Lateral lumbar interbody fusion. Surgical technique and current concepts

Matías Pereira Duarte,* Matías G. Petracchi,* Maximiliano E. Mereles,*
Marcelo Gruenberg,* Carlos A. Solá,* Federico P. Girardi**

*Spine Section, Orthopedics Department "Prof. Dr. Carlos E. Ottolenghi",
Hospital Italiano of Buenos Aires, Ciudad Autónoma de Buenos Aires, Argentina
**HHS Spine Service, Orthopedics Surgery, Hospital for Special Surgery, New York, US.

Received on July 26th, 2017; accepted after evaluation on July 13th, 2018 • MATÍAS PEREIRA DUARTE, MD • matias.pereira@hospitalitaliano.org.ar

How to cite this article: Pereira Duarte M, Petracchi MG, Mereles ME, Gruenberg M, Solá CA, Girardi FP. Lateral lumbar interbody fusion. Surgical technique and current concepts. Rev Asoc Argent Ortop Traumatol 2018;83(4):303-316. doi: 10.15417/issn.1852-7434.2018.83.4.754

Abstract
The minimally-invasive lateral approach of the lumbar spine for interbody fusion is a relatively new technique and has got promising results in patients with different lumbar spine conditions. It is a safe technique that provides the spine with appropriate structural support between vertebral endplates, it can correct deformities on coronal and sagittal planes and conduct indirect decompression of the spinal canal with preservation of the posterior elements. Over the past few years the evidence that backs this technique has been increasing and diversifying, there are reports on new indications and mid- and long-term results.
The aim of this work is to describe the surgical procedure step by step with its variant procedures as we conduct it at the Centers we work at, and to point out related current concepts based on a bibliographic revision.

Key words: Interbody fusion; anterior approach; lateral lumbar interbody fusion; lateral extreme interbody fusion; spine lateral approach; current concepts.
Level of efidence: IV

Artrodesis intersomática lateral de columna lumbar. Técnica quirúrgica y conceptos actuales

Resumen
El abordaje lateral mínimamente invasivo de columna lumbar para la artrodesis intersomática es una técnica relativamente nueva y ha conseguido resultados prometedores en los pacientes con diferentes patologías de la columna lumbar. Es una técnica segura que proporciona un adecuado soporte estructural entre los platillos vertebrales, puede corregir la deformidad en los planos coronal y sagital, y ejercer una descompresión indirecta del canal raquídeo respetando los elementos posteriores. La evidencia sobre esta técnica ha ido creciendo y diversificándose en los últimos años, se han comunicado nuevas indicaciones, y resultados a mediano y largo plazo.
El propósito de este trabajo es detallar el procedimiento quirúrgico paso a paso, con sus variantes tal como lo realizamos en nuestros Centros, y puntualizar los conceptos actuales basados en una revisión bibliográfica.

Palabras clave: Artrodesis intersomática; vía anterior; fusión intersomática lumbar lateral; fusión intersomática extremo lateral; abordaje lateral de columna; conceptos actuales.
Nivel de Evidencia: IV

Conflict of interests: The authors have reported none.

http://dx.doi.org/10.15417/issn.1852-7434.2018.83.4.754

Introduction

Lumbar interbody fusion can be carried out through a direct posterior approach (posterior lumbar interbody fusion [PLIF] or transforaminal lumbar intebody fusion [TLIF]) and through an anterior approach (anterior lumbar interbody fusion [ALIF], lateral lumbar interbody fusion [LLIF] or oblique lumbar interbody fusion [OLIF]).

The minimally-invasive lateral approach of the lumbar spine for interbody fusion, in English literature usually called LLIF or XLIF (extreme lateral interbody fusion), has got promising results in patients with degenerative conditions in their lumbar spine.[1,2] This is a relatively new technique that allows the surgeon to carry out an approach directly aimed at the interbody space through the retroperitoneum, going through the psoas muscle between the anterior and posterior longitudinal ligaments and thus managing to conduct extensive discectomy.[3,4]

This (unpublished) technique was introduced by Pimenta in 2001 and formally spread by Ozgur et al. in 2006.[1] On the other hand, Bertagnoli et al.[5] described this approach for the prosthetic replacement of the nucleus pulposus, calling it ALPA (AnteroLateral transPsoatic Approach).

This is a safe technique that provides the spine with appropriate structural support between vertebral endplates; it can correct deformities on the coronal plane and carry out indirect decompression of the spinal canal[3] with preservation of posterior elements such as paraspinal muscles, articular facets and the posterior ligament complex.[6] It was described for interbody spaces from T5 through L4-L5.[6]

Lateral fusion can be carried out as a unique procedure or in association with mechanical support devices such as transpedicular screws and unilateral or bilateral bars inserted through the same surgical approach or through a posterior approach.[3,7]

The aim of this work is to describe step by step the surgical procedure of lumbar interbody fusion carried out through lateral approach as well as its variant procedures as we conduct it at the Centers we work at, and to point out related current concepts based a bibliographic revision.

Advantages

Spine interbody fusion through lateral approach has been gaining popularity due to its advantages as compared to, for example, the anterior approach, avoiding the exposure of abdominal organs, great blood vessels and the sympathetic plexus.[1,3,7] Retrograde ejaculation is a complication exclusively associated with lumbosacral interbody fusion through transperitoneal or retroperitoneal anterior approach.[8] Since there is no lateral approach for this level (due to the interposition of the iliac bone), it is not possible to avoid complications using this technique.

Other advantages are the minimal ligament disruption, the fewer complications at the level of the abdominal wall (eventrations and asymmetries), the milder postoperative pain, the lower infection rates, the lesser blood loss, the shorter hospital stay, and the faster return to the activities of daily life.[1,4,6,9] At the time of restoring the disc height it is possible to indirectly carry out decompression by increasing the central and foraminal areas[6,10] (Figure 1), and to correct deformities.[3,4,11]

Indirect decompression involves an average 35%[12] of the preoperative foraminal area, independently of the position of the implant into the space.

The LLIF technique allows the surgeon to insert an implant with extensive contact surface, what might increase structural support and fusion surfaces as compared to posterior interbody fixation. Axial loads are better distributed on the vertebral body endplates; therefore, subsidence and fracture rates decrease (Figure 2).[1,13] LLIF also keeps stability when it allows the surgeon to keep the anterior common longitudinal ligament and part of the anterior vertebral annulus fibrosus,[7] what allows this one to be used as a "stand alone" technique in selected cases, a very useful option in the elderly, in patients with many comorbidities or in the addition syndrome.

The risks represented by incidental durotomy, the injury of the nervous roots and perineurous fibrosis that can occur in posterior or transforaminal approaches for vertebral interbody fusion are minimized with this technique.[3]

Indications

Some indications are adult *de novo* scoliosis, central or foraminal stenosis, grade 1 or 2 degenerative spondylolisthesis, degenerative changes in the adjacent segment, simple or multilevel degenerative discopathy, non-union, traumatism, tumors, infection, conversion of total disc arthroplasty and, sometimes, thoracic spinal disc herniation.[3,6] Moreover, this approach can be used to conduct anterior vertebral body removal if need be.[1,13,14]

Relative indications are patients who run the risk of undergoing lack of bone healing (non-union) due to obesity, smoke, spinal previous surgeries or osteoporosis.[3]

Relative contraindications are: L4-L5 interbody disc below the intercrest line, high grade spondylolisthesis due to the location of the lumbar plexus[1,3] and also rotational deformity.[1] Sometimes an drop-like psoas muscle with an anterior lumbar plexus can hinder the approach of the L4-L5 space.

