Clinical Neurology and Neurosurgery 184 (2019) 105381

Contents lists available at ScienceDirect

Clinical Neurology and Neurosurgery

journal homepage: www.elsevier.com/locate/clineuro

Perioperative complications associated with minimally invasive surgery of oblique lumbar interbody fusions for degenerative lumbar diseases in 113 patients

Chao Liu, Jian Wang*, Yue Zhou

Department of Orthopaedic Surgery, Affiliated Xinqiao Hospital, Army Military Medical University, No. 183, Xinqiao Street, Shapingba District, Chongqing 400037, People's Republic of China

ARTICLE INFO

Keywords:
Complications
Minimally invasive surgery
Oblique lumbar interbody fusion
Degenerative lumbar diseases

ABSTRACT

Objectives: To describe perioperative complications occurring during oblique lumbar interbody fusion (OLIF) assisted by a retractor system for degenerative lumbar diseases.

Patients and methods: The perioperative complications in 113 cases series utilizing a minimally invasive approach were recorded and analyzed. One hundred thirteen patients who received OLIF for degenerative lumbar diseases between November 2014 and February 2017 at a single center were evaluated. The most frequent diagnosis was spondylolisthesis (59 cases, 52.2%), followed by lumbar instability (24 cases, 21.2%), adjacent segmental disease (12 cases, 10.6%), adult degenerative scoliosis (11 cases, 9.8%) and discogenic low back pain (7 cases, 6.2%). One hundred thirty-four levels were treated, 88.5% one-level, 4.4% two-level, and 7.1% three-level surgeries. The most fused level was L4-5 (94 levels, 70.2%), followed by L3-4 (31 levels, 23.1%), and L2-3 (9 levels, 6.7%).

Results: All perioperative complications only included adverse events related to the OLIF procedure. The most observed complications were donor-site pain (24 cases, 21.2%), followed by vertebral endplate fracture (15 cases, 13.3%), thigh numbness/pain (12 cases, 10.6%), psoas/quadriceps weakness (5 cases, 4.4%), sympathetic nerve injury (2 case, 1.8%), paralytic ileus (one case, 0.9%), segmental artery injury (one case, 0.9%), intervertebral infection (one, 0.9%), and contralateral femoral nerve palsy (one, 0.9%). All complications, including postoperative ipsilateral or contralateral thigh paresthesia, pain, and psoas/quadriceps weakness, were observed when operating at L4-L5. The incidence of complications excluding donor-site pain was 24.8% (28/113 cases). The patients with donor-site pain, thigh numbness/pain, psoas/quadriceps weakness, sympathetic nerve injury and paralytic ileus recovered within two months following surgery. The patient with intervertebral infection recovered at 3 months after surgery. One case of contralateral femoral nerve palsy recovered completely with no residual sensory or motor deficit at 6 months.

Conclusions: OLIF performed using a retractor system is a validated option to treat a wide spectrum of degenerative lumbar diseases with few perioperative complications and a quick recovery. Judicious use of this technique at the L4/5 level is recommended. Close attention to detail during the procedure can minimize complications that may be associated with the learning curve.

1. Introduction

Lumbar fusion is an efficient treatment for various degenerative disorders, such as degenerative disc disease, spondylolisthesis and deformity. The lateral lumbar interbody fusion (LLIF) is being used increasingly as an alternative to conventional anterior or posterior procedures such as anterior lumbar interbody fusion (ALIF), posterior lumbar interbody fusion (PLIF) or transforaminal lumbar interbody fusion (TLIF).This retroperitoneal approach offers a relatively safe corridor to the spine, minimizing injuries to vascular and visceral structures encountered during ALIF [1–3] and avoid ingdural tears, multifidus muscular damage and nerve root injuries that can occur during the posterior approach such as PLIF and TLIF [4–6]. Although LLIF is an effective and increasingly performed treatment, there is still no consensus regarding the ideal approach.

Recently, the antero-oblique trajectory or oblique lumbar interbody

* Corresponding author.
E-mail address: tonywjxq_vip@163.com (J. Wang).

https://doi.org/10.1016/j.clineuro.2019.105381
Received 21 January 2019; Received in revised form 30 May 2019; Accepted 1 June 2019
Available online 03 June 2019

fusion (OLIF) has been introduced, providing another corridor to access the lumbar disc space [7,8]. This approach uses the anatomic space between the anterior vessels and psoas muscles, allowing efficient clearance of disc space and the application of a large interbody cage to afford distraction for indirect decompression and endplate preparation for fusion. The OLIF approach is the proposed solution to the approach-related disadvantages of the LLIF technique, while the lateral approach is associated with psoas muscle splitting and limited lower lumbar spine access [9,10]. The OLIF technique is increasingly employed to treat structural degenerative conditions of the lumbar spine. It can be used as a stand-alone procedure to manage isolated degenerative disc diseases or spondylolisthesis [11–13]. More recently, it is used as a part of reconstructive surgery in cases of degenerative deformity therapy [14]. Although there is great interest currently in the antero-oblique approach, few robust clinical studies have investigated the efficacy, advantages and disadvantages of the OLIF approach. The purpose of this work was to summarize the perioperative complications and early clinical results of the OLIF technique for degenerative lumbar diseases.

