Review Article

Lateral interbody fusion for adjacent segment disease: a narrative review

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Background and Objective: Adjacent segment disease (ASD) is a late complication of lumbar fusion characterized by persistent symptoms correlating to radiographic changes in the levels immediately above or below the prior fusion. Lateral interbody fusion (LIF) through a direct lateral approach is a minimally invasive and effective surgical treatment for ASD. Biomechanically, LIF for ASD provides significantly decreased motion in multiple planes. While hardware failure and injury to the lumbar plexus are potential complications, these risks may be outweighed by decreased blood loss, shorter operating room (OR) times, and possibly superior patient reported visual analog scale (VAS) scores compared to traditional posterior spinal fusion (PSF) alone. The purpose of this review is to summarize the history, uses, outcomes, and future directions of LIF for ASD.

Methods: A review of national databases (PubMed and SCOPUS) was performed using literature from 1900 to 2022. Keywords included terms "LATERAL" and "LUMBAR" and "INTERBODY" and "FUSION" and "ADJACENT" and "SEGMENT" and "DISEASE". Studies that aimed to describe the biomechanical, clinical course and complications, radiological outcomes, biomechanical aspects, need for revision surgery, and/or patient reported outcomes of the XLIF/LIF technique were included.

Key Content and Findings: This review includes a brief overview of the natural history of ASD and current approaches to address it. It then summarizes the main indications and utilization of LIF to address ASD, summarizing reported outcomes in regard to biomechanical, clinical, and radiographic outcomes.

Conclusions: LIF has emerged as a minimally invasive and effective surgical treatment for ASD. This mini-review suggests that LIF provides a solid foundational biomechanical construct that has been paired with good patient-reported, clinical, and radiographic outcomes. While further research is required, current literature suggests that LIF for ASD results in fewer complications, decreased morbidity, and decreased need for subsequent surgery compared to other commonly utilized techniques.

Keywords: Lateral; interbody; fusion; adjacent; segment

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Introduction

Lumbar fusion is a common surgery utilized for lumbar degenerative diseases and typically decompression of the spinal canal or foramina followed by stabilization of spinal segments using bone graft (1). The annual number of lumbar fusions in the United States increased by 262% between 1998 and 2015, with the incidence of lumbar fusions for degenerative disc disease increasing by 126% between 2000 and 2009 (2). This increase in lumbar fusions was associated with an increase in medical cost from $3.7 billion in 2004 to $10.2 billion in 2015 (3), with up to 20% of these procedures requiring reoperation within 4 years of index surgery (4).

Adjacent segment disease (ASD) is a general term to describe changes that occur adjacent to a previously operated spinal level (5). Symptomatic ASD is a late complication of lumbar fusion that is characterized by radiographic findings and clinical symptoms (6). Of note, in order to distinguish clinically significant ASD from minor symptoms, ASD's definition suggests that patients present more than once with the new symptom and request subsequent treatment. ASD does not typically include axial pain, spasms, or numbness that may be sequelae of the index fusion. Importantly, it is separate from adjacent segment degeneration, which is asymptomatic radiographic deterioration of adjacent segments following lumbar fusion. To our knowledge, there is no generally accepted and validated instrument to diagnose or quantify ASD (7-11). It is likely that the pathophysiology of ASD is multifactorial (12), but lumbar fusion is thought to accelerate its progression.

Several etiologies of ASD have been proposed. One school of thought attributes ASD to increased biomechanical demands on motion segments adjacent to the fused area. The loss of mobile segments and increased force lever arm transmitted by the fused segments to adjacent (nonfused) segments leads to changes of intradisc pressure, resulting in hypermobility of the adjacent segment and subsequent facet joint degeneration (13). Other theories include the notion that some spinal procedures may cause spinal instability due to the removal of bone and ligamentous structures, therefore accelerating degeneration at other spinal segments (14). Moreover, some suggest that open surgical dissection may induce ASD due to increased trauma to paraspinous musculature and ligaments relative to less invasive percutaneous approaches (15-18). To date, it has not been definitively demonstrated that percutaneous approaches reduce the incidence of ASD compared to open approaches (19).

