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Lateral Lumbar Interbody Fusion—Outcomes and Complications

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Abstract

Purpose of Review Lateral lumbar interbody fusion (LLIF) is a relatively new, minimally invasive technique for interbody fusion. The goal of this review is to provide a general overview of LLIF with a special focus on outcomes and complications.

Recent Findings Since the first description of the technique in 2006, the indications for LLIF have expanded and the rate of LLIF procedures performed in the USA has increased. LLIF has several theoretical advantages compared to other approaches including the preservation of the anterior and posterior annular/ligamentous structures, insertion of wide cages resting on the dense apophyseal ring bilaterally, and augmentation of disc height with indirect decompression of neural elements. Favorable long-term outcomes and a reduced risk of visceral/vascular injuries, incidental dural tears, and perioperative infections have been reported. However, approach-related complications such as motor and sensory deficits remain a concern.

Summary In well-indicated patients, LLIF can be a safe procedure used for a variety of indications.

Keywords Degenerative disc disease · Lumbar spine · Lateral lumbar interbody fusion · Outcomes · Complications

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Introduction

Lateral lumbar interbody fusion (LLIF) is a relatively new, minimally invasive technique for interbody fusion. This technique is also referred to as eXtreme Lateral Interbody Fusion (XLIF, NuVasive, Inc.) or Direct Lateral Interbody Fusion (DLIF, Medtronic Sofamor Danek) [1•, 2]. Since the first description of the technique, the indications for LLIF have expanded and the rate of LLIF procedures performed in the USA has increased [1•, 3•]. LLIF offers structurally sound support through a large footprint interbody cage spanning the dense apophyseal ring and indirectly decompresses neural elements. Using a retroperitoneal approach to the anterior spinal column, LLIF circumvents some of the challenges and morbidity risk of anterior or posterior lumbar interbody fusion techniques. However, LLIF is not without its unique complications. The aim of this review is to provide a general overview of LLIF with a special focus on outcomes and complications.

History

In 2003, Bertagnoli et al. described the so-called AnteroLateral transPsoatic Approach (ALPA) as a new technique for implanting prosthetic disc-nucleus devices [4]. In 2006, Ozgur et al. published the first article using a lateral transpsoas approach for interbody fusion with the title "Extreme Lateral Interbody Fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion," which is currently the most cited article on minimally invasive spine surgery in the literature [5, 6]. Since then, many adaptions of this approach as well as additional access techniques have been described [7–9].

Key Biomechanical Principles

Besides the reported advantages of minimally invasive surgery, including minimal tissue trauma during the approach, less blood loss, decreased postoperative pain, and shorter hospital stays, there are several theoretical advantages specific to LLIF [5].

Compared to posterior lumbar interbody (PLIF) and transforaminal interbody fusion (TLIF), LLIF allows the placement of wide interbody cages spanning the lateral borders of the apophyseal ring bilaterally. The apophyseal ring surrounding the periphery of the vertebral body consists of cortical bone. It is an ideal site for interbody cage placement since it offers more stability than the soft cancellous bone of the inner endplates. Compared to standard interbody cages (18 mm anterior/posterior dimension), wider cages (22 mm) have been shown to diminish the rate of high-grade subsidence and preserve segmental lordosis after LLIF [10]. Currently available 26-mm-wide cages provide even more stability and result in significantly reduced cage subsidence [11, 12].

Moreover, the lateral, retroperitoneal approach preserves the anterior and posterior annular/ligamentous structures. The intact anterior longitudinal ligament (ALL) and posterior longitudinal ligament (PLL) provide extra support for the interbody cage and theoretically provide greater stability in the setting of standalone constructs. Increased postoperative stability of the vertebral column and improved alignment are achieved utilizing ligamentotaxis [13].

In contrast to other fusion techniques which often rely on direct decompression of neural elements such as removal of ligamentum flavum, laminotomy/laminectomy, facetectomy, LLIF can provide indirect decompression. Through placement of large interbody cages, the disc height can be restored and the foramen opened. Average foraminal area increase of approximately 35% and posterior intervertebral height increases of 70% after LLIF cage placement have been reported [14]. In addition, patients suffering from symptomatic lumbar stenosis showed an increase of 33.1% in central canal diameter after treatment with standalone LLIF.

Lastly, LLIF offers sequential coronal correction of lumbar degenerative deformities. Reasonable coronal and sagittal correction in mild scoliotic deformities has been reported [15, 16].