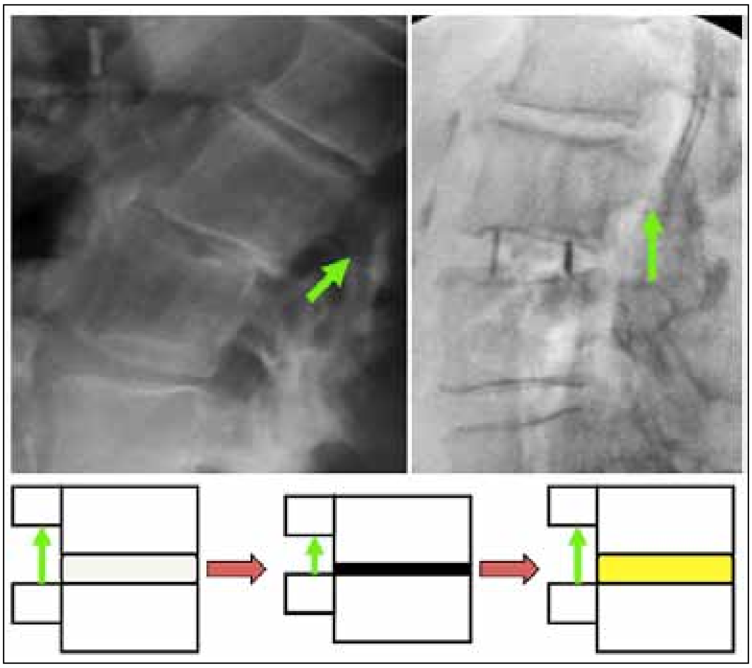


Figure 1. Images and diagram showing decrease in disc height, postoperative central and foraminal decompression in lateral interbody fusion.

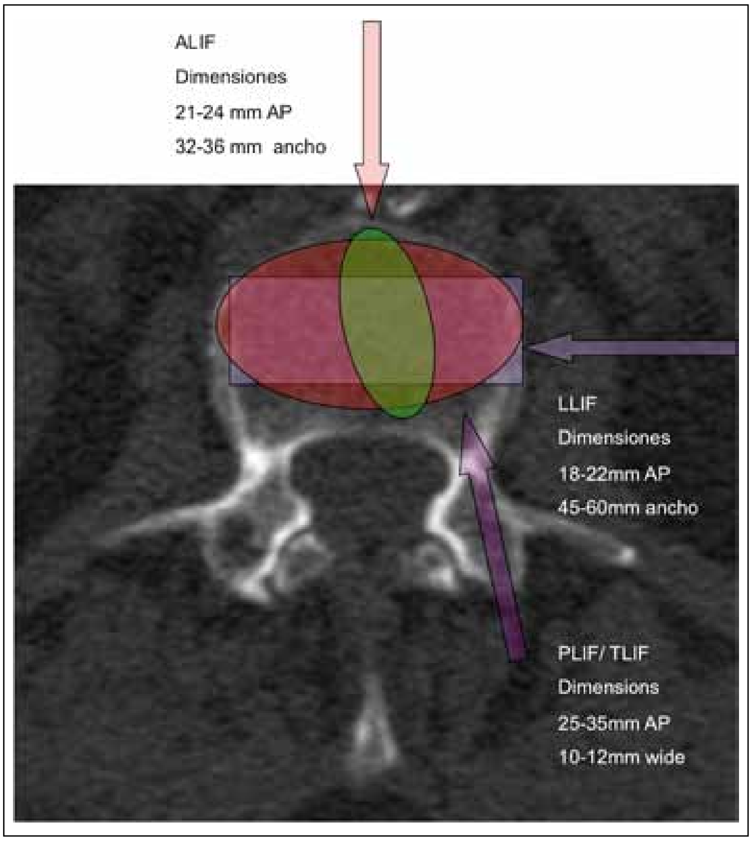


Figure 2. Diagram showing dimensional differences in the implants used in each approach for interbody fusion. AP=Anterior-posterior, ALIF = anterior lumbar interbody fusion, LLIF = lateral lumbar interbody fusion, PLIF = posterior lumbar interbody fusion, TLIF = transpedicular lumbar interbody fusion.

Thoracolumbar and thoracic approach

The lateral interbody fusion technique can be used in the surgery of the thoracic and the upper lumbar spine, where the risk of nervous injury due to the manipulation of the spinal cone and the spinal cord itself is significantly higher while using posterior interbody techniques.[3]

The thoracic technique somehow varies as compared to the original lumbar technique, a subject which goes beyond the aims of this work, but it is worth clarifying that there is agreement on approaching the levels above T12 through transthoracic approaches and those below L1-L2 through retroperitoneal approaches; on the other hand, if the level is between T12 and L1-L2, it is up to the surgeon to choose transthoracic, retroperitoneal or retropleural approaches.[15]

Karikari et al.[16] analyzed retrospectively 22 patients (15 females and 7 males) who averaged 64 years old (ranging from 50 to 81) and had an average follow-up of 16 months (ranging from 3 to 50). They operated on 47 thoracic/thoracolumbar levels (from T6 through L2) through an XLIF approach in the following conditions: degenerative scoliosis (11 cases), pathologic fractures (2 cases), addition syndrome (5 cases), thoracic disc herniation (3 cases) and discitis/osteomyelitis (1 case). Only one patient required posterior supplementation with pedicular screws. There were reports neither on nervous, visceral or vascular injury nor on patients' death. Complications were one wound infection, one implant subsidence and one addition syndrome, which required additional procedures. Six months later, they verified evidence of radiographic bone healing in 95.5% of the levels. The authors concluded that the XLIF approach can be indicated also at the level of the thoracic spine, where it is more favorable for the elderly and for patients with multiple comorbidities because it is less invasive. The only case they did not verify radiographic bone healing in at the level of the space operated on was that of a 72 year-old patient subject to T8-T9 fusion due to spondylodiscitis, who passed away three months later due to complications associated with her breast cancer-metastasis. Excluding this case, bone healing rates might reach 100% in the Karikari et al.'s series—we consider their conclusions to be appropriate.

In another publication, Meredith et al.[17] present a retrospective series of 18 patients (13% of females) who were 56.8 years old on average (ranging from 19 to 88) and 32 thoracolumbar levels (T3-L2) operated on by thoracic XLIF technique due to disc herniation, fracture, tumor, non-union, kyphosis above the union and degenerative conditions. Twelve patients out of the 18 ones were anterior supplements to anterior-posterior double stabilizations. The average follow-up was 14 months (ranging from 2 to 36) and they got bone healing in all cases, except one patient who passed away due to spread metastatic disease. They reported eight pleural effusions (6 mild cases; one of them required pleural tube drainage and another one, was re-admitted to the ICU), two incidental durotomies, one surgical wound infection, one instrument detachment, two cases of cardiac arrhythmia and one death due to unrelated causes.

In these articles,[16,17] the level more frequently operated on was the thoracolumbar union, which represents the most difficult from a technical point of view since it lies at the level of the diaphragmatic muscular insertions.

Biomechanics

The biomechanical profile of anterior, lateral or posterior lumbar body fusion is determined by the number of support structures that are removed, the size and the orientation of the implant, and the type of supplementary internal fixation in use.[7]

The lateral interbody fusion technique provides the spine with increased immediate stability in the affected segment— greater than that provided by the implants inserted by ALIF and TLIF techniques in their "stand alone" (without supplementary fixations) modalities.[7]

The LLIF implants are wider and less deep than those used in the ALIF technique, and they are wider and deeper than those used in the TLIF and PLIF techniques[15] (Figure 2), what gives the implant a greater contact surface for fusion.

