



# Lateral and Oblique Lumbar Interbody Fusion—Current Concepts and a Review of Recent Literature

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## Abstract

**Purpose** To review the relevant recent literature regarding minimally invasive, lateral, and oblique approaches to the anterior lumbar spine, with a particular focus on the operative and postoperative complications.

**Methods** A literature search was performed on Pubmed and Web of Science using combinations of the following keywords and their acronyms: lateral lumbar interbody fusion (LLIF), oblique lateral interbody fusion (OLIF), anterior-to-psoas approach (ATP), direct lateral interbody fusion (DLIF), extreme lateral interbody fusion (XLIF), and minimally invasive surgery (MIS). All results from January 2016 through January 2019 were evaluated and all studies evaluating complications and/or outcomes were included in the review.

**Recent Findings** Transient neurological deficit, particularly sensorimotor symptoms of the ipsilateral thigh, remains the most common complication seen in LLIF. Best available current literature demonstrates that approximately 30–40% of patients have postoperative deficits, primarily of the proximal leg. Permanent symptoms are less common, affecting 4–5% of cases. Newer techniques to reduce this rate include different retractors, direct visualization of the nerves, and intraoperative neuromonitoring. OLIF may have lower deficit rates, but the available literature is limited. Subsidence rates in both LLIF and OLIF are comparable to ALIF (anterior lumbar interbody fusion), but further study is required. Supplemental posterior fixation is an active area of investigation that shows favorable biomechanical results, but additional clinical studies are needed.

**Summary** Minimally invasive lumbar interbody fusion techniques continue to advance rapidly. As these techniques continue to mature, evidence-based risk-stratification systems are required to better guide both the patient and clinician in the joint decision-making process for the optimal surgical approach.

**Keywords** LLIF · XLIF · DLIF · OLIF · Anterior to psoas · MIS

## Introduction

One of the most significant developments in lumbar spine surgery over the past two decades has been the advent of minimally invasive approaches to the anterior lumbar spine.

The technique typically relies on a lateral window to the anterior lumbar spine through the psoas and is now commonly known as the lateral lumbar interbody fusion (LLIF, Fig. 1) [1]. It is also sometimes referred to by the industry-associated names direct lateral interbody fusion (DLIF, Medtronic) or extreme lateral interbody fusion (XLIF, NuVasive). Recently, a variant has been developed which takes advantage of the window between the peritoneum and the psoas muscle in lieu of splitting the muscle, which is called the oblique lumbar interbody fusion (OLIF) or the anterior to psoas (ATP) approach [2]. As with other minimally invasive techniques, the theoretical advantages include reduced blood loss, improved postoperative pain due to less retraction and smaller incisions, faster recovery, and the obviation for the need of an approach surgeon [3].

Despite these compelling advantages, LLIFs have their own unique complications, primarily related to the approach

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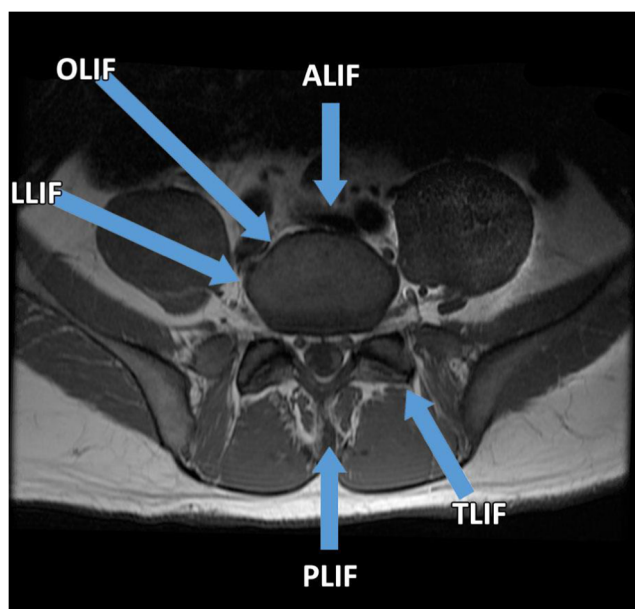
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**Fig. 1** Approaches to the lumbar spine. Diagrammatic representation of the various open and minimally invasive approaches to lumbar interbody fusion (LIF). Options include the anterior, transforaminal, posterior, latera, and oblique approaches