Indications

As described above, one advantage of the lateral approach is the ability to insert a large footprint interbody cage spanning the dense apophyseal ring bilaterally. However, in contrast to the other available approaches (e.g., anterior, posterior, transforaminal), the lateral approach is not appropriate to treat pathologies at the L5-S1 segment, since the iliac crest, neural structures, as well as vascular anatomy make this segment unreliable from a direct lateral approach.

As with any surgery, proper patient selection is critical. The indications for LLIF include many degenerative spinal conditions such as degenerative disc disease, degenerative scoliosis, spondylolisthesis, spinal stenosis, and disc herniations [1•, 3•, 14–20]. LLIF can also be a suitable option for revision surgery since it avoids a posterior revision approach through scar tissue adherent to the dura and neural structures [21]. Additionally, this approach is used for anterior corpectomies in the setting of traumatic spinal pathologies and tumors as well as lumbar total disc replacements [18–23]. A recent publication showed that, in properly selected patients, LLIF might also be an effective surgical treatment option for adjacent segment disease [24].

When deciding the optimal surgical approach, the contraindications of the LLIF technique should be considered as well. Patients with poor bone quality or severe osteoporosis might be at increased risk for cage subsidence and vertebral body fractures. Additional contraindications are active infection, history of retroperitoneal inflammatory disease (e.g., diverticulitis), and history of prior retroperitoneal injury or dissection [1]. Moreover, patients with posterior locked facets are not ideal candidates for a procedure relying on indirect decompression. An attempt to distract the fused levels might lead to endplate damage and increased risk of subsidence. Finally, a rising psoas sign at L4-5 on preoperative MRI may be associated with an increased risk of nerve injury during LLIF [25].

Evolution of the Technique

The originally described LLIF technique uses two incisions through which tubular dilators and an expandable retractor are successively inserted [5, 26]. Since no direct visualization is possible, this technique relies on handheld electrophysiological monitoring devices to avoid injury to the exiting nerve roots and lumbar plexus. This tubular dilator based technique has recently been modified to a single incision mini-open access technique, which is utilized at our institution. This technique allows for direct visualization of retroperitoneal and neural structures, digital palpation of the target disc as well as electrophysiological neurologic confirmation during the procedure [26]. Our institution's experience regarding sensorimotor complications and vascular injuries using the mini-open access technique has previously been published [26–29].

Surgical Technique

After induction of endotracheal anesthesia, the patient is placed in the lateral decubitus position. In patients without a coronal plane deformity, a left-sided approach is commonly used to reduce the risk of injury to the inferior vena cava [1•]. In patients with a coronal plane deformity, the spine should be approached from the concavity of the scoliotic curve that allows access to several levels through a single incision. In patients with L4-5 pathology, the principal determinant of laterality is the accessibility of the target level, which depends on the position of the iliac crest as well as the coronal angulation of the L4-5 disc space [21].

Since the lateral position is inherently more unstable compared to the prone or supine position, the patient needs to be properly secured to the table with adhesive tape [1•]. The surgical field is prepped and draped in the usual sterile fashion. Intraoperative fluoroscopy is used to estimate the operative segment.

An oblique incision is carried out through the skin with blunt dissection through the external and internal obliques as well as the transversalis. The muscles are sequentially split in minimal fashion, along the direction of their respective fibers [26]. The retroperitoneal space is then entered and developed under direct vision. The psoas muscle is palpated and blunt dissection is carried out through the psoas down to the disc space. At our institution, we use neuromonitoring only for confirmation of neuroanatomy. The mini-open technique which utilizes both palpating and visualization is not a blind approach and decreases reliance on neuromonitoring. After fluoroscopic confirmation of the appropriate level, a minimally invasive retractor is docked and dilated at the segment.

An annulotomy is carried out with a surgical #10 blade scalpel followed by a discectomy with the use of a pituitary rongeur. A wide Cobb is used to carefully release the cartilaginous endplate and the contralateral annulus, making sure not to over penetrate into the contralateral psoas muscle [1•]. Injuries to the contralateral side including psoas seroma and motor deficits have been described [28, 30, 31]. After adequate endplate preparation, sequential trialing utilizing bullet distractors is performed. To minimize implant subsidence and endplate fractures, overstuffing of the disc space should be avoided. An adequately sized implant is loaded with the surgeon's choice of graft material and inserted centrally. Reduction of the segment can be confirmed with fluoroscopy. A standalone construct can also be supplemented by a lateral screw or plate [21].