Biomechanical studies show that LLIF fixation results in greater reduction of ROM in flexion, extension, lateral bending and axial rotation as compared to the implants that are inserted by the ALIF or TLIF techniques.[18]

In a cadaveric biomechanical study, researchers found that the fusion of one spinal segment using the LLIF technique as one with no association with other fixation techniques resulted in a reduction in the ROM of the segment (31.6% reduction in normal flexion-extension, 32.5% reduction in lateral bending and 69.4% reduction in axial rotations) by percentages that are significantly higher than those in the ALIF or TLIF fusions that have been published.[7] The greatest reduction in ROM was that in the LLIF technique associated with transpedicular double posterior fixation, with either pedicular or interlaminar screws (13% in flexion-extension; 14.4% in lateral binding and 41.7% in axial rotation), followed by the LLIF technique with unilateral pedicular fixation.[7]

The preservation of the anterior common vertebral ligament and the annulus fibrosus with this technique not only imposes limits to spinal extension but by undergoing tension it also gives more initial stability to the implant.[7]

Some of the characteristics of the studies on cadaveric specimens that should be considered are the differences in mineral quality between specimens and the previous mobility between vertebral segments. Although the loads that are applied are similar to physiological loads, the stabilizing effects of peripheral muscles are not included, what can modify eventual results.[7]

Preoperative studies

All of our patients are evaluated by static and dynamic focused X-rays, AP and lateral spinogram, CT scan without contrast and MRI without contrast. These imaging studies provide us with supplementary information and do not exclude one another; however, imaging studies suggested for each candidate to this procedure are not standardized.

What follows is a description of some imaging study reports that can alter the choice of either the patient or the technique to be used.

Pre-operative MRI can be useful to infer the position of the lumbar plexus and the great blood vessels, but their location in prone position differs from that the patient is in during the surgery (lateral position with flexed hips and knees).[1,19,20] The importance of locating the lumbar plexus is due to the near position of the intervened canal.

Moreover, there is great variability in the position of the lumbar plexus both between patients and in an isolated patient depending on the side to be evaluated.[4]

There was a time when they used to use the "rising psoas sign" (rising sun sign) to indirectly deduce an anterior position of the lumbosacral plexus with respect to the interbody space; however, this tendency was proved not to be significant and, therefore, it may not be a reliable technique to infer the location of the plexus and there is no relationship between the position of the plexus and the shape of the psoas muscle.[4]

MRI neurography is a new technique to evaluate peripheral nerves that allows the surgeon to identify their shape, changes in their signal and their diameter. Recent publications set out this method as a pre-operative tool to classify the anatomic position of the lumbar plexus at the level of the L4-L5 disc.[4]

So as to determine if the surgical technique can be carried out in an isolated way or in association with some additional stabilization method, Melham et al.[21] suggest a series of conditions that might require greater fixation: osteoporosis, vertebral instability, more than to levels to be operated on or facet arthropathy. Since the vast majority of the patients show some of these characteristics, exclusive anterior instrumentation is used in selected cases.

Surgical technique

The patient should be in lateral position with flexed hips and knees, for the patient's greater trochanter to lie distal to the operating table hinge. The patient should be held on the operating table with wide adhesive tape (10 cm) at the level of their trochanters and thoracic spine.

The approach of choice is the left approach in patients with deformity on the coronal plane due to the anterior position of the aorta artery on the left side.

If possible, it is advisable to approach the spine from the concave side in the case of coronal deformity, since this approach allows the surgeon to treat several levels using minimal skin exposure.[3,22] If there is no coronal deformity, the approach side is determined on the basis of the access to the L4-L4 space in relationship with the iliac crest.[18]

So as to allow the surgeon a better approaching space, the operating table should be bent using the hinge between the pelvic bone and the thorax to lengthen the distance between the iliac crest and the rib edge on the patient's approaching side. The excess of angulation is counterproductive, however, since it causes too much tension in the psoas muscle and the nerves that go through it (Figure 3).[6]

Reaching the L4-L5 space can be difficult if the upper edge of the iliac crest lies above the middle of the L4 vertebral body. Nevertheless, this can be solved by placing properly the patient on the operating table and using bent instrumental devices.

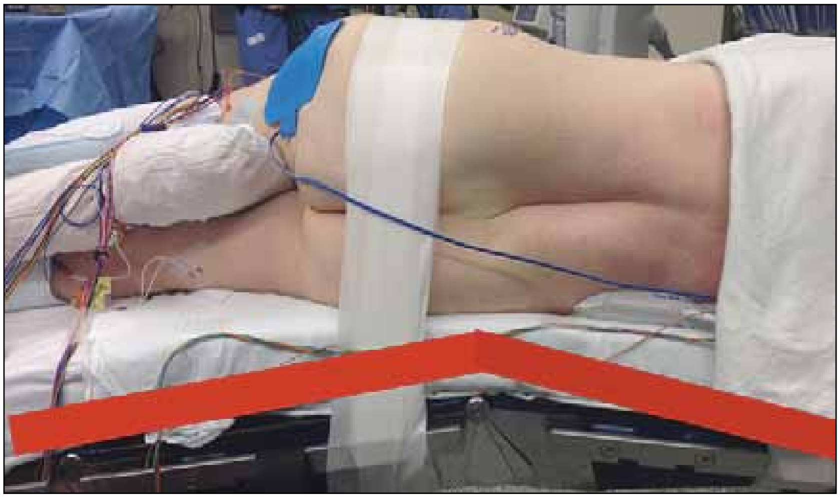


Figure 3. Patient in right lateral position with 90º-flexed hips and knees. The patient is held on the operating table with adhesive tape. The operating table is bent at the level of the lumbar deformity.

It is essential to get good images so as to verify the proper preparation of the vertebral endplate and the insertion of the implant (Figure 4).

Once the patient has been positioned on the operating table, with the fluoroscope- C arch in 0º and 90º normal to de floor, the inclination of the operating table should be modified towards the patient's lateral sides, or towards Trendelenburg or anti-Trendelenburg position, until getting strict AP and lateral fluoroscopic images of the interbody space about to be operated on. This is possible by the alignment of the spinous processes, equidistant from the related pedicles and the vertebral endplates at the level of the affected spaces.

The patient's skin should then be marked on the anterior, posterior, upper and lower edges of the affected vertebral bodies (Figure 5).

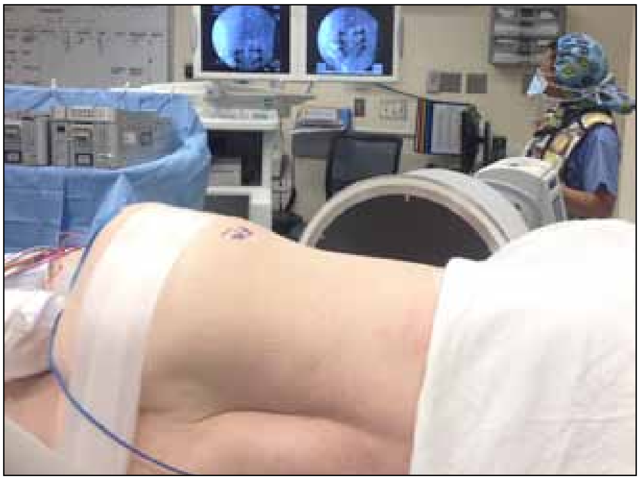


Figure 4. Good quality coronal and sagittal images.