Several etiological risk factors for ASD have been proposed, ranging from genetic predisposition to demographic characteristics and prior surgical intervention. Several population studies have supported a biological etiology of ASD. In particular, twin studies comparing patients in different occupations suggested 26% to 72% of variability in incidence of lumbar degeneration to genetic influences as opposed to physical exposures (18). There are no currently accepted demographic risk factors for ASD. Smoking, older age, body mass index, preexisting lumbar degenerative facet or disc disease have all been shown to be risk factors for ASD in some investigations but not others (20).

Lateral lumbar interbody fusion (LIF) is a minimally invasive technique for interbody fusion. Also referred to as eXtreme lateral interbody fusion (XLIF, NuVasive, Inc., San Diego, CA, USA) or direct lateral interbody fusion (DLIF, Medtronic Sofamor Danek), LIF has seen an expanding range of indications and significantly increased utilization since the modern LIF technique was first described in 2006 (21-23).

LIF accesses the lumbar spine using a direct lateral approach. To provide exposure, psoas fibers are gently dissected and retractors are inserted to expose the disc space and allow implantation of cages. Ozgur *et al.* (2005) initially described the LIF technique using two incisions, but modified techniques using a single mini-open incision have been adopted (23,24). The spectrum of indications for LIF includes degenerative conditions such as spondylolisthesis (25), disc herniation (26), spinal stenosis (27), and scoliosis (28). It is associated with a low risk of vascular, visceral, and dural injuries (29). Due to the proximity of the lumbar plexus within or beneath the psoas muscle (30), the transpsoas approach has been associated with neurologically adverse complications (31-33). The risk of persistent motor deficits following LIF has shown to be increased with utilizing bone morphogenetic protein-2 as a bone graft substitute (32). LIF cages without posterior instrumentation have been reported to be acceptable treatment options for foraminal stenosis (27).

Recently, LIF has been suggested as an effective surgical treatment option for ASD (34). Addressing ASD via a minimally invasive lateral approach affords large graft placement spanning the dense apophyseal ring, disc height restoration, and indirect decompression of neural elements. Moreover, it maintains a safe and efficacious profile for both ASD and degenerative scoliosis (35) and avoids a

Table 1 The search strategy summary

Items	Specification
Date of search	September 1–September 30, 2023
Databases and other sources searched	PubMed, SCOPUS
Search terms used	Lateral lumbar interbody fusion; adjacent segment disease
Timeframe	1900–2022
Inclusion criteria	English language; PubMed-indexed journal
Selection process	Conducted by all authors independently; all sources reviewed and selected by senior author (S.M.E.)

technically demanding posterior revision approach (36,37). Risks of a revision posterior approach include devitalizing the paraspinous musculature, durotomies, and traction neuropraxia (38). We present this article in accordance with the Narrative Review reporting checklist (available at https://jss.amegroups.com/article/view/10.21037/jss-23-16/rc).

Methods

A review of national databases (PubMed and SCOPUS) was performed using literature from 1900 to 2022. Keywords included terms "LATERAL" and "LUMBAR" and "INTERBODY" and "FUSION" and "ADJACENT" and "SEGMENT" and "DISEASE". Studies that aimed to describe the biomechanical, clinical course and complications, radiological outcomes, biomechanical aspects, need for revision surgery, and/or patient reported outcomes of the XLIF/LIF technique were included. Studies unavailable in English were excluded (*Table 1*).