#1 Vicryl is used to close the transversalis, internal and external obliques in an interrupted fashion, followed by a 2-0 subdermal and Monocryl on the skin. A standard sterile dressing is applied. At the end of the procedure, the patient is then converted to a supine position for extubation. The fusion of the anterior column can be supplemented by posterior pedicle screws or interlaminar stabilization systems depending on the clinical indication [21]. This can be performed either directly following the LLIF procedure or at a later point to allow the patient some time for recovery from the lateral procedure.

Outcomes

In a recent systematic review, Lehmen et al. reported on LLIF outcome profiles. Multiple studies showed favorable radiographic and clinical outcomes after LLIF, with some that had a minimum of 2-year follow-up. When reviewing outcomes, it is important to distinguish studies by indication such as degenerative versus deformity. Generally, there is good consistency of the reported data by clinical indication. Some of the variability of the reported outcomes can be explained by the heterogeneity in the treatment such as different types of fixation or cages sizes [3•]. Several high quality publications showed the efficacy of LLIF utilizing patient-reported outcome measures [1•].

Results of a retrospective case series of 84 LLIF patients with a mean follow-up of 15.7 months showed an averaged OR time of 199 min, an EBL of 155 mL, and a length of stay of 2.6 days. Sixty-eight patients had evidence of solid fusion on postoperative CT scans. At 1-year follow-up, VAS improved by 77% and ODI improved by 56% from baseline [32].

In a prospective analysis of 600 patients treated with LLIF for degenerative spinal conditions, average LOS of stay was found to be 1.21 days. VAS pain scores showed an immediate improvement of 65%. At minimum 1-year follow-up, 86.7% of patients were satisfied with their procedure and 90.7% stated that they would have the procedure again [33].

Phillips et al. reported on clinical and radiographic results of a prospective multicenter study with 24-month follow-up. One hundred seven patients with degenerative scoliosis were treated with LLIF with or without supplemental posterior fixation. At 24 month, statistically significant mean improvements in ODI, VAS for back pain and leg pain, as well as SF-36 physical and mental component scores were reported. Eighty-five percent of the patients reported satisfaction with their procedure and would elect to undergo the surgery again. Cobb angle improved from 20.9° to 15.2° with the highest correction in patients who underwent supplemental bilateral pedicle screw fixation [34].

A study including 31 patients with Grade I and II spondylolisthesis treated with LLIF combined with posterior percutaneous pedicle screw fixation showed statistically significant improvements in VAS, ODI and SF-35 measures. The reported estimated blood loss was 94 mL and the average hospital stay 3.5 days. All of the 31 patients had improvement in anterolisthesis. Residual postoperative listhesis was only noted in 4 patients (12.9%) [35].

Our institution reported on clinical and radiographic outcomes of 118 patients treated with LLIF at a minimum 2-

year follow-up. We found that the VAS for pain, ODI and the physical components summary of SF-12 improved by 53, 43, and 41%, respectively. In patients with a coronal deformity, the preoperative Cobb angle improved from 24.8° to 13.6°. All comparisons from baseline showed statistically significant improvements. In 88% of the treated levels, a successful fusion was achieved [36].

Strom et al. evaluated the combination of LLIF and open posterior surgery in the treatment for adult spinal deformity. Interestingly, in this study, the authors found better clinical outcomes, less EBL, fewer complications, and faster recovery in the hybrid group (LLIF and open posterior surgery) compared to the group with open posterior surgery alone [37].

The reported revision rate after standalone LLIF at 16-month follow-up has been reported with 10.3%. The causes for revision were primarily persistent radiculopathy and symptomatic spinal stenosis. The time to revision was 10.8 months at an average [17].

As highlighted by Lehmen et al. and Kwon et al., there is a lack of studies directly comparing LLIF to conventional approaches. More high-quality clinical evidence is still necessary to elucidate the proposed advantages of LLIF over conventional interbody fusion techniques [1•, 3•].

Complications

Despite the many advantages of the technique, LLIF has its unique set of approach-related complications.

Hip Flexion Weakness

Hip flexion weakness is very common postoperatively and considered a result of trauma to the psoas muscle during the approach and is probably not related to direct nerve injury. Tomeh et al. reported the results of a prospective multicenter study with 102 patients undergoing LLIF at L3-4 and/or L4-5. In their study, 27.5% of patients experienced postoperative hip flexion weakness, with a grade 4/5 in the majority of cases. The weakness was transient and typically resolved in the first 2 weeks after surgery [38]. Lee et al. evaluated hip flexion strength prospectively with a dynamometer. Similarly, in this study, the authors found hip flexion weakness in the immediate postoperative phase that returned almost to baseline within 2 weeks [39].