2. Materials and methods

2.1. Patient data

The approval of our institutional review board was obtained. The inclusion criteria were patients treated consecutively with oblique interbody fusion of the lumbar spine between November 2014 and February 2017 by a single surgeon (Wang) at one spinal center. Demographic and clinical data, including perioperative complications, were prospectively collected and reviewed from 113 patients undergoing OLIF. All the included patients underwent preoperative evaluation with detailed neurologic examination and radiologic imaging, which involved static (anterior-posterior and lateral) and dynamic (flexion and extension) plain lumbar radiographs, magnetic resonance imaging (MRI), and computed tomography (CT).

The average patient age at the time of surgery was 53.8 years (36–71years), and the study group comprised 69 women and 44 men. The most frequent diagnosis was spondylolisthesis (59 cases, 52.2%), followed by lumbar instability (24 cases, 21.2%), adjacent segmental disease (12 cases, 10.6%), adult degenerative scoliosis (11 cases, 9.8%) and discogenic low back pain (7 cases, 6.2%). All the patients were symptomatic with back pain, and the minority had varying degrees of radiating pain, neurological complaints, or a combination of these. All the patients had to have been treated conservatively for at least 3 months without success before consideration for surgical intervention. One hundred thirty-four levels were treated, 88.5% one-level, 4.4% two-level, and 7.1% three-level surgeries. The most fused level was L4-5 (94 levels, 70.2%), followed by L3-4 (31 levels, 23.1%) and L2-3 (9 levels, 6.7%). because OLIF is not suitable for diseases with L5–S1 involvement, patients with diseases involving the L5–S1 were excluded from the study. Patients were excluded using the following criteria: (1) spinal tumor pathologies, (2) spinal infections, and (3) spinal trauma. The patients' demographic characteristics of two groups are listed in Table 1.

Table 1
Demographics and treatment data for patients undergoing OLIF.

Number of patient	113
Mean age (years)	53.8 ± 8.4
Gender (M/F) (% male)	44/69 (38.9)
Diagnoses [no. (%) of patients]	
Spondylolisthesis	59 (52.2)
Instability	24 (21.2)
Adjacent segmental disease	12 (10.6)
Adult degenerative scoliosis	11 (9.8)
Discogenic back pain	7 (6.2)
Level of fusion [no. (%) of patients]	
L2-L3	9 (6.7)
L3-L4	31 (23.1)
L4-L5	94 (70.2)

2.2. Surgical technique

After the induction of general anesthesia, the patients were positioned in the lateral decubitus position on their right side. Fluoroscopy was used to ensure that good, unobstructed images of the target disc space were obtained on both the cross table anteroposterior (AP) and lateral views. All the patients underwent OLIF only through the left-side approach without neurophysiologic monitoring. The procedures were performed utilizing expandable retractors (OLIF 25 system; Medtronic, Memphis, TN, USA) based on the standard procedure described previously [11]. Polyetheretherketone (PEEK) intervertebral cages (OLIF25 Clydesdale Spinal System; Medtronic Sofamor Danek, Minneapolis, MN, USA), filled with autologous bone grafts from the iliac crest and allograft bone, were used to achieve fusion. After completion of the anterior procedure, seventy-five patients were turned to the prone position, and supplementary percutaneous pedicle screw fixation was performed. No direct posterior decompression was performed or 113 cases. In thirty-eight cases that had no lumbar spondylolisthesis that cannot be actively reset and no osteoporosis, a stand-alone OLIF was performed.

2.3. Clinical and radiographic measures

The operative time and blood loss, except those for pedicle screw fixation, were prospectively recorded. All the intraoperative and postoperative complications associated with anterior OLIF, except for those for posterior percutaneous pedicle screw fixation, were reported and followed up. Perioperative complications included postoperative neurological complications, infections, hematomas, vascular or ureter injury, vertebral endplate fractures, paralytic ileus, and donor-site pain.

