Review Article

Comparison of ALIF *vs*. XLIF for L4/5 interbody fusion: pros, cons, and literature review

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The incidence of lumbar fusion for the treatment of various degenerative lumbar spine diseases has increased dramatically over the last twenty years. Many lumbar fusion techniques have been developed and popularized, each with its own advantages and disadvantages. Anterior lumbar interbody fusion (ALIF) initially introduced in the 1930's, has become a common and widely accepted technique for lumbar fusions over the last decade offering several advantages over standard posterior lumbar interbody fusion (PLIF) or transforaminal lumbar interbody fusion (TLIF). More recently, the lateral trans-psoas approach termed extreme, direct or lateral lumbar interbody fusion (XLIF, DLIF, LLIF) is gaining widespread popularity. The aim of this paper is to compare the approaches, advantages and disadvantages of ALIF and XLIF for L4/5 interbody fusion based on relevant literature.

Keywords: Lateral lumbar interbody fusion (LLIF); extreme lateral interbody fusion (XLIF); anterior lumbar interbody fusion (ALIF); spine

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Introduction

The incidence of lumbar fusion for the treatment of various degenerative lumbar spine diseases has increased dramatically over the last 20 years (1). Many lumbar fusion techniques have been developed and popularized, each with its own advantages and disadvantages. Anterior lumbar interbody fusion (ALIF), initially introduced in the 1930s, has become a common and widely accepted technique for lumbar fusions over the last decade offering, several advantages over standard posterior lumbar interbody fusion (PLIF) or transforaminal lumbar interbody fusion (TLIF) (1). More recently, the lateral trans-psoas approach, termed Extreme, Direct or Lateral lumbar interbody fusion (XLIF Nuvasive®, DLIF, Medtronic®, LLIF), is gaining widespread popularity. Initially developed in the late 1990s by Luiz Pimenta, it was first published in the literature in 2006 by Ozgur *et al*. (2), and since then has maintained exponential acceptance as a minimally invasive option for thoracolumbar fusions.

ALIF and XLIF may offer advantages over traditional posterior approaches. Both techniques provide means for a more extensive discectomy and enable a larger surface area for intervertebral graft positioning. This not only promotes a healthy fusion environment but also allows re-expansion of disc space and segmental lordosis, without compromising posterior tension bands or causing posterior muscular injury (3). The undeniable importance of sagittal balance and its restoration in spine disease, resonates with ALIF and XLIF as both of these techniques are considered superior for restoration of normal spinal sagittal balance by achieving greater segmental lordosis (3-5), as well as allowing some degree of coronal correction where necessary. Both approaches are generally considered minimally invasive accompanied by smaller incisions, reduced hospital stays, operative times, blood loss, postoperative pain, fewer complications and faster recovery times (4).

Fusion can be achieved in the majority of cases at L4/5 utilizing either technique of ALIF or XLIF (5,6). The aim

of this paper is to compare the approaches, advantages and disadvantages of ALIF and XLIF for L4/5 interbody fusion based on relevant literature.

Approach, indications and relative contraindications

Generally, the indications for ALIF and XLIF are similar. Broad indications include low back pain and/or radiculopathy attributed to symptomatic lumbar degenerative disc disease, degenerative or isthmic spondylolisthesis, foraminal stenosis, deformity, reconstruction of the anterior column, iatrogenic segmental instability, lateral listhesis, pseudoarthrosis and sagittal malalignment (3,7). Other indications include revision of failed posterior procedures, additional support for long fusion and spinal infection. The general contraindications for either procedure include pathologies that require posterior decompression, such as severe canal stenosis that cannot be addressed via an anterior or lateral approach, calcified vasculature limiting mobility, severe anterior/anterolateral infection, abnormal plexus and vascular anomalies (6,7).

The advantages of ALIF over traditional posterior approaches have been well described in literature (4,6,8,9). In most cases, ALIF is a somewhat easier approach for L5–S1, below the bifurcation of the great vessels. At L4-5, where the iliac vessels bifurcate, the risk of vascular injury is higher. The incidence of vascular injury during ALIF procedure has been reported as high as 18%, though most authors have found the rate to be much less, between 2.2% and 6.7%. Additional risk considerations for ALIF include the potential for visceral injury (5%), retrograde ejaculation and sympathetic dysfunction (3%) (10), and difficulty with revision due to the potential for scar tissue formation on the interface between the aorta and common iliac vein on the anterior border of the spine (8).