itself [3]. The most commonly described complication has been transient, and less commonly permanent, sensorimotor deficits of the groin and/or thigh. However, critically interpreting earlier studies is difficult due to a general lack of standardization of reporting neurological deficits in the literature [4]. For example, one of the first published studies of LLIF patients showed 14% incidence of postop psoas weakness and 3.5% incidence of slight thigh atrophy in a series of 85 patients [5], while a subsequent retrospective study of 59 patients found 62.7% of patients had postoperative sensory or motor thigh symptoms, with over 90% resolving within a year of surgery [6]. Conversely, one of the largest reported LLIF series reported no intraoperative complications, with only 4 in 600 patients reporting transient postoperative nerve deficits [7]. Further difficulties in parsing the literature include the use of different terminology for the techniques, including some papers which refer to OLIF as LLIF. Here we present a concise review of the relevant recent literature regarding minimally invasive approaches to the anterior lumbar spine, with a particular focus on the operative and postoperative complications.

## Methods

A literature search was performed on PubMed and Web of Science using combinations of the following keywords and their acronyms: lateral lumbar interbody fusion (LLIF), oblique lateral interbody fusion (OLIF), anterior-to-psoas approach (ATP), direct lateral interbody fusion (DLIF), extreme

lateral interbody fusion (XLIF), and minimally invasive surgery (MIS). All results from January 2016 through January 2019 were first evaluated by reading the titles and abstracts. If the article met the criterion of studying of the above procedures for complications and/or outcomes, the full text was accessed, read in its entirety, and included in the review if relevant to the specific subheadings of the discussion.

## Thigh symptoms

The sensorimotor deficits observed in patients undergoing lateral or oblique access surgery have been thought to be related to traction of the nerve(s) during surgery. An MRI evaluation of nearly 60 patients found that the lumbar plexus was approximately 5 to 13 mm from the center of the lumbar disc space, while the distance from the genitofemoral nerve was on average less than 1 mm at the L2/L3 level [8]. Historically, LLIF has been associated with 20–40% rate of thigh numbness or pain associated with prolonged muscle retraction of over 20–40 min per level [9]. In light of larger studies having shown a correlation between retraction and nerve symptoms [10], surgeons are still advised to minimize retractor time during this procedure.

A recent PRISMA-compliant systematic review and meta-analysis of older data through June 2016 identified 63 articles describing 6714 patients undergoing 11,325 levels of lumbar fusion (average 1.69 levels per patient) [11]. Due to study heterogeneity, most complications were analyzed for far fewer patients. Neurological deficit was the most common complication, with a pooled transient postoperative deficit rate of 36% in an aggregate sample of 5046 patients. Persistent symptoms, again primarily thigh sensorimotor loss, were seen in 4–5% of patients with the difference in definition between transient and persistent somewhat arbitrary at a cut-off of 6 months [12]. A small series of 18 patients in which LLIF was used to treat spondylolisthesis patients found a third (33%) of the patients developed sensory deficit of the thigh but also that all had resolved within 6 months postoperatively [13]. Similarly, another small series from a different institution evaluating this same procedure and pathology found 3 in 16 (19%) patients developed transient sensory loss that resolved within 1 year. [14]

In contrast to these high rates, a more recent, single-institution study of single-level LLIFs found that 2.6% (6 in 230 patients) suffered severe thigh weakness (as defined by strength of 3/5 or lower in either hip flexion or knee extension) over 6 weeks in duration. Twenty-two patients (9.6%) sustained sensory loss consistent with the surgery [12]. One possible explanation for the lower complication rate may be an improvement of the techniques with time, with newer retractors possibly associated with a reduced the rate of LLIF-related thigh symptoms [15, 16].

Other proposed advancements also show promise in decreasing the incidence of these complications with the direct visualization of the nerves. Two recent studies proposing this modification to the LLIF technique have demonstrated positive data. One found that by utilizing direct endoscopic visualization, the genitofemoral nerve was found within the surgical corridor in 33% (7/21) of patients. The nerve could be freely mobilized, with only one patient requiring intramuscular dissection for mobilization of the nerve [17]. Similarly, Levi and colleagues found that after implementing routine visualization of the lumbosacral plexus during their LLIFs, sensory deficits decreased from 60 to 19% and psoas weakness reduced from 23.7 to 3.1% [18]. Both of these studies are limited by the use of historical comparisons, but this topic clearly merits further study. Lastly, although intraoperative neuromonitoring of motor-evoked potentials has been found to be effective in preventing postoperative lumbar plexus deficits during LLIF, [19] its routine use is controversial [20].