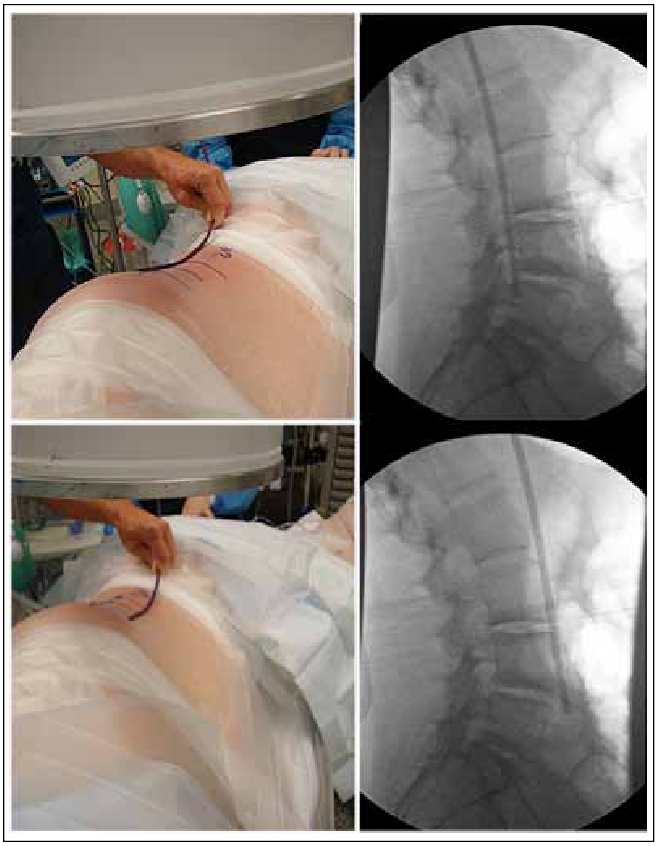
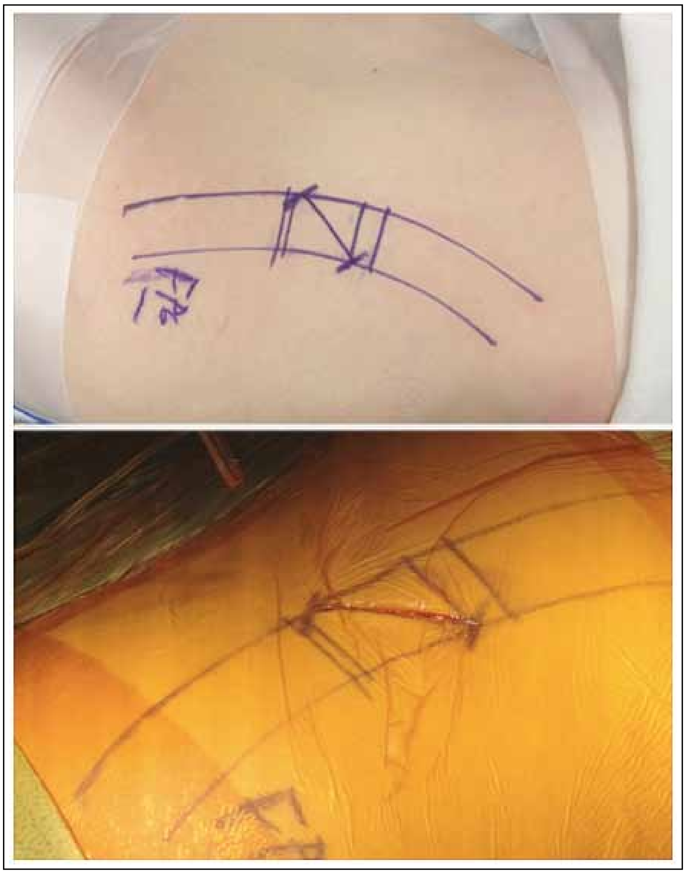


Figure 5. Approach cutaneous marks guided by fluoroscopy.

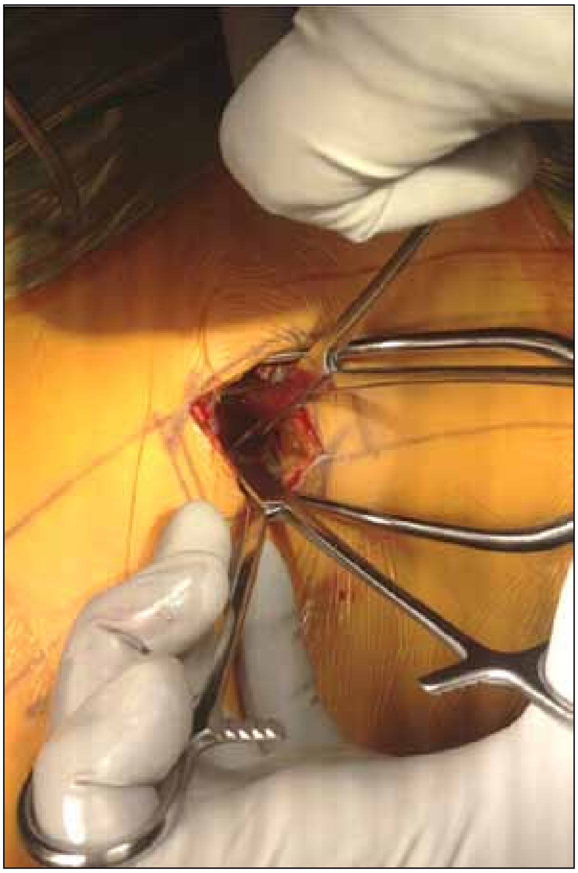
The skin incision is oblique and goes from the anterior-inferior pole of the underlying vertebral body to the posterior-superior pole of the overlying vertebral body (Figure 6). At the Centre we work at we carry out this approach aided by a general surgeon trained in these kinds of procedures or by a vascular surgeon but, contrarily to uses in anterior approaches, in this approach we could do without these surgeons' collaboration.

The surgical approach in the XLIF technique involves the following three stages:[6]

1) The muscular stage, through the patient's lateral side in which muscle is torn apart by blunt devices through the external oblique, the internal oblique and the transverse abdominal muscles following the orientation of the fibers so as to minimize traumatism (Figure 7);



▲ **Figure 6.** Lateral approach. Incision from the anterior-inferior pole of the underlying vertebral body to the posterior-superior edge of the overlying vertebral body.



▲ **Figure 7.** Abdominal muscle blunt dissection along the orientation of the fibers of the internal, external and transverse abdominal muscles.

2) The retroperitoneal stage, in which the surgeon spots the psoas muscle by sweeping the visceral abdominal contents in anterior direction with blunt instrumental devices. It is necessary to identify and protect nervous structures with the aid of real-time pneumoperitoneum[3] (the subcostal nerve from the T12 root, which supplies the rectus abdominis muscle and the external oblique muscle; the iliohypogastric nerve from the T12 and L1 roots, and the ilioinguinal nerve from the L1 root, which supply the transverse and internal oblique muscles; and the lateral cutaneous femoral nerve, from the L2 and L3 roots) (Table). The surgeon should also individualize the genitofemoral nerve, from the L1 and L2 roots, which supply the sensitive area of the femoral triangle and the cremaster muscle in males and the mons pubis and labia majora in females.[6]

3) The transpsoas stage, when the surgeon should be most cautious due to the presence of the lumbar plexus.[4] In some cadaveric studies, researchers have tried to determine the exact location of the lumbar plexus in relationship with vertebral interbody discs so as to avoid complications during the LLIF procedure.