The XLIF approach was developed as a less-invasive alternative to conventional ALIF as it avoids retraction of great vessels and sympathetic chain (11,12). Relative contraindications to the approach may include instances where L5–S1 is to be incorporated in the fusion, where the approach is limited by the iliac crest position (high riding crest), or where lumbarized sacral segments are related to anteriorly positioned plexus (bunny ear sign seen on MRI) (7,12,13). Other relative contraindications include patients with bilateral retroperitoneal scarring (e.g., prior kidney surgery), patients with anomalous vascular anatomy interfering with the lateral approach (as may occur in rotational deformities), and degenerative spondylolisthesis ≥ grade II, where exiting nerve roots are more anterior and limit access. The vascular and plexal anatomy may also present relative contraindications which often can be identified preoperatively through careful review of axial magnetic resonance imaging (MRI), noting the location of these structures relative to the lateral approach (12).

ALIF and XLIF require different operating room set ups and patient positioning. ALIF is generally a simple supine position with hips and knees partially flexed with the surgeon approaching either through the side or lithotomy position (4), whereas XLIF demands a true lateral decubitus position. This initial positioning for XLIF is one of the most important aspects of successful surgery. It needs to be ensured during positioning for XLIF that the surgical working plane is perpendicular to the sagittal plane of the disc space and requires a clear fluoroscopic shot in both the AP and lateral planes as parallax error may lead to oblique placement of cages (11). The lateral position simultaneously allows the abdominal contents to fall forward more easily during peritoneal release from the retroperitoneal space and thus lowers the risk of injury to the peritoneum and its contents (2). Therefore, patient positioning for XLIF is more time-consuming compared to ALIF. The difference in positioning can play a role in patient selection for L4/5 fusion specifically when dealing with obese patient. Obesity can be a relative contraindication to an anterior approach, whereas for the XLIF approach, the abdominal obesity actually pulls the peritoneal contents anteriorly making a retroperitoneal approach relatively straightforward.

Neuromonitoring for electromyography (EMG) assessment is recommended in XLIF approaches as the lumbar plexus is being approximated when approaching the L4/5 disc space in a trans-psoas fashion (11). Neuromonitoring is unnecessary in the ALIF approach as the lumbar plexus is not encountered in the anterior midline approach. As such, availability of neuromonitoring and potential costs may be a determining factor of approach.

Biomechanical stability is an important factor when considering construct options. Oxland *et al*. (14) in their literature review showed that supplemental pedicle screw fixation to ALIF cage substantially improved stabilization in all directions (flexion, extension, lateral bending and rotation). Similarly, Gerber *et al*. (15) showed that although range of motion was decreased with an ALIF cage alone, supplemental fixation either from anterior plate/screws or pedicle screws was required for superior biomechanical stability. More recently, the new stand-alone cages (with screws) have been shown to have improved stability in all planes comparable to

that of an anterior cage and pedicle screw fixation (16).

Laws *et al*. (17) demonstrated that XLIF cage alone was superior in reducing the range of motion compared to an ALIF cage. Cappuccino *et al*. (18) subsequently showed that when an XLIF cage is supplemented with bilateral percutaneous pedicle screws it offered the greatest reduction in the range of motion and provided more stability than a stand-alone ALIF construct with screw fixation. Due to the small risk of subsidence and the requirement for superior segmental stability, it is recommended that XLIF be supplemented with posterior percutaneous pedicle screw fixation either unilaterally or bilaterally (11). Unilateral screw placement can be achieved with the patient remaining in a lateral position, whereas bilateral percutaneous screw placement is usually performed with the patient prone, requiring a positional change and minor increase in operative time.

Endplate preparation

It has been well documented that the cross-sectional endplate area available for the placement of an interbody graft is an important factor for successful interbody fusion (19). In addition to the increased surface area for the biological fusion process to occur, a greater discectomy and endplate preparation area allows for larger intervertebral spacers, which helps in disc height restoration, the potential for larger lordotic correction and reduces the risk of cage subsidence (19). The results of a cadaveric study by Tatsumi *et al*. (20) demonstrated that a higher percentage of disc space preparation was achieved with XLIF compared to ALIF at the level of L2/3 and L3/4. However, at the level of L4/5 there was no difference in endplate preparation with either technique (20). Overall, discectomy and endplate preparation can be achieved adequately by both techniques and are considered superior to posterior approaches.

Foraminal height

Both ALIF and XLIF are considered superior techniques for restoring and/or increasing foraminal height as compared to traditional posterior approaches as posterior compression is applied in traditional TLIF/PLIF approaches (21). Hsieh *et al*. (21) compared foraminal height for ALIF *vs*. TLIF and showed that foraminal height increased by 2.7 mm in the ALIF group; however, it decreased by 0.5 mm in the TLIF group. Alimi *et al*. demonstrated in their series of 145 XLIF operations that foraminal height increased on average by 2.5 mm (22). The data seems to suggest that XLIF and ALIF are comparable in terms of increasing/restoring foraminal height.