Neurologic Injury

Hijji et al. recently published a systematic review analyzing the complication profile of LLIF. Their study included a total of 63 articles and 6819 patients. The most commonly reported complications were transient neurologic injuries (36.07%). The clinical significance of those transient findings, however, is unclear since the rate of persistent neurologic complications was much lower (3.98%) [40•].

We retrospectively analyzed the rates of anterior thigh/groin pain, sensory and motor deficits in a cohort of 451 patients undergoing LLIF (919 treated levels) at our institution. In the immediate postoperative phase, the reported rate of anterior thigh/groin pain, sensory and motor deficits were 38.5, 38.0, and 23.9%, respectively. The rates decreased over time with persistent surgery-related motor deficits of 3.2% and sensory deficits of 9.6% at minimum follow-up of 18 months. Although the inclusion of the L4-5 disc space has been reported to be a risk factor for neurologic deficits after LLIF, no significant increase in the rate of neurologic deficits at the last follow-up were noted in our study. Interestingly, the use of rhBMP-2 was associated with higher rates of persistent motor deficits, which might be explained by a direct deleterious effect of this agent on the lumbosacral plexus [29].

In a retrospective chart review of 118 patients, Cahill et al. determined the incidence of femoral nerve injury, which is considered one of the worst neurological complications after LLIF. The authors reported an approximate 5% femoral nerve injury rate of all the LLIF procedures performed at L4-5. There were no femoral nerve injuries at any other levels [41].

During a 6-year time period of performing LLIF at our institution, we noted a learning curve with a decreasing proportional trend for anterior thigh pain, sensory as well as motor deficits [42]. Le et al. also observed a learning curve with a significant reduction in the incidence of postoperative thigh numbness during a 3-year period (from 26.1 to 10.7%) [43].

Vascular Injury

One of the advantages of LLIF is the avoidance of an anterior approach, which has been associated with visceral and vascular injuries [44, 45]. The incidence of major vascular complications during anterior lumbar spinal surgery has been reported to be 2.9% [45]. For LLIF, an access surgeon is generally not needed, since it is not necessary to violate or retract the peritoneum or the great vessels [5]. Compared to the supine position, the vascular structures move a significant distance away from the surgical corridor when the patient is positioned in the lateral decubitus position [46].

Nonetheless, vascular injuries are still possible and are probably among the most significant complications of LLIF [1•]. The overall incidence of vascular injury at our institution using LLIF is 0.056% per case and 0.029% per level. The mini-open access technique has been shown to be useful for immediate repair of minor vascular injuries [26]. Although rare, potentially lethal major vascular complications during LLIF are possible. In the setting of an implant breakage and endplate violation, an aortic perforation occurred at our institution and required emergent laparotomy and vascular suture repair [47]. Assina et al. published the first report of a fatal intraoperative injury to the great vessels during an LLIF procedure. A 50-year-old woman underwent an LLIF at L4-5 in an outpatient surgicenter. During the procedure, a tubular retractor system with a detachable, nonfixed anterior blade was used causing injury to the posterior wall of the inferior vena cava and the right iliac vein confluence. The patient was emergently transferred to a university hospital, underwent multiple operations over the course of 4 weeks and died of multiple organ failure due to septic shock [48].

Subsidence

Subsidence is a common phenomenon after lumbar interbody fusion. Its etiology and clinical significance are still not fully understood. To some extent, subsidence is considered a reaction to normal bone incorporation caused by physiological loading with little clinical significance. Excessive sinkage, however, may result in mechanical failure of the anterior column support. This can lead to nonunion, loss of disc-height, and sagittal imbalance [49]. Since LLIF relies on indirect decompression, subsidence is clinically of greater concern when compared to alternative techniques utilizing direct decompression of the neural elements [50].

Le et al. reported an overall radiographic subsidence rate of 14.3% and a clinical subsidence rate of 2.1% in 140 patients undergoing LLIF using polyetheretherketone cages of different sizes. In 70% of the cases, subsidence occurred at the superior end plate. Interestingly, subsidence rates were significantly lower in the 22-mm-wide cages (1.9%) than in the 18-mm-wide cages (14.1%). Moreover, constructs with bilateral pedicle screws had a lower rate of subsidence than constructs with supplemental lateral plates. The authors concluded that the widest possible cage should be used for LLIF to protect against subsidence [50]. Also, Marchi et al. found lower subsidence rates and better restoration of segmental lordosis in cases utilizing wider cages compared to standard-sized cages [10].