Results

Biomechanical studies

Multiple biomechanical studies have demonstrated sufficient reconstruction and stability of LIF for ASD. Chioffe *et al.* found significantly decreased L3–L4 motion in all planes and without loading compared to an intact spine (39). In cases of prior L4–S1 posterior spinal fusion (PSF) constructs, L3–L4 LIF decreased motion by 61.2% (39). This study also demonstrated that LIF without instrumentation above previous posterolateral fusion decreases adjacent segment motion. Metzger *et al.* demonstrated LIF supplemented with additional MIS instrumentation could give comparable stability with more traditional revision approaches for ASD (40). The authors found that adding a lateral interbody device to a two-level fusion reduced motion in flexion, extension, and lateral bending significantly. Lateral bending and torsion could be reduced with addition of a lateral plate through LIF approach. A spinous process plate could reduce range of motion (ROM) in the sagittal plane. In the LIF construct, posterior cortical screws and posterior cortical screws provided the most stable construct; this had comparable ROM with a three level TLIF. Shasti *et al.* compared ROM in specimens receiving prior PSF with ASD; they compared stability of LIF alone, LIF and plate fixation, or LIF and anterior screw rod fixation and calculated range of motion as a percentage of intact spine (41). LIF instrumentation alone reduced ROM in all planes when implanted proximal to an existing fusion model, while PSF had the greatest reduction in ROM in all planes, no matter the order of instrumentation ($P<0.05$). This study also demonstrated that supplementation of LIF with single screw rod instrumentation provided greater stability than LIF alone, suggesting that expansion of posterior instrumentation provides the most biomechanically stable construct.

Intra- peri-, and post-operative findings and complications

In a retrospective case series in which patients who had undergone LIF without supplemental pedicle screws at two different institutions, Wang *et al.* reported a range of operative time from 45 to 155 minutes, averaging 86 minutes (35). They reported an average of 93.1 cc blood loss. The average hospital stay was 2.4 days and all patients were discharged home. This suggested that LIF reduces blood loss and post-operative complications secondary to not re-exploring a previous laminectomy. Palejwala *et al.* reported one pulmonary embolism in post-operative courses in a three-patient case series (42). They also reported posterior incision drainage which required

irrigation and debridement for wound dehiscence on postoperative day 13. Aichmair *et al.* reported a significantly shorter duration of surgery in standalone LIF averaging 119.2 minutes compared to 236.1 minutes in patients undergoing circumferential fusion (P<0.001) (34). Malham *et al.*'s study of 33 patients receiving an expandable lateral titanium interbody cage with an integrated lateral fixation (eLIFp) device reported an estimated blood loss of 50 mL for all patients with a mean total psoas retraction time of 30.5 minutes (43). Pressman *et al.* had a rate of hardware failure (screw breakage or rod fracture) of 2.6% on post-operative imaging, finding that long posterior constructs, additional interbody devices, and patients with increased levels of lateral fusion had the greatest risk of hardware failure (44). Yasmeh *et al.* reported multiple complications in their retrospective cohort study of patients undergoing LIF in surgical treatment of ASD and stenosis refractory to nonoperative management including proximal junctional failure via vertebral body fracture of L2, incisional hernia at side of lateral surgery, dural tear at site of revision laminectomy (45). They also had two patients who underwent instrumentation removal at the proximal aspect of their fusion construct, and two patients developed proximal ASD. However, the authors did not encounter pseudarthrosis, wound issues, or infections in 36 patients and 46 motion segments. Overall, currently literature suggests that LIF for ASD can provide adequate without adding undue patient morbidity.

Patient reported outcomes

Multiple studies have shown that LIF for ASD is associated with excellent patient-reported outcomes. In a retrospective two center study, Aichmair *et al.* assessed the outcomes of single level LIF for ASD (34). Visual analog scale (VAS) score for back pain improved from 7.8 preoperatively to 2.3 immediately post-op and 3.8 at last follow-up in patients who did not undergo re-operation; VAS scores were 8.2, 2.7, and 5.1 in patients who did undergo reoperation. VAS leg pain scores were 7.0, 2.1, and 2.8 in patients who did not under-go reoperation, and 8.5, 2.7, and 5.0 for patients who underwent re-operation at pre-op, immediate post-op and last follow-up visits, respectively. VAS scores decreased above the acceptable threshold described by Solberg *et al.* (46). Aichmair *et al.*'s findings suggest that LIF for ASD decreases patient pain and increases their independent function after surgery.