An impetus for the development of the oblique approach was to reduce this complication [2] avoiding the psoas and subsequent traction injury to the nerves. Because of its novelty, there is a paucity of data, and a recent analysis of OLIF-related complications found only 16 papers of sufficient quality and relevance [21]. Notably, the overall combined rate of postoperative thigh symptoms was 1–3%, which is markedly lower than what has been observed in the literature for transpsoas approaches. However some caution is warranted, as the review generally identified very low incidence rates for all complications. More recent patient series are reporting thigh weakness or numbness in approximately 5–14% of patients, [22–24], but one study has found no deficits in any patients with a minimum 6 months of follow-up [25]. Critically, direct comparisons of LLIF and OLIF have not yet been performed with scientific rigor. A small retrospective series [26] comparing LLIF ( $n = 31$ ) to OLIF ( $n = 14$ ) found that OLIF was associated with lower risk of thigh numbness. Likewise, a similar comparison of OLIF to LLIF in 43 total patients found OLIF to be significantly superior in preventing nerve deficits of the thigh [23]. However, the heterogeneity of the patient populations between the two groups in these papers makes it difficult to draw strong clinical conclusions.

### Incomplete Decompression

An additional drawback of LLIF/OLIF is that the decompression of the neurological elements is generally achieved indirectly, via ligamentotaxis, risking incomplete relief. This concern has been confirmed in a retrospective series of 28 patients (53 levels) undergoing OLIF. The patients were evaluated with intraoperative CT myelograms to assess neural decompression after cage placement, and in 9 patients, (11 levels) the CT revealed inadequate radiographic decompression of the

nerve root. All of these 9 patients then underwent additional direct posterior decompression as per the authors' institutional protocol, with satisfactory outcomes [27]. Conversely, it is unclear if the improvement in direct decompression is clinically significant and affects outcomes. For example, a small prospective series ( $n = 55$ ) comparing TLIF and LLIF with 2-year follow-up found that the TLIF group had improved decompression radiographically but did not detect a meaningful postoperative clinical difference, with a notable exception of hip flexion weakness only being seen in the LLIF group [28, 29].

Consequently, there is interest in defining risk factors for successful or failed indirect decompression through the lateral or oblique windows. A prospective multicenter trial evaluated several radiographic variables and their ability to predict a failure of indirect decompression during LLIF, as defined by need for revision surgery or inadequate improvement of symptoms at 6 months [30]. Disc height, foramen height, foramen area, central canal diameter, subarticular diameters, severity of facet arthropathy, and the presence of a bony lateral recess stenosis were evaluated. Of these, only bony lateral recess stenosis was found to be a significant predictor of indirect decompression. This is a significant finding that we believe is more clinically relevant to surgeons, as typically the adequacy of decompression is reported by radiographic parameters [31]. A separate study evaluating the radiographic appearance of the facet joints, specifically joint degeneration or facet angulation, did not find a relationship between the preoperative measurements and postoperative radiographic and clinical outcomes [32].

### Sagittal Balance, Subsidence, and Fusion

There may also be technique-related issues with achieving proper decompression as well as sagittal balance. A retrospective patient series demonstrated that anterior positioning of the cage improved sagittal balance in LLIF as expected, with equivalent decompression when compared with placing the implant in the middle of the disk space [33]. Specially designed cages for improving lordosis may additionally be beneficial in restoring proper sagittal balance in LLIF [34], but open approaches may be superior in achieving the desired alignment [35]. When utilizing the minimally invasive lateral window in adult spine deformities, release of the ALL for anterior column reconstruction will improve lordosis versus LLIF alone [36]. Surgeons should also keep in mind that intraoperative fluoroscopy may not provide adequate accuracy in judging cage placement in OLIF when compared against the postoperative CT [37].