Clinical outcome parameters included visual analog scores (VAS) for back/leg pain and the Oswestry disability index (ODI). Back/leg pain was quantified by VAS collected from the patients preoperatively and in the last follow up. The Oswestry disability index (ODI), version 2.0, was used both before surgery and after surgery to provide the surgeon with information about how the patient's back (or leg) trouble affected his/her ability to manage everyday life. The sex question (Section 8) is unacceptable in our culture, and most patients were reluctant to answer this section. Therefore, it was omitted in this study. The total possible score is 45.After discharge from the hospital, the patients were followed up regularly by the corresponding author. Plain lumbar radiographs were ordered to assess interbody fusion. CT/MRI was performed only if the patient complained of radiculopathy postoperatively or fusion was suspected to be suboptimal. Fusions were assessed by an independent radiologist using static and dynamic plain X-rays in the last follow up. Definitive fusion was identified by the formation of continuous trabecular bony bridges along contiguous vertebral bodies at the operated levels and less than 4° of segmental movement.

2.4. Statistical analyses

The data are shown as the means ± SEM. Student's *t* test was used to compare continuous variables such as low back pain VAS and ODI before and after the surgery. Statistical analyses were performed using SPSS 17.0 for windows. *P* values less than 0.05 were accepted for significance.

3. Results

3.1. Operating parameters

The operative time and blood loss of the patients who underwent one-level OLIF excluding posterior instrumentation were

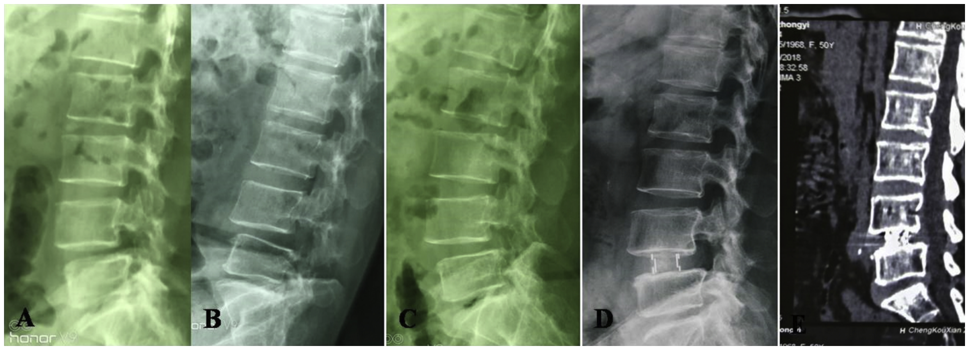

Fig. 1. A, B and C is a 47-year-old male spondylolisthesis patient with lumbar dynamic position X-ray. D is the lumbar lateral X-ray 1 month after operation. E is a sagittal image of lumbar CT scan 3 months after surgery, suggesting interbody fusion.

43.7 ± 6.5 min and 26.6 ± 5.8 mL, respectively; those for two-level OLIF were 69.3 ± 6.4 min and 35.8 ± 9.4 mL, respectively; those for three-level OLIF were 104 ± 15.8 min and 115.7 ± 49.2 mL, respectively. None of the patients needed to be converted to open surgery.

3.2. Clinical outcomes

The mean VAS back pain score improved from 6.1 ± 1.7 preoperatively to 1.2 ± 1.2 in the last follow up (P = 0.03). The mean VAS leg pain score improved from 2.1 ± 0.6 preoperatively to 0.2 ± 0.1in the last follow up ($P > 05$). The mean Oswestry Disability Index improved from 33.4 ± 16.2 preoperatively to 6.5 ± 4.1 in the last follow-up (P = 0.01). The fusion rate was 93.8% (106/113 cases) (Fig. 1). Seven patients with fusion failure refused revision surgery because of no obvious complaints (Table 2).

3.3. Complications

The mean follow up was 16.2 ± 5.7 months with a range of 12–25 months. The most observed complication was vertebral endplate fracture (15 cases, 13.3%), which led to cage subsidence during the procedure (Fig. 2). There was one intraoperative segmental artery laceration (0.9%). The patient with adult degenerative scoliosis and osteoporosis underwent a three-level OLIF procedure. Vascular injury occurred at L2-L3, likely during exposure of the disc space with excessive retraction of the vascular structures. The bleeding was managed with direct pressure and bipolar electrocautery. Immediately after surgery, the most observed complication was donor-site pain (24 cases, 21.2%), followed by transient thigh numbness/pain (12 cases, 10.6%) and psoas/quadriceps weakness (5 cases, 4.4%), all of which recovered completely with no residual sensory or motor deficit within two months after surgery. Contralateral sympathetic nerve injury was observed in two cases (1.8%), which recovered completely without additional intervention within six weeks. A postoperative incomplete paralytic ileus occurred in one patient. The patient was treated conservatively with laxative measures and recovered within one week. During the early postoperative period, there was one intervertebral infection (0.9%) (Fig. 3). The case was effectively treated using antibiotic and conservative treatment without revision surgery and recovered at three months after surgery. There was one case of contralateral femoral nerve palsy (0.9%) with a 4/5 muscle weakness of the L4 innervated muscle groups followed by numbness. The patient improved fully to 5/5 strength with no residual sensory deficit without additional surgical interventions under observation and physiotherapy at 6 months. All neurological complications, such as thigh numbness/pain, psoas/quadriceps weakness, sympathetic nerve chain injury, and femoral nerve palsy, were observed when operating at L4-L5. Approach-related neurological complications arose in eleven (31.4%) of the 35 OLIF cases in the first year, seven (13.5%) of the 52 patients in the second year, two (7.7%) of the 26 patients in the third year. The rate of neurological complications following OLIF steadily reduced with increased experience. The sixty-two perioperative complications occurred in 53 cases, among which 3 complications occurred in 4 cases (2 cases with donor-site pain), 2 occurred in 6 cases (2 cases with donor-site pain), and one occurred in 38 cases (20 cases with donor-site pain). The incidence of complications excluding donor-site pain was 24.8% (28/113 cases).No intraoperative visceral injuries and permanent neurological sequelae were recorded in our series (Table 3).