These studies have defined "safe zones" on the grounds of intebody spaces at each level. This "window" goes narrower downwards, and distally the plexus runs its greatest risk due to its migration.[4]

We carry out neurophysiological monitoring during the different maneuvers at this stage. If the zone is "safe", we

Table. Lumbar plexus: muscles supplied and cutaneous branches

Nerve	Segment	Supplied muscle	Cutaneous branches
Lumbar plexus			
Iliohypogastric	T12-L1	Transverse	Anterior cutaneous branch
		Internal Oblique	Lateral cutaneous branch
Ilioinguinal	L1		Anterior scrotal branches in males
			Anterior labia majora in females
Genitofemoral	L1,L2	Cremaster (males)	Femoral branch
			Genital branch
Lateral femoral cutaneous	L2,L3		Lateral femoral cutaneous
Obturator	L2-L4	External oblique	Cutaneous branch
		Adductor longus	
		Gracilis	
		Pectineus	
		Adductor magnus	
Femoral	L2-L4	Iliopsoas	Anterior cutaneous branch
		Pectineus	Saphenous
		Sartorius	
		Quadriceps	
Muscular branches	T12-L4	Psoas	
		Quadratus	
		Iliacus	
		Lumbar intertransverse	

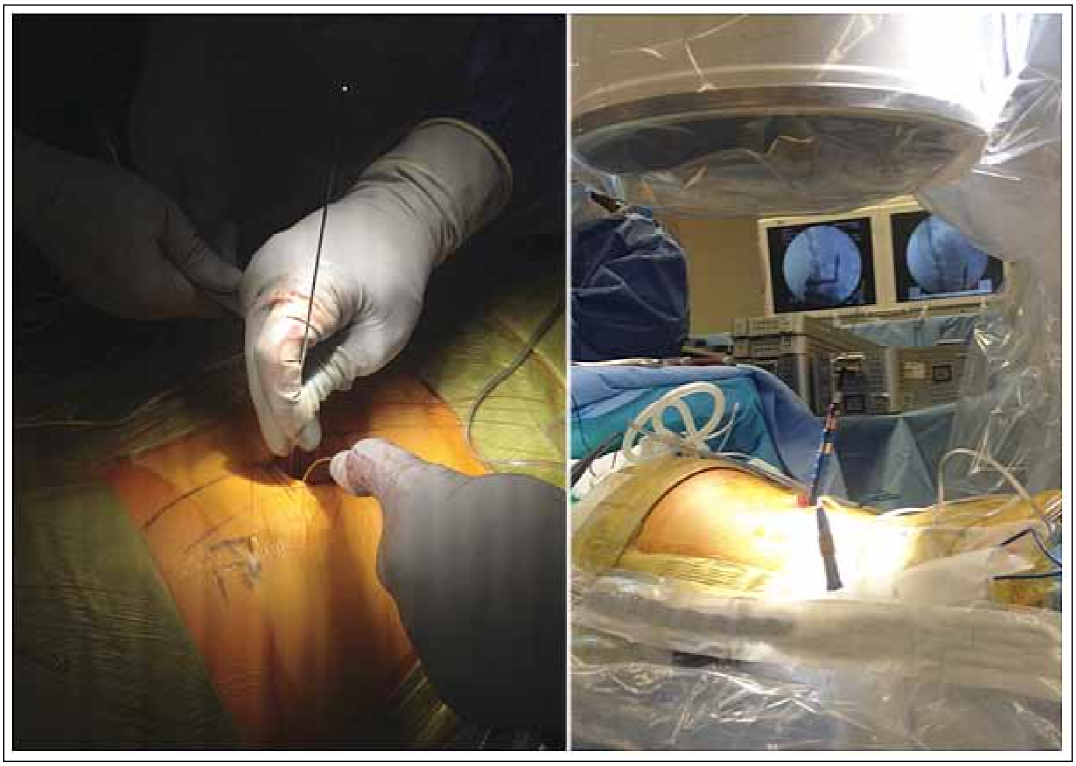


Figure 8. Transpsoas blunt tear, identification of the level and confirmation by fluoroscopy.

introduce a Kirschner wire at the level of the mid-section of the disc and check positions by fluoroscopy (Figure 8) (working on the anterior half of the disc would allow us prolordotic correction.

Separation is kept by means of a system of self-devices attached to the operating table or maneuvered by means of blunt renal separating devices.

Retractors work mainly in downward direction, although separation can also be kept in AP direction or preferably in PA direction because the nervous plexus is more frequently located behind the retractors (Figure 9). The time of use of retractors or separating devices is of utmost importance, because it has been directly associated with an increase in the rates of postoperative neurological injuries.[9,23-25] Uribe et al.[26] identified significant differences in the time of retraction of psoas muscle between patients with and without postoperative symptomatic neurorpraxia (32.3 min vs. 22.6 min, p=0.031).

We carry out disectomy using trephines, gouges, pituitary clamps and curettes (Figure 10).

Cobb elevators go through both ending vertebral endplates towards the other side to release the insertions of the annulus fibrosus contralateral to the approach. The whole procedure is indirectly monitored by fluoroscopy, as it is the size of the implant by successive 2 mm-increasing trials.[22]

The different implants in use have different lordosis degrees from neutral to 12º-implants. Under special circumstances it is possible to use more angulated hyper-lordotic cages so as to carry out correction on the sagittal plane. Many times it is technically difficult to insert a 30º-cage due to the decreased interbody space; therefore, Deukmedjian et al.[27] suggested releasing the anterior common vertebral ligament so as to widen the intebody space and try to avoid the damage of the ending vertebral endplates.

The larger the cage supporting surface on the vertebral endplates, the more stability; therefore, the size of the cage in AP and lateral directions is important at the time of carrying out fusion, especially if there are no supplementary fixation devices.

So as to generate vertebral interbody fusion, the cage should be preferably filled with iliac crest autograft. Other options are bank allograft, bone substitutes and bone morphogenetic protein.

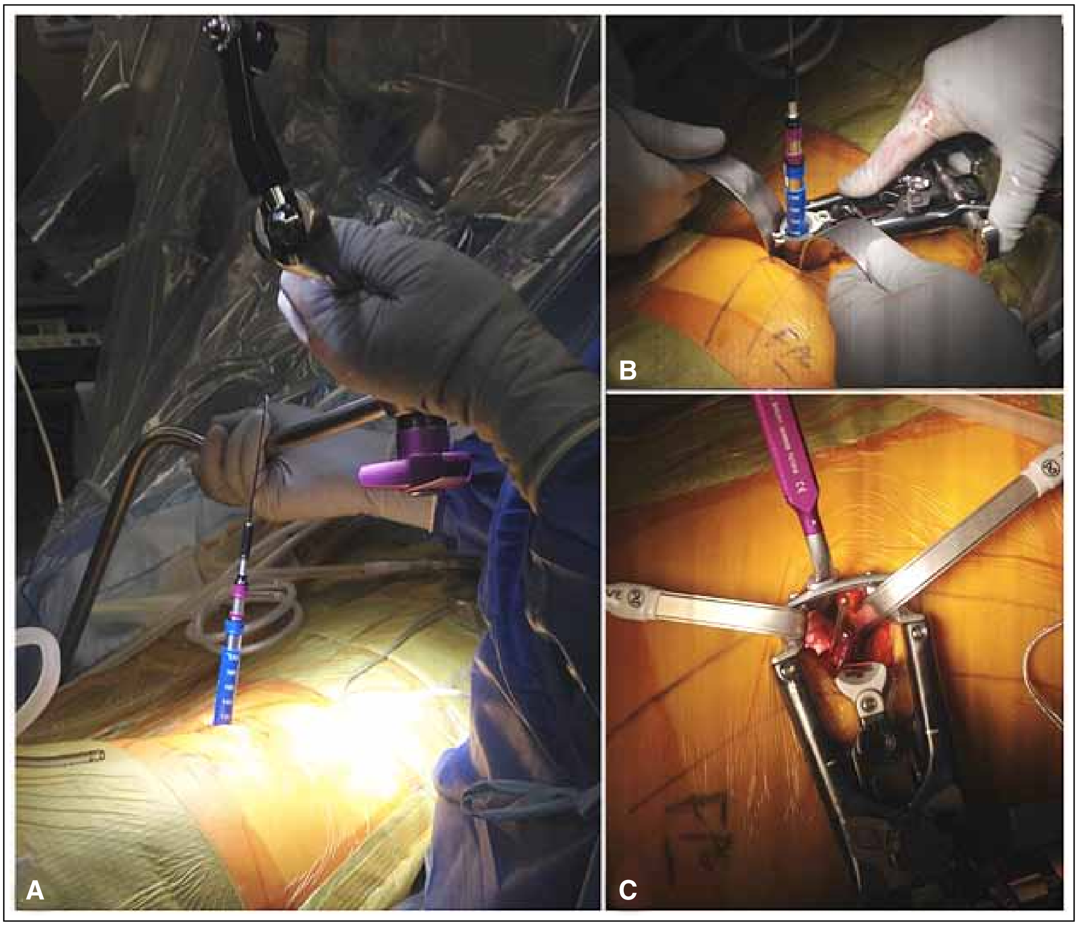


Figure 9. A. Static frame held on the operating table. **B.** Separation devices at work. **C.** Distraction mainly in downward direction.