In a prospective, observational study of symptomatic ASD patients receiving a standalone treatment of an expandable lateral titanium interbody cage with an integrated lateral fixation (eLIFp) device, a significant reduction in VAS scores for leg and back pain (P<0.001) was reported (43). Mean back and leg pain scored improved from 7.8 to 0.6 and 6.9 to 0.6, respectively. Quality of life scores also increased from pre-op to one-year follow-up, with the physical component score and mental component score improving by 69% and 42%, respectively. Similarly, in a retrospective case series of 25 patients undergoing stand-alone LIF for symptomatic ASD, Louie *et al.* reported a significant improvement in Oswestry Disability Index (ODI) scores from preoperative values 46.6 to final follow-up 30.4 (P=0.002) (47). VAS score for back pain improved from 8.4 to 3.2 while the VAS score for leg pain improved from 3.6 to 1.9 (P<0.001) postoperatively. In a study of patients receiving stand-alone LIF to treat ASD using three-dimensional-printed porous titanium, no patients underwent revision, and back pain numeric rating score was significantly better than those receiving polyetheretherketone cages (P=0.001) (48). Yasmeh *et al.* reported 83.5% of patients had complete resolution of pre-op lower extremity and back pain at final follow-up (P<0.001) (45). Back pain was resolved at a median time of 6 weeks, and median time to resolution of radicular pain was 6 weeks. About 16.7% had persistent pain, albeit less than pre-operatively. ODI score improved at final follow-up from 49.8 pre-operatively to 34.7 post-operatively (P=0.001.) VR12 physical component was significantly improved at final follow-up with an average change of 6.6 (P=0.012). Wang *et al.* reported leg pain Net Promoter Score (NPS) improved from mean 6.3 to 1.9 (P<0.01) after MIS lateral interbody fusion; back pain NPS improved from 7.5 to 2.9 (P<0.01) (35). In their three patient case series, Palejwala *et al.* reported that anterior thigh numbness improved in all patients throughout their post-op course (42).

Clinical outcomes

In Aichmair *et al.*'s study, pre-op, immediate post-op, and last visit post-op sensory deficits were present in 22.6%, 22.6%, and 16.1% of patients who did not undergo revision surgery and 42.9%, 28.6%, and 23.8% of patients who underwent revision surgery, respectively. Pre- immediate post- and last post-op motor deficits were present in 19.4%, 25.8%, and 6.5% of patients who did not undergo revision surgery and 23.8%, 14.3%, and 14.3% in patients who underwent revision surgery, demonstrating successful

Table 2 Radiographic outcomes

Outcome	Result	Author
Intervertebral settling on CT at last follow-up	1.7 mm	Wang *et al.* (35)
Pre-operative intervertebral height	10.4 mm	Wang *et al.* (35)
At last follow-up	8.7 mm	Wang *et al.* (35)
L1–S1 lordosis pre-op	44°	Wang *et al.* (35)
L1–S1 lordosis last visit	42°	Wang *et al.* (35)
Disc height restoration	5.5 mm	Aichmair *et al.* (34)
Change in lumbar lordosis	2.0°	Aichmair *et al.* (34)
Change in segmental lordosis	–0.3°	Aichmair *et al.* (34)
Subsidence	1.7 mm	Aichmair *et al.* (34)
Fusion rate per CT (circumferential fusion + LIF)	87.5%	Aichmair *et al.* (34)
Fusion rate per CT (standalone LIF)	53.8%	Aichmair *et al.* (34)
Interbody fusion rate at 12 month per CT	94%	Malham *et al.* (43)

CT, computed tomography; LIF, lateral interbody fusion.

clinical outcomes for patients status post LIF for ASD (34).