Segmental lordosis

The concept and benefits of sagittal balance restoration has been unequivocally confirmed through the intensive work of international researchers (23,24). Careful assessment prior to surgical intervention enables a surgical plan to be implemented aiming to restore segmental and global lordosis. ALIF is considered superior to achieving greater magnitudes of segmental lordosis compared to any other fusion approach due to the fact that the anterior longitudinal ligament (ALL) is resected, offering greater segmental mobility (25). Watkins *et al*. (25) in their series determined comparative lordotic correction between ALIF and XLIF as 4.5 and 2.2 degrees respectively. Hsieh *et al*. (21) reported lordotic improvements of 8.3 degrees in their series of ALIF, whilst Sharma *et al*. (26) and Acosta *et al*. (27) have also reported similar lordotic improvement of 2.8 and 2.9 degrees respectively for XLIF. Caputo *et al*. (28) analyzed lordotic improvement at multiple levels from L1 to L5 for XLIF and found the only significant improvement of lordosis was at L4/5 of 2.4 degrees. Malham *et al*. (29) in their direct comparison of ALIF and XLIF reported lordosis of 4.7 degrees *vs*. 2.1 degrees respectively.

Uribe *et al*. (30), in their 3D model of the spine, resected ALL via a lateral approach and using hyperlordosis cages of 20 and 30 degrees, demonstrated improvement of lordosis of almost 7 and 11 degrees respectively. Deukmedjian *et al*. (31) in their series of 7 patients showed an increase in segmental lordosis of 17 degrees with ALL released and the use of hyperlordosis cages via XLIF approach. Similarly, Akbarina *et al*. (32) reported lordotic improvement up to 23 degrees in their series of 17 patients. However, it must be recognized that several patients underwent simultaneous pedicle subtraction osteotomy in conjunction with hyperlordosis cages and ALL release, confounding data extrapolation.

Based on current data, ALIF appears superior in achieving segmental lordosis at L4/5. It must be noted that there is evolving data pertaining to hyperlordosis XLIF grafts which incorporate resection of ALL and that this may show equivocal segmental lordotic correction compared to ALIF.

Fusion rates

Fusion rates well over 90% are reported for both ALIF and XLIF (33-36). A recent series of 125 patients from

Rao *et al*. (10) demonstrated an overall fusion rate of 98% for ALIF using a variety of bone graft substitutes (iFactor-Cerapedics, Westminster, Colorado, Infuse-Medtronic, Memphis, Tennessee, autologous iliac crest bone and allograft). Similarly, Berjano *et al*. (37) also reported a fusion rate of 98% for XLIF in their series of 77 patients using a combination of autologous bone, calcium triphosphate and Attrax (Nuvasive). Rodgers *et al*. (38) reported XLIF a fusion rate of 93.2% with a mean follow-up of 17.3 months utilizing autograft and demineralized bone matrix with bone marrow aspirated from the iliac crest. Malham *et al*. (29) reported a fusion rate of 94.6% for the ALIF and 85.3% for XLIF at 12-months follow-up. Overall, fusion rates for both procedures are high with no significant differences identified.

Complications

General complication rates appear similar between ALIF (26.6%) and XLIF (25%) approaches (39). However, approach-related complication profiles differ slightly depending on the technique utilized. Complications of ALIF include risk of vascular injury, visceral injury, sympathetic dysfunction including retrograde ejaculation (40,41), whereas, XLIF has approach-related groin and anterior thigh pain, numbness/paresthesia in the thigh, hip flexor weakness and a risk of nerve root injury from lumbar plexus. Both techniques have been associated with incisional hernia (39). Mortality associated with both procedures approaches is rare and has been reported to be 0% in most recent literature, however articles from the 1990s and early 2000s reported mortality rates from 0.3% to 2.5% for ALIF (40,41).

The reported incidence of venous injury during ALIF ranges from 0% to 18% (3). Venous laceration is the most common type of vascular injury due to vessel retraction. The most frequently injured vessels are the left common iliac vein, inferior vena cava, and the iliolumbar vein (3). Occasionally, a deep vein thrombosis develops at the site of venous laceration (42). Most venous injuries in ALIF occur at the level of L4-5 (3). Baker *et al*. (42) reported a 15% incidence of vascular complications following ALIF in 85 patients. Similarly, injury to the common iliac vein or inferior vena cava was reported by Westfall *et al*. (43) to occur in 15.6% of cases. The identification and ligation of the iliolumbar vein in the early phase of the exposure has been recommended to prevent inadvertent avulsion of the vein (44). The incidence of arterial injury is rare, ranging from 0% to 5.2% and most commonly involves the left common iliac artery (44). Brau *et al*. (3) cautioned that thrombosis with occlusion of the common iliac artery after ALIF can be a rare complication and has been noted in 0.45% of cases.