Table 2
Clinical outcome.

	Preoperation	Postoperation	P
Back pain VAS	6.1 ± 1.7	1.2 ± 1.2	0.031
Leg pain VAS	2.1 ± 0.6	0.2 ± 0.1	0.029
ODI score	33.4 ± 16.2	6.5 ± 4.1	0.015
Fusion rate		93.8% (106/113)	

4. Discussion

Surgeons have evolved the technique of lumbar interbody fusion—for example, ALIF, PLIF, TLIF, XLIF, and DLIF. The aim of this evolution has been to maintain the efficacy of the procedure while reducing surgery-related morbidity. The lateral approach, such as XLIF and DLIF, is not new and has been used for more than a decade as an alternative to the direct anterior approach. This approach was developed to eliminate the need for an approach surgeon, but the retroperitoneal transpsoas approach places the lumbosacral plexus at a significant risk of injury. This approach is associated with a complication rate of up to 20%, the most common being anterior thigh numbness/pain, iliopsoas and/or quadriceps weakness [8–10]. Meanwhile, the L4/L5 intervertebral disc space is difficult to access due to the lumbar plexus and iliac crest.

The anterior-to-psoas technique was first described by Mayer in 1997 [7] and waster med OLIF by Silvestre et al. in 2012 [8]. The surgical nuances and clinical outcomes of this technique have been reported by various groups. These groups have also provided early evidence to support OLIF as a viable alternative to existing lumbar interbody fusion techniques, by showing radiologic and clinical improvements in patients with degenerative lumbar disease, including spondylolisthesis, kyphoscoliosis, and discogenic pain [11–14].

The indications for OLIF have expanded over time to include a wide spectrum of degenerative disorders, from single-level discogenic back pain to multilevel degenerative scoliosis. This approach allows surgeons to avoid the risks of thecalsac injury, arachnoiditis, and posterior element damage occurring during PLIF/TLIF procedures, and it achieves indirect decompression and sagittal and coronal restoration via the insertion of a larger interbody cage supporting bilateral epiphyseal rings. Compared with TLIF/PLIF, OLIF may significantly reduce tissue

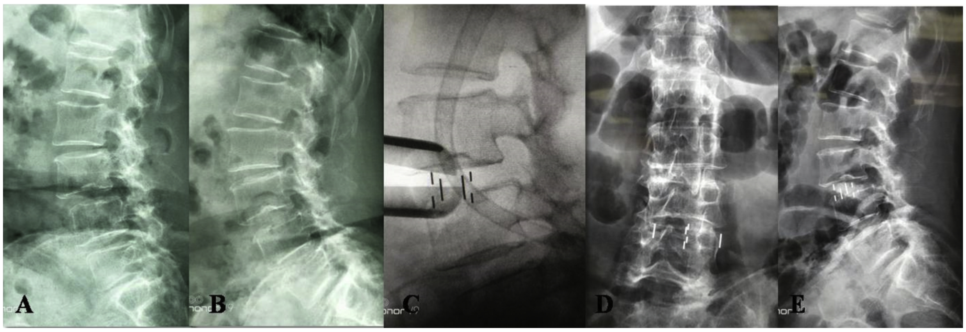

Fig. 2. A, B is a 58-year-old female spondylolisthesis patient with lumbar dynamic position X-ray. C is the lateral image of the lumbar spine during intraoperative cage implantation. It can be seen that the endplate fracture of the lumbar 4 vertebral body causes the cage subsidence. D, E is X-ray 1 month after surgery, visible cage subsidence.

trauma and blood loss, decrease the operating time, and preserve the posterior longitudinal ligament complex by using a retroperitoneal space approach between the major vessels and psoas. Compared with XLIF/DLIF, this technique may also reduce the risk related to the transpsoas approach, such as injuries to the psoas muscle, lateral femoral cutaneous nerve, genitofemoral nerve, and lumbosacral plexus. The OLIF technique avoids the shortcoming of ALIF and LLIF, such as great vessel injury and retrograde ejaculation [3,15–17].