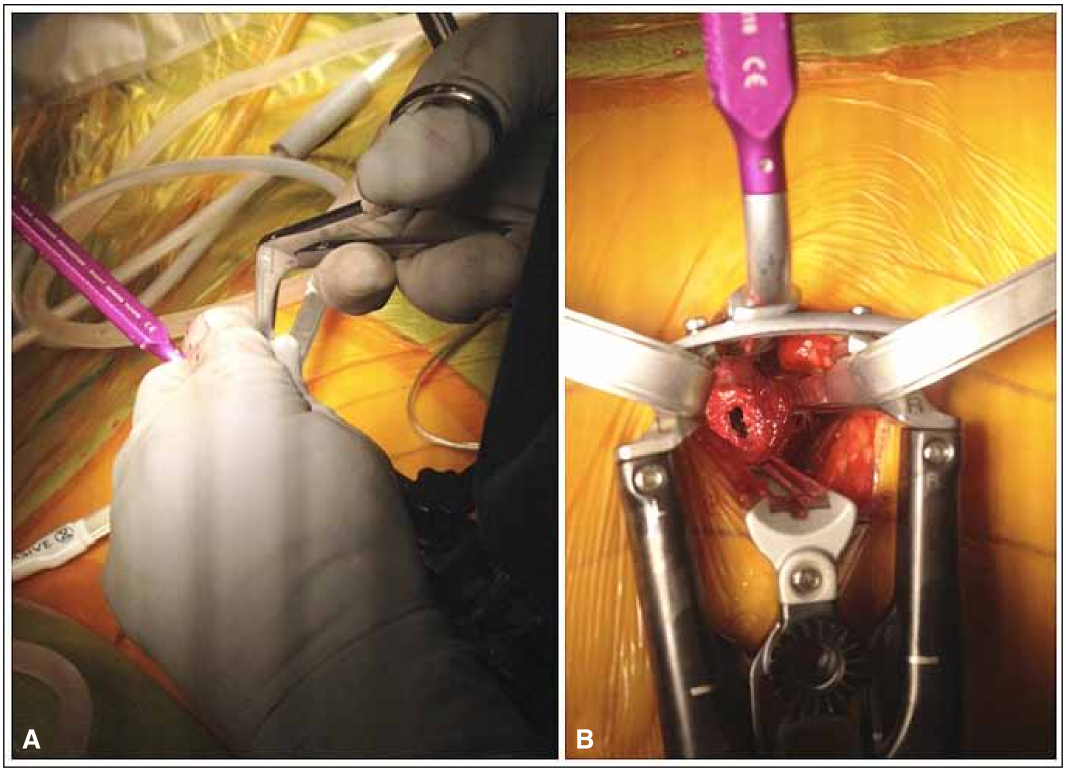


Figura 10. A. Discectomy by gouges and curettes. **B.** Approach and end of discectomy.

The implant can be used on its own or in association with another fixation technique, either anterior plating or posterior screws. Usually drainage devices are not required.

All in all, the patient starts walking the postoperative day 1 after the surgery, using corset during the first postoperative weeks. He or She should be warned against flexing or rotating forcefully their trunk.[3,4,6]

Patients' hospital stay varies accordingly to the patients' status, the number of levels involved and the complexity of the additional procedures,[6] but it is 1 or 2 days on average.

In order to summarize the surgical technique we can enumerate the key bullet-points described by Berjano et al.:[6]

1. Positioning the patient correctly is essential.

2. Repositioning the operating table while operating on the different levels is advisable in multilevel cases.

3. Preoperative planning based on the position of the psoas muscle and the neurovascular structures at each level is of utmost importance.

4. In general the patient's concave side is preferable to carry out the surgical approach.

5. The appropriate preparation of the vertebral plateaus and the release of the contralateral disc are essential to ensure optimal fusion rates and maximal indirect foraminal decompression.

6. The preoperative administration of a dexamethasone bolus may seem to be useful to decrease plexopathy at the time of approaching the L4-L5 disc.

7. It is important to avoid overdistraction to prevent implant subsidence.

8. The greatest disadvantage is the relatively high —although transitory—rate of psoas weakness, groin pain and thigh pain associated with dysesthesia and numbness (from 23%[27] to 39%[28]).

Results and complications

There are reports on good results with this technique in adult patients who suffer degenerative scoliosis and significant comorbidities, because it allows the surgeon to carry out indirect decompression of central and foraminal stenosis at the time of correcting deformities on both coronal and sagittal planes.[3,4] Therefore, apical selective fusions in adults with *de novo* scoliosis are possible with results which can be compared to those in posterior constructions, and less morbidity. This makes this one an interesting technique to treat patients who run high surgical risk due to their comorbidities.

Although success in this procedure depends widely on intraoperative fluoroscopy, about 2700 yearly procedures would be necessary to go beyond the maximal allowed radiation dosis,[29] even in less protected areas such as the armpit and the eye.

Bone healing and fusion

Functional results and consolidation rates are relatively predictable with the LLIF technique, and they compare favorably with other fusion techniques.[30] Fusion is verified by the presence of bone bridges through discs, and the absence of instability.

In 2010, Youssef et al. in a series of 84 patients reported bone healing verified by CT scan in 68 patients (81%) and perioperative and postoperative complication rates were 2.4% and 6.1%, respectively.

Kotwal et al.[22] evaluated retrospectively functional and radiologic results in 118 patients with an average follow-up of 27.5 months (ranging from 25 to 38). In 102 patients, they combined the LLIF technique with posterior fusion and, in 16, the used isolated LLIF techniques. The authors found significant improvement in the visual analogue scale, the Owestry Dissability Index and the physical component of the SF-12,[14,22] although not in its psychological component. Moreover, the disc height, the coronal angle and lordosis were significantly restored in degenerative scoliosis.[11,22,23] Acosta el al. did not show improvement in the sagittal balance.[14] Fusion rates were 88% and the most frequent complication was thigh pain (36%).[22]

Correction on the sagittal and coronal planes

With respect to the correction of the deformity, the LLIF technique is useful to correct lumbar deformities[11,12] and even thoracolumbar and thoracic deformities, although to a lesser extent than formal posterior approaches associated with osteotomies.[16]

The effects of the LLIF technique on lordosis depends on several factors; among others, the lordosis of the implant, the involvement of the vertebral endplate and the presence of osteoporosis.[8] The affected level and the patient's height also play a part. The lower the level and the higher the patient, the greater the possibility that the vertebral axis has a posterior result.[8]

In 2010, Dakwar et al. were the first ones to assess correction on the sagittal plane after a LLIF procedure. They reported that the sagittal balance improved in 16 out of 25 patients with degenerative scoliosis; however, the did not report the patients' preoperative status, nor did they describe the methods they used to assess results.[32]

