0.3
					Ileus	0.6
					MI	0.2
					RE	0.1
					Venous injury	0.8
					Wound infection	0.4
Brau et al. [52]	2003	Prospective nonrandomized observational study	45 patients	ALIF	Left iliac artery compression causing distal oxygen desaturation	57
Brau et al. [18]	2004	Retrospective review of prospective database	1,310 patients	ALIF	Iliac artery thrombosis	0.5
					Venous injury	1.4
Faciszeswki [59]	1995	Retrospective chart review	1,233 (contains other anterior thoracolumbar cases)	ALIF	Vascular injury	0.3
Fantini et al. [51]	2007	Retrospective chart review	338 patients	ALIF	Aorta injury	0.3
					Common iliac vein injury	2.6
Fantini et al. [11]	2013	Literature review	9 studies	ALIF	Vascular injury	1.6–4.3
Flynn et al. [12]	1984	Survey	4,500 patients	ALIF	Impotence	0.44
					RE	0.42
Garg et al. [13]	2010	Retrospective review of prospective database	212 patients	ALIF	Vascular injury	6.1
Hamdan et al. [53]	2008	Retrospective cohort study	480 patients	ALIF	Vascular injury	11
Hrabalek et al. [54]	2012	Retrospective chart review	120 patients	ALIF	Sympathectomy	15.8
Hrabalek et al. [72]	2014	Retrospective chart review	175 patients	Mini-open ALIF	Hernia	2.9
					Sympathetic dysfunction	1.1
					Vascular injury	1.1
					Wound dehiscence	1.1
Inamasu et al. [55]	2006	Literature review	31 studies 6,923 patients	ALIF	Vascular injury	0–20
Jiang et al. [4]	2012	Systematic review	9 studies 948 patients	ALIF	DVT/PE	6.3
					Hernia	0.4
					RE	3.1
					Vascular injury	2.2
					Wound infection/dehiscence	6.4
Kulkarni et al. [14]	2003	Case–control study	336 patients	ALIF	Arterial injury	2.4
Li et al. [49]	2010	Prospective nonrandomized observational study	112 patients	ALIF	Vascular injury	1.8
					Wound infection	7.1
Lindley et al. [15]	2012	Retrospective cohort study	54 patients	ALIF	RE	7.4
Penta et al. [8]	1997	Retrospective cohort study	103 patients	ALIF	PE	3.9
					Wound infection/dehiscence	2.8
Quraishi et al. [73]	2013	Retrospective chart review	304 patients	ALIF ADR	Arterial injury	1.6
					Venous injury	6.2
					Wound dehiscence	3.9
					Wound infection	4.3

Table 7 continued

References	Year	Study design	Number of patients/ studies	Procedure	Complication	Incidence (%)
Rajaraman et al. [61]	1999	Retrospective chart review	60 patients	ALIF	Acute pancreatitis	1.7
					Bowel Injury	1.7
					DVT	1.7
					Ileus	5.0
					Sexual dysfunction	5.0
					Sympathetic dysfunction	10.0
					Vascular injury	6.7
					Wound incompetence	3.3
Regan et al. [57]	1999	Retrospective chart review	58 patients	ALIF	RE	1.7
					Vascular injury	5.2
Sasso et al. [16]	2003	Multicenter, prospective nonrandomized observational study	146 patients	ALIF	RE	4.1[a]
Scaduto et al. [58]	2003	Retrospective chart review	88 patients	ALIF	Ileus	6
					Vascular injury	2
Wood et al. [17]	2010	Systematic review	40 studies	ALIF	Vascular injury	0–16
Zahradnik et al. [60]	2013	Retrospective chart review	260 patients	ALIF	Vascular injury	13.8

ALIF Anterior lumbar interbody fusion, *ADR* artificial disc replacement, *DVT* deep vein thrombosis, *MI* myocardial infarction, *PE* pulmonary embolism, *PLIF* posterior lumbar interbody fusion, *RE* retrograde ejaculation, *TLIF* transforaminal lumbar interbody fusion, *XLIF* extreme lateral interbody fusion

[a] Incidence of RE was 1.7 % through retroperitoneal approach and 13.3 % through transperitoneal approach

advanced pathology, as one would expect from any procedure.