Lymphocele is a rare complication. Lymph vessels are located lateral to the left common iliac artery and can be injured during dissection of the left ascending lumbar vein while exposing the L4-5 or L3-4 disc space (45).

The reported incidence of sympathetic dysfunction following ALIF is 9% to 43% (41). The risk of injury to the superior hypogastric plexus, which in men results in retrograde ejaculation, is reported to be less than 3% (10,46). Retrograde ejaculation is less frequently observed with L4/5 approaches than L5/S1 and also, the incidence is significantly reduced with a retroperitoneal approach compared to a transperitoneal approach (47,48). In contrast to the ALIF studies, retrograde ejaculation in men has not been yet reported for XLIF (31). Nerve root injury or ureteral injury is extremely uncommon for either the XLIF or ALIF procedure (3).

The XLIF technique gains access to the lumbar spine via a lateral approach that passes through the retroperitoneal fat and psoas major. In this way, the potential complications with an anterior approach to the lumbar spine (for ALIF) can be avoided. The great vessels, peritoneal contents and sympathetic chain are not usually encountered. Rodgers *et al*. (49) reported in their series of six hundred XLIF patients no vascular or intraoperative visceral injuries.

However, XLIF may be complicated by postoperative groin and thigh pain, with an incidence ranging from 10% to 30% (6,7,11,39). This is posited to be a result of upper lumbar plexopathy secondary to stretch injury through retraction or sensory nerve injury on approach (50). Groin and thigh hyperesthesia is likely the result of injury to the iliohypogastric or ilioinguinal nerve during preparation through the abdominal wall with hyperesthesia usually spontaneously resolving (51). Dakwar *et al*. (52) and Oliveira *et al*. (53) reported transient postoperative anterior thigh numbness, ipsilateral to the side of approach in 12% and 14.3% of cases respectively. Short-term thigh dysthanasia and hip flexor weakness are well documented due to direct trauma to the psoas muscle yet quickly resolve in most cases (50). Longer psoas retraction time has been associated with lumbar plexopathy thought to be due to nerve compression and/or stretch (41). Bendersky *et al*. (50) showed in their retrospective review that patients who had a retraction time of less than 20 minutes did not have lumbar plexopathy and it is widely recommended that retraction times be kept to a minimum, aiming to be less than 20–30 minutes

per operative level.

Motor deficits are the area of greatest concern to spinal surgeons and have been discussed frequently in relation to the lateral approach to the spine. Post-operative motor deficits have been reported with XLIF (41). There is a theoretical increased risk of developing motor complication at the L4/5 level as the neurovascular structures are located more anteriorly and in the "operative zone" in 44% of the cases (51). Advanced intraoperative neuromonitoring techniques with dynamic multidirectional stimulation and free-run EMG is considered essential by most surgeons in order to minimize motor deficit. Knight *et al*. (54) reported 2 cases (3.4%) of permanent motor deficits thought to be due to injury to the L4 root. The largest series in literature by Rodgers *et al*. found motor deficits in 4 out of 600 patients (0.7%) (49). Overall, the data supports a very low risk of motor deficit for XLIF performed at L4/5.

XLIF and ALIF offer safe options for attaining fusions at L4/5. They allow for excellent biomechanical stability, especially when combined with percutaneous posterior pedicle fixation, although the latter may not be needed when using stand-alone ALIF cages (screws incorporated). The main advantages of XLIF over ALIF appear to be reduced probability of vascular complications, post-sympathectomy syndrome and retrograde ejaculation. Whereas ALIF offers reduced risk of plexopathy, both motor and sensory, by avoiding the psoas, intraoperative monitoring (IOM) is not required and retraction time becomes less important.

Conclusions

ALIF and XLIF both offer safe, reliable and reproducible results for L4/5 fusions, each with a slightly different risk profile. The choice of approach remains factor-dependent: surgeon experience, patient morphology, vascular and neural anatomy, pre-existing scar tissue, surgical levels and goals. ALIF appears to offer greater ability for segmental lordotic correction, yet hyperlordotic XLIF cages with ALL resection may prove to offer equivocal results. XLIF offers lower risks of vascular and hypogastric plexus injury, yet a higher incidence of transient plexopathy. As a result, each case of L4-5 fusion needs to be carefully assessed and the approach independently tailored to suit the patient and surgical goals, aiming to minimize the specific risks.

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Footnote

Conflicts of Interest: Dr. Winder is a consultant and teaching proctor for Nuvasive Pty Ltd. Dr. Gambhir has no conflicts of interest to declare.

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