Among patients receiving eLIFp cages, Malham *et al.* reported two neurologic complications; one patient reported anterior thigh numbness for two weeks and another patient had new-onset L4 radiculopathy and motor deficits following L3-L4 eLIFp (43). Indirect neural decompression with eLIFp was successful with no patients requiring subsequent posterior direct decompression for either central or foraminal stenosis.

Radiographic outcomes

A summary of pertinent reported radiographic outcomes is summarized in *Table 2*. Wang *et al.* found bridging bone in all patients on CT at the time of their last follow-up appointment; intervertebral settling averaged 1.7 mm. Pre-operative intervertebral height was 10.4±1.4 and was 8.7±1.6 mm at last follow-up. L1-S1 lordosis improved from 44°±21° to 42°±19° at last follow-up. Regional lumbar lordosis at operative level increased from 9.8°±3.2° to 11.9°±2.2° at follow-up. They concluded that additional posterior instrumentation is not required for all cases of ASD, especially fusion occurring L3–S1 level. This may reduce neurological complications and preserve rostral facet joint capsules, thereby preventing additional degeneration of supra-adjacent levels (35). Aichmair *et al.* demonstrated that patients who underwent LIF for ASD had increased lordosis and vertebral height as compared to preoperative imaging reported 5.5 mm disc height restoration, –2.0° change in lumbar lordosis, –4.5° in segmental lordosis change, and 1.7 mm of subsidence in patients who did not undergo reoperation after initial LIF for ASD (34). At 12 months post-op, CT scans demonstrated fusion rates of 87.5% in patients who underwent circumferential fusion *vs.* 53.8% inpatients who underwent standalone LIF. This study suggested that while standalone LIF decreased adverse events associated with larger surgery, additional posterior instrumentation increases fusion rates.

Malham *et al.* reported a solid interbody fusion rate of 94% at 12 months postoperatively on CT scans. There was no significant difference in eLIFp interbody fusion rates between 1- and 4-level prior posterior segmental fusions, although 2 nonunions in the study were found at the L4–L5 level (43). Louie and colleagues reported significant improvement in segmental and regional lordosis and intervertebral disc height (P<0.001) postoperatively. Additionally, pelvic incidence-lumbar lordosis mismatch improved at the first postoperative visit (P=0.029) and was maintained at the most recent follow-up (P=0.45). Adl Amini's study demonstrated that patients receiving titanium cages had significant disc height (P<0.001) and foraminal height restoration (P=0.011) as well as significantly less subsidence rate (20% *vs.* 58.8%, P=0.004) whereas only disc height restoration was significant among those receiving the polyetheretherketone cage (P=0.003) (48).

Need for revision surgery

Revision posterior decompression and fusion surgery is technically challenging due to the generation of scar tissue from prior surgery and hardware and is associated with increased rates of surgical site infections and dural injury. Nayar *et al.* conducted a retrospective review of patients who underwent stand-alone LIF by a single surgeon for degenerative spine disorders and demonstrated 3.3% operative rate of ASD over four years with an annual incidence of 0.88% on Kaplan-Meier survival analysis [95% confidence interval (CI): 0.67–1.09%]. Nayar and colleagues found that patients with operative ASD had significantly higher BMIs and poorer pre-operative ODI score (P<0.01) (49). Reoperation rate has been shown to be higher in patients who underwent standalone LIF; according to Aichmair *et al.*, the reoperation rate was 72.7% among those who initially underwent standalone LIF compared to 56.1% of patients who underwent circumferential fusion. They suggested that factors contributing to the higher reoperation rate include insufficiency of the LIF approach to stop ASD progression, pseudoarthrosis, biomechanical stress, and changes in the lumbar anatomy (34). In contrast, Louie *et al.* found that only 12% of patients receiving standalone LIF for symptomatic ASD required a revision surgery that involved posterior decompression and fixation, suggesting that LIF alone may be sufficient in select patients (47).