A few studies on intra- and perioperative complications of the OLIF have been based on small cohorts of patients undergoing surgery for different indications. Sato et al reported that 20 patients with lumbar degenerated spondylolisthesis underwent OLIF and percutaneous pedicle screw fixation without posterior laminectomy [11]. Segmental artery injury occurred in one patient and was treated using an ultrasonic scalpel. Slight cage subsidence at one level was observed in two patients with osteoporosis. Extraordinary numbness and pain were observed in one patient. Thigh pain and numbness were diminished within 2 weeks of surgery. Fujibayashi et al. reported that 28 cases of OLIF were successfully performed without major complications such as vascular injury, neural injury, and ureter injury [12]. Eight cases (28.5%) of approach-related complications such as hip flexor weakness in 2 cases and thigh pain/numbness in 6 cases were resolved spontaneously within 3 months postoperatively. Donor-site (iliac crest) pain was frequently seen, and the occurrence was noted in eight patients. Thirty-five cases with lumbar spinal degenerative disease underwent the OLIF procedure [13]. Twelve patients with degenerative lumbar kyphoscoliosis underwent the OLIF procedure without major complications [14]. Cage subsidence at a single level was observed in one patient with osteoporotic kyphoscoliosis. Thigh pain was found in one patient and thigh numbness in two patients. Thigh pain and numbness diminished within two weeks of surgery. Owing to the small cohorts, these figures were not meaningful with respect to the low incidence of neurological complications in general.

Silvestre et al. [8] reported the results of 179 patients who underwent oblique lumbar interbody fusion. There were 19 (10.6%) patients with a single complication and one (0.6%) with two complications, including two patients with postoperative radiculopathy after L3-5 OLIF. The most common complication was incisional pain (2.2%), followed by sympathetic chain injury (1.7%). Vascular injury to the iliac or ilio lumbar vessels occurred in three patients (1.7%) and were successfully repaired. Abe et al. reported that the overall incidence of perioperative complications of OLIF surgery reached 48.3%, of which only 1.9% resulted in permanent damage in one study of 155 patients [18]. The average perioperative complication rate without the incidence for subsidence was maintained approximately 20% except after the introductory phase. The most common complication was subsidence/endplate fracture (18.7%), followed by transient thigh pain/numbness and/or psoas weakness (13.5%) and segmental artery injury (2.6%). The perioperative incidence of complications was 50% at the early stage after OLIF introduction and 38% in the late stage, indicating the existence of a learning curve. The study by Mehren et al. [19] remains the largest cohort study so far describing few early complications of the OLIF procedure. There were two superficial (0.24%) and three deep (0.37%) wound infections and five superficial (0.62%) and six deep (0.86%) hematomas during the early postoperative period. The percentage of vascular complications was 0.37% (n = 3). The percentage of neurologic complications was 0.37% (n = 3). A total of 3.7% (30/812) of patients who underwent the oblique lumbar interbody fusion developed complications intraoperatively or during the hospital stay. The authors caution readers that head-to-head studies will need to be performed to confirm their very preliminary comparisons and results with the OLIF approach. Similarly, future studies will need to evaluate this approach in terms of later-presenting complications. Complications associated with OLIF as reported on the literature were list on table four (Table 4).

Compared with the literature, the incidence of donor-site pain was significantly increased in this study. The cause may be that, in our hospital, no reliable BMP exists to promote fusion; thus, we chose to use a large number of autologous iliac crest as a mixed part of allogeneic bone filling for the cage and intervertebral space. Of course, donor-site pain hardly affected the patient's postoperative recovery, and all recovered completely within 1 month. The most consistently reported complication was transient weakness and pain in the thigh/groin area, which were resolved from between 2 weeks to 3months [12,13]. It was

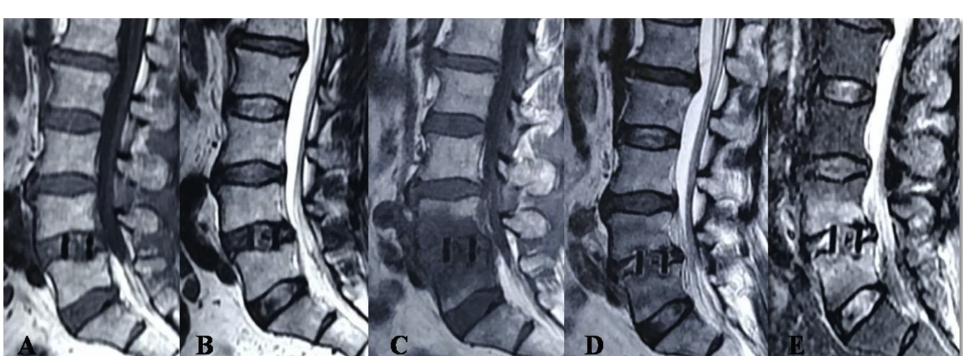

Fig. 3. A, B is a 63-year-old male patient with lumbar instability who has a sagittal T1 and T2-weighted image of the lumbar at 1 week after OLIF. C, D and E were respectively T1 and T2 weighted images and lipid inhibition image of lumbar mri sagittal position 3 weeks after surgery. MRI images of 3 weeks after surgery showed vertebral signal changes, suggesting intervertebral space infection.