Because the approach allows for wider exposure of the disc space, cages used in OLIF and LLIF have a much wider footprint than implants typically utilized in posterior approach

surgeries. Therefore, they are thought to better resist subsidence. An analysis of aggregated FDA-submitted biomechanical data indeed shows that LLIF implants are more resistant to subsidence compared with PLIF or TLIF, and equivalent to ALIF implants [38]. However, a different biomechanical study suggested that LLIF with cage alone, without posterior supplemental fixation, may not be sufficient in providing adequate stability for 3 or more levels of fusion, perhaps contributing to subsidence [39]. Clinically, the subsidence rate is poorly defined and poorly reported, making comparisons difficult. A study of nearly 300 patients who underwent LLIF without posterior instrumentation found a relatively low rate (11%) but determined that this was significantly correlated with risk for revision surgery [40]. In contrast, another series of 63 patients who underwent OLIF demonstrated that there was a very high subsidence rate of 33% at 1-year postop detected by CT, and these authors did not find a correlation between these radiographic findings with clinical outcomes [41]. While a meta-analysis found the pooled subsidence rate to be 6.6% [11], due to the large differences in how subsidence is defined, its clinical significance is unclear. Regardless, this is a clear concern that requires further observation and study, and the more recent data do appear to correlate with previously reported subsidence rates of 11–30% [42].

The overall successful fusion rates of LLIF/OLIF are comparable with that of established anterior and posterior fusion techniques. [43, 44] One active area of investigation currently is determining the role of supplemental fixation to increase rigidity and decrease the risk of pseudarthrosis, which is thought to be around 6% in the short- to medium-term [11]. As noted above, it appears that for 3 or more levels of fusion, an LLIF cage without supplementation is insufficient to maintain the necessary rigidity for solid fusion [39]. However, in a separate cadaveric study of 3 lumbar levels, supplemental lateral or posterior fixation was found to be stiffer as expected, but the LLIF cage alone demonstrated adequate stability [45]. There is ultimately a paucity of data to answer this question and further studies are required.

## Uncommon Complications

Previously described arterial injury rates in open anterior lumbar spine surgery are 0.3–2.4% [46] and both LLIF and OLIF compare relatively favorably to this rate [11, 21, 47]. An important difference, however, is that the injuries in the minimally invasive approaches appear to primarily involve the segmental arteries [22, 25]. This has led to a newly described and relatively rare complication, symptomatic contralateral psoas hematomas, likely due to injury to the segmental artery intraoperatively during release of the contralateral annulus [48]. While the approach is theoretically designed to avoid the great vessels entirely, in contrast with the ALIF [49], injury to these

vascular structures has been reported, including an injury to the iliac veins leading to perioperative mortality [50]. A recent anatomic study utilizing MRI data from 180 patients demonstrated that there is less anatomic variance on the left side, as well as the concave side of the deformity in the case of scoliosis [51]. Surgeons are also reminded that more caudal levels narrow the safe corridor significantly with respect to the great vessels, and care should be taken to not violate the anterior longitudinal ligament (ALL) inadvertently [50, 51].

Other complications, such as visceral injuries or intraoperative durotomies, are very uncommon and generally reported in the 1% or below range [21, 23, 52]. One rare complication more recently being reported is delayed incisional hernias and pseudohernia through the incision site [53, 54]. Because these are almost always operative, and sometimes urgently so, spine surgeons are encouraged to maintain a high index of suspicion. [54]

## Conclusion and Commentary

The outcomes from lateral lumbar interbody fusion techniques have led to advocates for the procedure to be performed on an outpatient basis in ambulatory surgery centers [55]. Although our institutional experience has mirrored excellent patient tolerance with reasonable complication risk, we do not perform this in the outpatient setting for the potential emergent complication of vascular or visceral injury. We routinely use intraoperative neuromonitoring, direct visualization during trans-psoas dissection, and aim for retractor times below 20 min. We also now routinely utilize an anterior to psoas technique, particularly in the multilevel setting. For the deformity indication, we have found that the use of multilevel lateral interbody fusion is more effective for the coronal plane rather than the sagittal plane deformity, although sagittal correction can be obtained with attention to anterior cage placement accompanied by posterior column osteotomy. Anecdotally, indirect decompression may be more successful in patients who have relief of symptoms with sitting or lying down. Transient thigh numbness and weakness is observed, and further work needs to be done to compare the relative risks of neurologic symptoms in the different lumbar interbody strategies. As this technique continues to mature, evidence-based risk-stratification systems are required to better guide both the patient and clinician in the joint decision-making process for the optimal surgical approach.

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## Compliance with Ethical Standards

**Conflict of Interest** Dr. Hah has received personal fees as a consultant for NuVasive. Dr. Kang declares that he has no conflict of interest.

**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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