Oblique lateral interbody fusion (OLIF) for ASD

It should be noted that OLIF has also been investigated in the context of ASD, but further studies are warranted. Jin *et al.* (50) performed a case-control study evaluating 26 patients with symptomatic ASD after lumbar fusion. Twelve patients underwent single-segment OLIF with or without posterior instrumentation and 14 patients underwent posterior reoperation. Total operative time, resultant blood loss, and hospital stay in the OLIF group were significantly lower compared to the posterior group. In the posterior approach group, 6 of 14 patients (42.8%) had a dural tear, while none in the OLIF group had this complication (P<0.05). The ODI score (13.2±4.2 *vs.* 19.2±7.2, respectively; P=0.014) and the VAS back pain score were lower in the OLIF group postoperatively and at last follow-up. The authors therefore concluded that OLIF is a safe and effective treatment option for patients with ASD. However, further research and high-quality studies on utilizing OLIF for ASD is indicated.

Technique

Axial slices should be visualized on preoperative magnetic resonance imaging (MRI) to examine psoas anatomy and potential vascular anomalies. A flat table capable of flexion/extension, rotation, and Trendelenburg should be used and placed in reverse. Following induction of general anesthesia, the patient is placed in the lateral decubitus position and secured with tape and/or straps. A right lateral decubitus position with the left side up is more common to reduce the risk of injury to the inferior vena cava, but a left lateral decubitus position may be used when advantageous for access. In general, it is more manageable to approach where the convexity opens at the disc space. The iliac crest should be just proximal to the break in the bed with slight flexion of the hip to decrease psoas tension. This configuration ensures that the pelvis tilts away from the spine allowing access to most of the lumbar spine. The arms are strapped and protected away from the field to allow room for fluoroscopy.

A direct lateral incision is planned with the aid of fluoroscopy and a posterolateral incision marked perpendicular to the erector spinae musculature. Prior to sterile preparation and draping, true lateral and AP fluoroscopic images are obtained via table adjustments. A 5–6 cm posterolateral skin incision is made and subcutaneous tissue is then bluntly dissected until lumbodorsal fascia is encountered. A tonsil aimed toward the transverse process is used to poke through the fascia and is carefully spread. The transverse process is felt after bluntly dissecting through retroperitoneal fat and psoas muscle to create direct passage into the retroperitoneal space.

The second direct lateral 5–6 cm incision is made followed by blunt dissection through oblique abdominal muscles and transversalis fascia prior to reaching retroperitoneum. The initial dilator is then introduced and placement is confirmed on imaging. The majority of systems use a neuromonitoring device to stimulate and assess the distance to lumbar plexus nerves. A probe is inserted into the appropriate disc and soft-tissue dilators are placed sequentially over a guidewire to expand access through the psoas. A self-retaining retractor is then placed and neuromonitoring is utilized to ensure appropriate distance from the lumbar plexus. The retractor is then opened and a lateral box annulotomy is performed for subtotal discectomy. The contralateral annulus should also be carefully released, which is necessary to distract the disc space, achieve desired coronal alignment, and to

place a large interbody that spans the ring apophysis. The disc space is then thoroughly debrided under fluoroscopic guidance.

A trial interbody is placed into the disc space to determine final implant size. Oversizing the final implant increases the risk of cage subsidence, pseudoarthrosis, and sagittal imbalance (48). The final interbody implant containing graft material is then advanced across the disc space using fluoroscopic guidance.

Conclusions

LIF has emerged as a minimally invasive and effective surgical treatment for ASD. This mini-review suggests that LIF provides a solid foundational biomechanical construct that has been paired with good patient-reported, clinical, and radiographic outcomes. While further research is required, current literature suggests that LIF for ASD results in fewer complications, decreased morbidity, and decreased need for subsequent surgery compared to other commonly utilized techniques.

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Footnote

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Reporting Checklist: The authors have completed the Narrative Review reporting checklist. Available at https://jss.amegroups.com/article/view/10.21037/jss-23-16/rc

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