Other authors evaluated 21 patients with an average follow-up of 21 months and verified significant changes in the Cobb angles on the coronal plane, but neither the sagittal plane nor lordosis were affected.[14] Tormenti et al. also reported good correction on the coronal plane and the preservation of lumbar lordosis when the LLIF technique was used along with posterior fixation.[33]

Cammisa et al. report the use of the LLIF technique both in an isolated way and associated with lateral plates and screws or in association with posterior instrumentation. These authors report reduction in deformities on the coronal plane and also on the sagittal plane when they used implants with lordosis and also when implants were inserted in the anterior third of the interbody space.[3]

A group of researchers carried out a systematic bibliographic revision and analyzed the correction of the sagittal balance using the lateral interbody fusion technique in patients with degenerative spodilopathy. They evaluated 1266 levels in 476 patients analyzing 14 publications. They concluded that this technique is especially effective when the correction goal is <10º of lumbar lordosis and <5 cm of global sagittal balance.[8] In this same article, they report that the lumbar coronal curve improved 50.5%. Twenty-eight percent of the levels received fusion exclusively through lateral approach, whereas the rest of them underwent additional fixation.[8]

Complications

The first publication by the Pimenta's team, in 2006,[1] did not report complications in the first 13 patients who had undergone this treatment. However, complications started showing as the procedure was gaining popularity.

The most frequent complications are anterior thigh pain or thigh paresthesia. Theories about its pathophysiology describe the irritation of the psoas muscle or neurpraxia of the genitofemoral nerve (branch from the lumbar plexus) during blunt dissection of the psoas muscle, due to overpressure by retractors, by indirect ischemia or ischemia due to hematoma. [1,4,19,20,22,24,30,34,35] These complications rates oscillate between 23%[36] and 39%[28]. Rodgers et al.[24] describe a far wider range, from 0.7% to 62.7%. Most of these injuries occur at the time of going through the psoas muscle with tearing apart devices or distractors,[37] and the time of their use is directly related to the rates of postoperative neurologic injuries.[9,23-26]

It has been shown that nervous structures at the level of the L4-L5 disc lie on the surgical area in 44% of the cases, what makes an injury more likely in procedures conducted at this level.[20]

In a series of 600 patients and 741 intervened levels, Isaac et al. reported neither wound infections nor vascular or visceral injuries, although they presented four cases of postoperative neurological deficit (0.7%). They also reported 12.1% of major complications, what can be compared to the rates reported in the treatment of degenerative deformities.[23]

Pumberger et al. evaluated 181 patients without detecting injuries in organs or iliac vessels. One patient suffered an injury in the lumbar segmental artery, two of them underwent injury in the ascending iliolumbar vein, 38% attended with anterior thigh pain 6 weeks after the surgery; this percentage was decreasing gradually— 11% 12 weeks after the surgery and 1% at postoperative week 26. There are reports on this injury recovering in 50% of the patients at postoperative month 3 and in 90% of them one year after the surgery.[6]

Published rates of deficit in muscular strength for hip flexion vary between 1% and 36%.[11,22,23,31,36]

Pawar et al. reported deficit in mechanical flexion in patients' psoas muscles in 13.1% of the patients (n=32) 6 weeks after the surgery, 3.7% (n=9) at postoperative week 12, 2.9% (n=7) 6 months after the surgery and 1.6% (n=4) at postoperative month 12. On the other hand, the motor deficit associated with lumbar plexus impairment was 4.9% (n=12), 4.9% (n=12), 2.9% (n=7) and 2.9% (n=7), respectively. The female sex and the duration of the surgery were independent risk factors for the mechanical flexor deficit, whereas the duration of the surgery was the only independent risk factor for the deficit associated with impairment in the lumbar plexus.[3]

There are reports on complications at the level of the abdominal wall and an abdominal wall neurological deficit. Dakwar et al. report asymmetry at the level of the abdominal wall due to contents protrusion—it is believed that the reason is the lack of nervous supply for the internal oblique and the transvers abdominal muscles due to the injury of the ilioinguinal and iliohypogastric branches. Moreover, subcostal nerves from T12 roots supply the rectus abdomini and the external oblique muscles and, therefore, they should be properly protected.[38]

There are reports on 14.3% of complication rates associated with the subsidence of the implant (34 of 237 intervened levels),[4] and with the fracture of the vertebral endplante.[30,39-41] According to Essing et al.,[42] old age, osteoporosis and a sagittal orientation of the facets were the risk factors for the subsidence of the implant when this technique was used in an isolated way; therefore, they suggest supplementation by posterior support devices. Other complications that have been published are: ileus, heart arrhythmia, respiratory failure, gastric ulcer, acute urine retention and delayed wound healing. All of them are associated with <1% rates.[4]

In a study conducted on 156 obese and 157 non-obese patients,[43] complication rates and their severity were not modified by the patients' overweight factor; however, this did have an effect on those treated with supplementary fixation through open posterior approaches.

Conclusions

The LLIF technique has become a highly useful therapeutic tool for the spinal surgeon. It is minimally invasive, it gives nervous elements indirect decompression, it causes minimal blood loss and it allows the patient faster recovery as compared to other techniques if it is used in an isolated way. Although there are suggestions in specialized literature, precise indications are still to be determined so as to use this one as an isolated technique without posterior fixation. It can be useful in obese patients in whom anterior and posterior techniques are more difficult to implement and are associated with higher infection rates. Patients with addition syndrome in posterior fusion are good candidates. It is possible to associate them with supplementary internal fixation to get more stability.

Long-term studies are required so as to verify potential benefits in the long run, but its initial results are promising.

Bibliography

1. Ozgur BM, Aryan HE, Pimenta L, Taylor WR. Extreme lateral interbody fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion. *Spine J* 2006;6:435-43. doi: https://doi.org/10.1016/j.spinee.2005.08.012
2. Geisler FH, Blumenthal SL, Guyer RD, McAfee PC, Regan JJ, Johnson JP, et al. Neurological complications of lumbar artificial disc replacement and comparison of clinical results with those related to lumbar arthrodesis in the literature: results of a multicenter, prospective, randomized investigational device exemption study of Charite intervertebral disc. Invited submission from the Joint Section Meeting on Disorders of the Spine and Peripheral Nerves, March 2004. *J Neurosurg Spine* 2004;1:143-54. doi: https://doi.org/10.3171/spi.2004.1.2.0143
3. Pawar A, Hughes A, Girardi F, Sama A, Lebl D, Cammisa F. Lateral lumbar interbody fusion. *Asian Spine J* 2015;9(6):978-83. doi: https://doi.org/10.4184/asj.2015.9.6.978
4. Quinn JC, Fruauff K, Lebl DR, Giambrone A, Cammisa FP, Gupta A, et al. Magnetic resonance neurography of the lumbar plexus at the L4-L5 disc: development of a preoperative surgical planning tool for lateral lumbar transpsoas interbody fusion (LLIF). *Spine (Phila Pa 1976)* 2015;40(12):942-7. doi: https://doi.org/10.1097/BRS.0000000000000899
5. Bertagnoli R, Vazquez RJ. The Anterolateral TransPsoatic Approach (ALPA): a new technique for implanting prosthetic disc-nucleus devices. *J Spinal Disord Tech* 2003;16(4):398-404. https://bit.ly/2Rf6Oc0
6. Berjano P, Gautschi OP, Schils F, Tessitore E. Extreme lateral interbody fusion (XLIF®): how I do it. *Acta Neurochir (Wien)* 2015;157(3):547-51. doi: https://doi.org/10.1007/s00701-014-2248-9
7. Cappuccino A, Cornwall GB, Turner AW, Fogel GR, Duong HT, Kim KD, et al. Biomechanical analysis and review of lateral lumbar fusion constructs. *Spine (Phila Pa 1976)* 2010;35(26 Suppl):S361-7. doi: https://doi.org/10.1097/BRS.0b013e318202308b