Out of 77 surgeons who met the initial inclusion criteria, 40 (52 %) responded and reported on 13,004 MIS-LIF patients treated from 2003 to 2013 at various institutions. To our knowledge, this is the largest series of MIS-LIF patients and the response rate from the current survey study, while not ideal, is comparable with other survey studies in spine [48–50]. And while the survey did not meet the 65 % response rate threshold that the authors had hoped to achieve (in order to minimize responder bias), this response rate for spinal surgeon surveys is largely consistent with earlier reports, mostly notably by Carl et al. [50] receiving a 44 % response rate for a survey sent to 1,500 North American Spine Society (NASS) members regarding threaded fusion cages.

A literature search of complications following conventional approaches for lumbar interbody fusion, including TLIF, PLIF, and ALIF, showed a wide range of vascular and visceral complication rates. Vascular injuries were primarily associated with the ALIF procedure and ranged from 0 to 20 %, with the vast majority of studies citing an incidence rate between 2 and 6 % [1, 4, 10, 11, 13, 14, 18, 51–59]. Visceral (bowel) injuries were less common, with studies citing incidence rates between 0 and 5 %, but most commonly in the range of 1–2 % [8, 10–18, 51, 53, 55, 60, 61]. With respect to posterior approaches, incidence of visceral complications following TLIF has been reported between 1.2 and 6.4 % and most commonly in the range of 2.7–4.0 % [9, 20, 22, 25, 62, 63]. It is of note that the incidence of ileus, rather that direct injury, tended to fall at the higher end of these ranges. Incidence of direct visceral (bowel) injury following MIS TLIF has been reported as 1.2 % by Lee et al. [22] in their series of 85 patients treated with single-level MIS TLIF. Injury to the great vessels has also been reported in PLIF and other posterior decompression and discectomy procedures [19, 28, 55, 64, 65]. In particular, Papadoulas et al. [28] reported a vascular complication rate of 3.8 % in a large series of 2,590 patients, with injuries ranging from laceration in 30 % of cases, arteriovenous fistula in 67 %, and pseudoaneurysm in 3 %.

By comparison, in the current study of over 13,000 patients who underwent MIS-LIF, vascular injuries were reported in 0.1 % of patients and visceral injuries in 0.08 % of patients. This demonstrates a low, though non-zero, rate of vascular and visceral complications following MIS-LIF. And while management of a vascular injury during an MIS-LIF procedure is very likely to be more challenging to manage than a similar injury in an anterior procedure, the very low relative rate of these injuries as well as the largely favorable outcomes in this series suggest that successful management is common in the rare instances that they occur. With respect to approach side and number of incisions used [one (lateral incision only) or two

Table 8 Literature review of vascular, visceral, and wound complications following transforaminal (TLIF) or posterior lumbar interbody fusion (PLIF)

References	Year	Design	Number of patients/studies	Procedure	Complication	Incidence (%)
Cho et al. [20]	2007	Retrospective review of prospective database	47 patients	TLIF with PLF	Ileus Wound complication[a] Death (pulmonary embolism)	6.4 6.4 2.1
Faundez et al. [67]	2009	Retrospective chart review	65 patients	TLIF	Wound infection	9.2
Hackenberg et al. [3]	2005	Prospective nonrandomized observational cohort	52 patients	TLIF	Wound infection	2
Khan et al. [21]	2013	Retrospective chart review	187 patients	73 Primary TLIF 114 Revision TLIF	Wound complication[a]	3.2
Lau et al. [70]	2011	Retrospective chart review	22 patients	10 MIS TLIF 12 Open TLIF	Wound infection: MIS Open	0 10
Lee et al. [22]	2012	Retrospective chart review	84 patients	TLIF	Bowel injury	1.2
O'Toole et al. [23]	2009	Retrospective review of prospective database	1,274 patients	MIS posterior lumbar fusion	SSI	0.7
Papadoulas et al. [28]	2002	Retrospective chart review	2,590	Posterior disc surgery	Vascular injury	3.8
Parker et al. [24]	2011	Literature review	30 studies 1,495 patients	362 MIS TLIF 1,133 Open TLIF	SSI: MIS Open	0.6 4.0
Potter et al. [25]	2005	Retrospective chart review	100 patients	TLIF	Ileus Wound complication[a]	4.0 5.0
Poh et al. [9]	2011	Retrospective chart review	112 patients	TLIF	Ileus Wound complication[a]	1.8 3.6
Rihn et al. [62]	2009	Retrospective cohort study	119 patients	TLIF	Ileus Wound complication[a]	1.7 6.7
Rivet et al. [66]	2004	Prospective nonrandomized observational study	42 patients	TLIF	Retained drain Wound complication[a]	2.4 9.5
Salehi et al. [26]	2004	Retrospective chart review	24 patients	TLIF	Retained drain	4.2
Szolar et al. [19]	1996	Retrospective chart review	8,099	Posterior disc surgery	Vascular injury	0.05
Taneichi et al. [27]	2006	Retrospective chart review	86 patients	TLIF	SSI	1.2
Tormenti et al. [69]	2012	Retrospective review of prospective database	531 patients	TLIF	Wound infection	3.8
Villavicencio et al. [63]	2006	Retrospective chart review	167 patients	TLIF	DVT Ileus Wound infection	1.8 3.6 3.6