Table 3
Complications following OLIF.

	No. of patients	Incidence	Outcome
Total complications	62	54.9	
Donor site pain	24	21.2	Full recovery within 1 month
Vertebral endplate fracture	15	13.3	Cage subsidence
Thigh pain/numbness	12	10.6	Full recovery within 2 months
Psoas/quadriceps weakness	5	4.4	Full recovery within 2 months
Sympathetic nerve injury	2	1.8	Full recovery within 6 weeks
Paralytic ileus	1	0.9	Full recovery within 1 week
Segmental artery laceration	1	0.9	No bleeding during procedure
Intervertebral infection	1	0.9	Full recovery within 3 months
Contralaterl femoral nerve palsy	1	0.9	Full recovery within 6 months

suspected that irritation of the psoas muscle itself, the lumbar plexus, genitofemoral and lateral femoral cutaneous nerve, or a combination of these from prolonged retraction of the psoas muscle during the procedure was responsible for these transient postoperative deficits. Additional complications included postoperative sensory and temporary motor weakness (17.7%) in our series compared with those mentioned above [8,18,19]. Conversely, the risks of neurologic complications were less frequent in anterior lumbar interbody fusion procedures. Faciszewski et al. [20] reported a 0.10% (one of 930 patients) risk of lumbar plexus injury in one larger cohort study. In a review summarizing 18 studies with 2310 patients, 304 patients had complications related to lumbar plexus injury, representing a 13% risk [21] despite intraoperative neuro monitoring. Our overall neurological complication risk was comparable to those reported for the XLIF, although these complications were transient and reduced steadily with increased experience in the OLIF approach in 113 patients. There were fewer vertebral endplate fractures/subsidence (13.3%) in our series than those (18.7%) reported by Abe et al. [18]. Currently, no literature is devoted to preventing the subsidence of OLIF surgical cages. However, some reports have described the incidence of XLIF fluctuating between 0.3% and 22%. Cage subsidence is associated with axial pain in the patient and recurrent neurological symptoms associated with indirect decompression loss. In general, cage subsidence depends on various factors related to the technology, implant material and patient bone quality. Some of the specific conditions reported in the literature that tend to cause the cage subsidence include over dispersion, multisegment fusion and smaller cages. We believe that in the first surgical procedure, endplate fractures are avoided during the intervertebral space distraction, especially in patients with osteoporosis. Second, when placing the cage, the appropriate size of the cage is selected to allow the cage to contact the left and right bone scale rings. It is important to consider that the end plates are most durable at the periphery and weak at the center. Thus, large and wide cages that are in contact with both sides of the end plate have a reduced risk of subsidence. With respect to previous studies on the oblique psoas-sparing approach, no intervertebral infection was reported. Vascular complication occurred in 0.9% (one of 113 patients) of our patients. This was higher than the risk of vascular complications (0.4%) reported by Mehren et al. [19] but lower than the vascular complication risks of 1.7% and 2.6% reported by Silvestre et al. [8] and Abe et al. [18], respectively. The vascular complication rate was comparable to that for far lateral approaches such as the XLIF, which ranges from 0% to 0.11% in large case series [22,23]. In most instances, because of the right lateral positioning of the patients and left-sided approach, there is no need for any vessel preparation.

Because the OLIF technique is a relatively novel technique, there is a paucity of studies available in the literature, including high-level evidence [24]. However, promising early results demonstrate the feasibility of OLIF and there are some ongoing studies.

It is stressed that great care should be taken to avoid neural and vessel injuries by proper patient positioning, gentle blunt dissection, correct placement of the retractor, exact intraoperative orientation, gentle penetration of the contralateral annulus fibrosus, and shorter operating duration, which can be more easily achieved during the OLIF procedure. Thorough knowledge of the vascular, neural, and visceral anatomy is essential in minimizing approach-related complications. Vascular injury is, perhaps, the most feared complication of anterolateral exposure of the lumbar spine. The spinal surgeons should ensure the availability, when required, of general and vascular surgeons

Table 4
Complications reported in the literature.