In addition to using wide cages, careful endplate preparation intraoperatively, the use of posterior instrumentation and preoperative treatment of osteoporosis might lower the rate of subsidence after LLIF. Besides inferior and superior migration into the vertebral endplate, lateral cage migration has also been described in the literature [51].

Vertebral Body Fracture

Although an uncommon complication, vertebral body fractures following LLIF have been reported [33, 52–57]. Most of these fractures were associated with the use of lateral plates and vertebral screws [53, 55, 56]. Dua et al. and Kepler et al. reported vertebral body fractures in 2 osteoporotic patients after single-level LLIF with plate fixation and unilateral pedicle screw fixation. The authors stated subsidence of the cage and a cut-through mechanism of the rigidly locked plate screws through the osteoporotic vertebral body as a possible explanation. They concluded that lateral plating should be used with caution in patients with poor bone quality [55, 56]. Brier-Jones et al., however, reported on vertebral body fractures occurring even in nonosteoporotic patients [54]. Tempel et al. recently reported on 2 vertebral body fractures following stand-alone LLIF. Possible risk factors for fractures after stand-alone procedures included poor bone quality, obesity, intraoperative endplate violation, graft subsidence, and the use of oversized grafts [52].

Pseudohernia

Injury to the motor nerves that supply the anterior abdominal musculature can lead to paresis and bulging of the abdominal wall. This condition is often referred to as a "pseudohernia." The abdominal wall mainly consists of 4 muscles including the rectus abdominis, external oblique, internal oblique, and transverse abdominis. The nerves innervating these muscles are the subcostal, iliohypogastric, and ilioinguinal. During the early stages of the LLIF approach, it is very important to avoid damaging these neural structures. Dakwar et al. reported the first case series of abdominal wall paresis following LLIF. The incidence rate was found to be approximately 1.8% and patients were diagnosed within 2–6 weeks postoperatively. Abdominal CT scanning was performed in some patients to exclude an abdominal wall defect or hernia. All of their reported patients were treated conservatively and showed no long-term sequelae [58]. A case of a delayed pseudohernia 5 months after LLIF requiring surgical repair has recently been reported in the literature [59].

Visceral Injury

Bowel perforations are a rare but potentially life-threatening complication of the LLIF procedure. To avoid violation of the peritoneum with subsequent visceral injuries, complete development of the retroperitoneal space during the LLIF approach is crucial [60]. Two cases of bowel perforation secondary to LLIF have been described in the literature [60, 61]. An additional anecdotal case has been recently reported by Epstein [62]. Besides direct visceral (bowel) injury, there is a relatively high rate of postoperative ileus after LLIF. The incidence of prolonged or recurrent postoperative ileus at our institution was approximately 7.0%. A history of gastroesophageal reflux disease, posterior instrumentation as well as LLIF at L1-L2 were found to be independent risk factors [63].

Wound Infections

Uribe et al. conducted a survey study of more than 13,000 cases to evaluate the incidence of wound complications after

LLIF. Only experienced spine surgeons active in the society of lateral access surgery (SOLAS) participated in the study. In this study, LLIF was shown to have lower rates of surgical site infections compared to the reported rates of conventional interbody fusion. The incidence of superficial wound infections was 0.38%, while deep lateral-incision wound infections occurred in 0.14% of the cases [64].

Conclusion

In the past years, the rate of LLIF procedures performed in the USA increased. LLIF is used for a wide array of indications and can be performed as a standalone procedure or as part of a circumferential fusion. In review of the literature, most authors agree that the placement of a wide interbody cage spanning the dense apophyseal ring and avoiding dissection through the spinal canal or neural foramina are the major advantages of this technique, resulting in good clinical outcomes. Approach-related neurologic deficits, however, remain a concern. In summary, LLIF can be a safe and versatile procedure in patients indicated for anterior fusion with the use of a proper surgical technique.

Compliance with Ethical Standards

Conflict of Interest Stephan N. Salzmann and Jennifer Shue declare that they have no conflict of interest. Alexander P. Hughes reports grants from MiMedx Group, Inc., grants from NuVasive, personal fees from Altus Spine outside the submitted work.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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