DVT deep vein thrombosis, *MIS* minimally invasive, *PLF* posterolateral fusion, *SSI* surgical site infection, *TLIF* transforaminal lumbar interbody fusion

[a] Wound complications include hematoma, seroma, infection

(posterolateral fascial and lateral incisions)], 70 % of visceral injury patients were treated through a single lateral incision while 30 % had a two-incision approach. While this may appear to suggest that a two-incision approach may decrease the change of a visceral injury, it should be noted that it is not known from this survey the rates of one- and two-incision approaches used across the other 12,994 patients. As one-incision approaches are commonly used, these rates of injury could represent an even distribution based on incision preference (i.e., distribution of all treated patients may have been 70 % single- versus 30 % two-incision). Similarly, and with similar explanatory argument, 80 % of vascular injury patients were treated through a single lateral incision and 70 % were treated through a left side exposure.

Wound infections, both superficial and deep, ranged in the literature for TLIF/PLIF from 0.8 to 9.2 %, with slightly lower numbers for MIS TLIF [3, 9, 20, 21, 23–27, 62, 63, 66–70]. Wound infection and dehiscence were also commonly reported for ALIF, with rates ranging from 0.4 to 7.1 % [1, 4, 8, 56, 61, 71–73]. In the current study, the superficial wound infection rate was 0.38 % and deep wound infection rate was 0.14 %, both lower than rates of surgical site infections described for conventional interbody fusion procedures, and substantially equivalent or superior to those rates seen in alternative minimally invasive procedures [23]. In fact, outside of this report, these authors were unable to find an example of a deep wound infection in the anterior (MIS-LIF) incision within the published literature, despite several large-series studies [74, 75]. Thus, this represents the first such report in the literature.

Based on the results of this study, it appears that the occurrence of vascular and visceral complications, as well as superficial and deep wound infections in MIS-LIF, is likely multifactorial in etiology, with contributing factors potentially being surgeon experience, patient demographics, and/or pathological complexity of the surgery. Despite this multi-factorial nature, the extremely low incidence of such events in a large patient series from diverse practice settings and training suggests that the tenets of less invasive surgery are fulfilled in this procedure, with attenuation of the complications of conventional approaches [76] with equivalent or improved clinical outcomes [77, 78].

Limitations of the current study included a survey response rate below 65 % (which may introduce selection bias [79]), non-compliance by some respondents to provide patient-level complication data, reliance on recall for identification, as well data collection from multiple databases instead of a centralized database (some lack of uniformity in parameters captured). Despite these shortcomings with the data and their collection, the information captured here represents the best evidence available from a large, diverse sample to guide expectations and prognosis under a variety of complications scenarios in MIS-LIF. Another limitation is that neural injuries were not captured in this study due to the lack of standardization in capturing and reporting such events and their outcome among different spine surgeons [80]. However, to our knowledge, this represents not only the largest patient sample of MIS-LIF, but also the first systematically collected data related to vascular and visceral complications and anterior infections, in an attempt to better understand true incidences (rather than case examples) of these important complications.

Conclusions

The minimally disruptive retroperitoneal, transpsoas approach for a lateral interbody fusion (XLIF) is a reproducible procedure with low rates of infections and vascular and visceral injuries when compared to existing complication data from established techniques for lumbar interbody fusion (ALIF/TLIF/PLIF). Further large-scale studies may focus on evaluation of the incidence of other intraoperative and postoperative neural complications and their associated factors.

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