Author	Sample size (patients)	Complications reported (N = patients)	Follow-up (months)
Silvestre et al. [8]	179	Incisional pain = 4, sympathetic chain injury = 3, neurological deficit = 2, Iliac vein laceration = 1, Iliac vein laceration and bilateral deep venous thrombosis = 1, Iliolumbar vein laceration = 1, peritoneal laceration = 1, postoperative peripheral ischemia in lower extremities = 1, transient psoas paresis = 1, transient groin numbness = 1, pseudarthrosis = 1, minor complications = 3	11.2
Sato et al. [11]	20	Cage subsidence = 2, thigh pain = 1, thigh numbness = 1, segmental artery injury = 1	12
Fujibayashi et al. [12]	1003	Sensory nerve injury = 35, psoas weakness = 30, vertebral body fracture = 22, motor nerve injury = 10, anterior longitudinal ligament rupture = 6, surgical site infection = 4, pleural laceration = 5, segmental artery injury = 7, peritoneum laceration = 8, cage malpositioning = 3, retroperitoneal hematoma = 3, ureteral injury = 3, abdominal wall hernia = 2, ileus = 1, major vascular injury = 1, posterior conversion = 1	NR
Ohtori et al. [13]	35	Cage subsidence = 1, quadriceps weakness = 1, thigh pain = 1, thigh numbness = 3, segmental artery injury = 1	7
Ohtori et al. [14]	12	Cage subsidence = 1, thigh pain = 1, thigh numbness = 2	14.5
Abe et al. [18]	155	Spinal nerve injury = 1, cauda equina injury = 1, transient thigh pain/numbness, psoas weakness = 21, endplate injury = 29, segmental artery damage = 4, other vessels = 2, ureteral injury = 1, pleural laceration = 2, peritoneal laceration = 3, breakage of the LIF cage = 2, surgical instrument failure = 2, surgical site infection = 3, reoperation = 3, postoperative death = 1	NR
Mehren et al. [19]	812	Infection = 5, hematoma = 11, paralytic ileus = 2, iliac vein injury = 2, aortic injury = 1, irritation of the ilioinguinal and genitofemoral nerve = 1, irritation of the lumbar plexus = 2	NR

to assist in dealing with vascular injury. The key step in overcoming the OLIF learning curve is correct initial placement of the tubular retractor during the procedure. Incorrect placement of the retractor can lead to a high rate of neurological and great vessel injuries. All the patients who experienced donor-site pain had undergone harvesting of a tri-cortical bone block for the anterior iliac crest. This complication rate was significantly decreased after we modified methods of harvesting iliac bone. The patients' ODI and back/leg pain VAS scores were diminished, suggesting that this technique could be effective in improving the functional ability of the patients. The theoretical advantages of OLIF over ALIF and LLIF approaches to the L1-L5 levels are apparent and warrant further investigation.

However, it was noted that no patient underwent OLIF at the L5-S1 level, given the difficulty retracting the iliac vein and ascending lumbar vein in our series. The current study has some limitations. It was not a study on a single disease entity, and differences in surgical difficulty for various types of disease were not considered. Some data such as comorbidities, body mass index, bone mineral density, and anatomical structure, were not acquired in the study, while these factors can affect the incidence of complication. Larger randomized controlled trials with a long-term follow up should be conducted to evaluate the advantage of OLIF over alternative lumbar interbody fusion techniques.

5. Conclusions

The OLIF is a safe and valuable tool in the treatment of lumbar degenerative diseases with good clinical outcomes. The approach can be an alternative for ALIF, XLIF or DLIF with a low risk of vascular and neurologic complications, which can be performed without costly intraoperative neuro monitoring and without the need for an additional access surgeon. It has many advantages that make it attractive. However, there is a risk of neurological and vascular complications associated with OLIF that should be considered when choosing this approach.

References

[1] V. Rajaraman, R. Vingan, P. Roth, et al., Visceral and vascular complications resulting from anterior lumbar interbody fusion, J. Neurosurg. 91 (1 Suppl) (1999) 60–64.

[2] R.C. Sasso, B.J. Kenneth, J.C. LeHuec, Retrograde ejaculation after anterior lumbar interbody fusion: transperitoneal versus retroperitoneal exposure, Spine (Phila Pa 1976) 28 (2003) 1023–1026.

[3] K. Phan, G.K. Thayaparan, R.J. Mobbs, Anterior lumbar interbody fusion versus transforaminal lumbar interbody fusion-systematic review and meta analysis, Br. J. Neurosurg. 29 (2015) 705–711.

[4] B.M. Ozgur, H.E. Aryan, L. Pimenta, et al., Extreme lateral interbody fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion, Spine J6 (2006) 435–443.

[5] S.J. Kim, Y.S. Lee, Y.B. Kim, et al., Clinical and radiological outcomes of a new cage for direct lateral lumbar interbody fusion, Korean J. Spine 11 (2014) 145–151.

[6] K.W. Micheal, T. Yoon, Complication avoidance in the lateral approach for interbody fusion, Semin. Spine Surg. 25 (2013) 182–190.

[7] H.M. Mayer, A new microsurgical technique for minimally invasive anterior lumbar interbody fusion, Spine (Phila Pa 1976) 22 (1997) 691–699.

[8] C. Silvestre, J.M. Mac-Thiong, R. Hilmi, et al., Complications and morbidities of mini-open anterior retroperitoneal lumbar interbody fusion: oblique lumbar interbody fusion in 179patients, Asian Spine J6 (2012) 89–97.

[9] D.L. Bergey, A.T. Villavicencio, T. Goldstein, et al., Endoscopic lateral transpsoas approach to the lumbar spine, Spine (Phila Pa 1976) 29 (2004) 1681–1688.

[10] M.D. Cummock, S. Vanni, A.D. Levi, et al., An analysis of postoperative thigh symptoms after minimally invasive transpsoas lumbar interbody fusion, J. Neurosurg. Spine 15 (2011) 11–18.

[11] J. Sato, S. Ohtori, S. Orita, et al., Radiographic evaluation of indirect decompression of mini-open anterior retroperitoneal lumbar interbody fusion: oblique lateral interbody fusion for degenerated lumbar spondylolisthesis, Eur. Spine J. 26 (2017) 671–678.

[12] S. Fujibayashi, R.A. Hynes, B. Otsuki, et al., Effect of indirect neural decompression through oblique lateral interbody fusion for degenerative lumbar disease, Spine 40 (2015) E175–E182.

[13] S. Ohtori, S. Orita, K. Yamauchi, Mini-open anterior retroperitoneal lumbar interbody fusion: oblique lateral interbody fusion for lumbar spinal degeneration disease, Yonsei Med. J. 56 (2015) 1051–1059.

[14] S. Ohtori, C. Mannoji, S. Orita, et al., Mini-open anterior retroperitoneal lumbar interbody fusion: oblique lateral interbody fusion for degenerated lumbar spinal kyphoscoliosis, Asian Spine J. 9 (2015) 565–572.

[15] J. Quillo-Olvera, G.X. Lin, H.J. Jo, J.S. Kim, Complications on minimally invasive oblique lumbar interbody fusion at L2-L5 levels: a review of the literature and surgical strategies, Ann. Transl. Med. 6 (6) (2018) 101.

[16] J.K. Houten, L.C. Alexandre, R. Nasser, et al., Nerve injury during the transpsoas approach for lumbar fusion, J. Neurosurg. Spine 15 (2011) 280–284.

[17] T.V. Le, C.J. Burkett, A.R. Deukmedjian, et al., Postoperative lumbar plexus injury after lumbar retroperitoneal transpsoas minimally invasive lateral interbody fusion, Spine (Phila Pa 1976) 38 (2013) E13–E20.

[18] K. Abe, S. Orita, C. Mannoji, et al., Perioperative complications in 155 patients who underwent oblique lateral interbody fusion surgery: perspectives and indications from a retrospective, multicenter survey, Spine (Phila Pa 1976) 42 (January (1)) (2017) 55–62.

[19] C. Mehren, H.M. Mayer, C. Zandanell, et al., The oblique anterolateral approach to the lumbar spine provides access to the lumbar spine with few early complications, Clin. Orthop. Relat. Res. 474 (September (9)) (2016) 2020–2027.

[20] T. Faciszewski, R.B. Winter, J.E. Lonstein, et al., The surgical and medical perioperative complications of anterior spinal fusion surgery in the thoracic and lumbar spine in adults: a review of 1223 procedures, Spine (Phila Pa 1976) 20 (1995) 1592–1599.

[21] A. Ahmadian, A.R. Deukmedjian, N. Abel, et al., Analysis of lumbar plexopathies and nerve injury after lateral retroperitoneal transpsoas approach: diagnostic standardization, J. Neurosurg. Spine 18 (2013) 289–297.

[22] J. Kueper, G.A. Fantini, B.R. Walker, et al., Incidence of vascular complications during lateral lumbar interbody fusion: an examination of the mini-open access technique, Eur. Spine J. 24 (2015) 800–809.

[23] W.B. Rodgers, E.J. Gerber, J. Patterson, Intraoperative and early postoperative complications in extreme lateral interbody fusion: an analysis of 600 cases, Spine (Phila Pa 1976) 36 (2011) 26–32.

[24] K. Phan, M. Maharaj, Y. Assem, et al., Review of early clinical results and complications associated with oblique lumbar interbody fusion (OLIF), J. Clin. Neurosci. 31 (September) (2016) 23–29.