8. Costanzo G, Zoccali C, Maykowski P, Walter CM, Skoch J, Baaj AA. The role of minimally invasive lateral lumbar interbody fusion in sagittal balance correction and spinal deformity. *Eur Spine J* 2014;23(Suppl 6):699-704. doi: https://doi.org/10.1007/s00586-014-3561-y

9. Pumberger M, Hughes AP, Huang RR, Sama AA, Cammisa FP, Girardi FP. Neurologic deficit following lateral lumbar interbody fusion. *Eur Spine J* 2012;21:1192-9. doi: https://doi.org/10.1007/s00586-011-2087-9

10. Oliveira L, Marchi L, Coutinho E, Pimenta L. A radiographic assessment of the ability of the extreme lateral interbody fusion procedure to indirectly decompress the neural elements. *Spine (Phila Pa 1976)* 2010;35(26 Suppl):S331-7. doi: https://doi.org/10.1097/BRS.0b013e3182022db0

11. Mundis GM, Akbarnia BA, Phillips FM. Adult deformity correction through minimally invasive lateral approach techniques. *Spine (Phila Pa 1976)* 2010;35(26 Suppl):S312-21. doi: https://doi.org/10.1097/BRS.0b013e318202495f

12. Kepler CK, Sharma AK, Huang RC, Meredith DS, Girardi FP, Cammisa FP Jr, et al. Indirect foraminal decompression after lateral transpsoas interbody fusion. *J Neurosurg Spine* 2012;16(4):329-33. doi: https://doi.org/10.3171/2012.1.SPINE11528

13. Petracchi M, Camino Willhuber G, Tripodi M, Bassani J, Gruenberg M, Sola C. Monosegmental combined anterior posterior instrumentation for the treatment of a severe lumbar tuberculous spondylodiscitis: case report and literature review. *Rev Bras Ortop* 2016; doi: https://doi.org/10.1016/j.rboe.2016.12.010

14. Acosta FL, Liu J, Slimack N, Moller D, Fessler R, Koski T. Changes in coronal and sagittal plane alignment following minimally invasive direct lateral interbody fusion for the treatment of degenerative lumbar disease in adults: a radiographic study. *J Neurosurg Spine* 2011;15:92-6. doi: https://doi.org/10.3171/2011.3.SPINE10425

15. Sun JC, Wang JR, Luo T, Jin XN, Ma R, Luo BE, et al. Surgical incision and approach in thoracolumbar extreme lateral interbody fusion surgery: an anatomic study of the diaphragmatic attachments. *Spine (Phila Pa 1976)* 2016;41(4):E186-90. doi: https://doi.org/10.1097/BRS.0000000000001183

16. Karikari IO, Nimjee SM, Hardin CA, Hughes BD, Hodges TR, Mehta AI, et al. Extreme lateral interbody fusion approach for isolated thoracic and thoracolumbar spine diseases: initial clinical experience and early outcomes. *J Spinal Disord Tech* 2011;24(6):368-75. doi: https://doi.org/10.1097/BSD.0b013e3181ffefd2

17. Meredith DS, Kepler CK, Huang RC, Hegde VV. Extreme lateral interbody fusion (XLIF) in the thoracic and thoracolumbar spine: technical report and early outcomes. *HSS J* 2013;9(1):25-31. doi: https://doi.org/10.1007/s11420-012-9312-x

18. Laws CJ, Coughlin DG, Lotz JC, Serhan HA, Hu SS. Direct lateral approach to lumbar fusion is a biomechanically equivalent alternative to the anterior approach: an in vitro study. *Spine (Phila Pa 1976)* 2012;37(10):819-25. doi: https://doi.org/10.1097/BRS.0b013e31823551aa

19. Guerin P, Obeid I, Bourghli A, Masquefa T, Luc S, Gille O, et al. The lumbosacral plexus: anatomic considerations for minimally invasive retroperitoneal transpsoas approach. *Surg Radiol Anat* 2012;34(2):151-7. doi: https://doi.org/10.1007/s00276-011-0881-z

20. Kepler CK, Bogner EA, Herzog RJ, Huang RC. Anatomy of the psoas muscle and lumbar plexus with respect to the surgical approach for lateral transpsoas interbody fusion. *Eur Spine J* 2011;20(4):550-6. doi: https://doi.org/10.1007/s00586-010-1593-5

21. Malham GM, Ellis NJ, Parker RM, Blecher CM, White R, Goss B, Seex KA. Maintenance of segmental lordosis and disc height in stand-alone and instrumented extreme lateral interbody fusion (XLIF). *Clin Spine Surg* 2017;30(2):E90-E98. doi: https://doi.org/10.1097/BSD.0b013e3182aa4c94

22. Kotwal S, Kawaguchi S, Lebl D, Hughes A, Huang R, Sama A, et al. Minimally invasive lateral lumbar interbody fusion: clinical and radiographic outcome at a minimum 2-year follow-up. *J Spinal Disord Tech* 2015;28(4):119-25. doi: https://doi.org/10.1097/BSD.0b013e3182706ce7

23. Isaacs RE, Hyde J, Goodrich JA, Rodgers WB, Phillips FM. A prospective, nonrandomized, multicenter evaluation of extreme lateral interbody fusion for the treatment of adult degenerative scoliosis: perioperative outcomes and complications. *Spine (Phila Pa 1976)* 2010;35(26 Suppl):S322-30. doi: https://doi.org/10.1097/BRS.0b013e3182022e04

24. Rodgers WB, Gerber EJ, Patterson J. Intraoperative and early postoperative complications in extreme lateral interbody fusion: an analysis of 600 cases. *Spine (Phila Pa 1976)* 2011;36(1):26-32. doi: https://doi.org/10.1097/BRS.0b013e3181e1040a

25. Lykissas MG, Aichmair A, Hughes AP, Sama AA, Lebl DR, Taher F, et al. Nerve injury after lateral lumbar interbody fusion: a review of 919 treated levels with identification of risk factors. *Spine J* 2014;14(5):749-58. doi: https://doi.org/10.1016/j.spinee.2013.06.066

26. Uribe JS, Isaacs RE, Youssef JA, Khajavi K, Balzer JR, Kanter AS, et al. Can triggered electromyography monitoring throughout retraction predict postoperative symptomatic neuropraxia after XLIF? Results from a prospective multicenter trial. *Eur Spine J* 2015;24 (Suppl 3): 378-85. doi: https://doi.org/10.1007/s00586-015-3871-8

27. Deukmedjian AR, Dakwar E, Ahmadian A, Smith DA, Uribe JS. Early outcomes of minimally invasive anterior longitudinal ligament release for correction of sagittal imbalance in patients with adult spinal deformity. *Scientific World Journal* 2012;2012: 789698. doi: https://doi.org/10.1100/2012/789698

28. Cummock MD, Vanni S, Levi AD, Yu Y, Wang MY. An analysis of postoperative thigh symptoms after minimally invasive transpsoas lumbar interbody fusion. *J Neurosurg Spine* 2011;15:11-8. doi: https://doi.org/10.3171/2011.2.SPINE10374
29. Taher F, Hughes AP, Sama AA, Zeldin R, Schneider R, Holodny EI, et al. 2013 Young Investigator Award winner: How safe is lateral lumbar interbody fusion for the surgeon? A prospective in vivo radiation exposure study. *Spine (Phila Pa 1976).* 2013;38(16):1386-92. doi: https://doi.org/10.1097/BRS.0b013e31828705ad
30. Sharma AK, Kepler CK, Girardi FP, Cammisa FP, Huang RC, Sama AA. Lateral lumbar interbody fusion: clinical and radiographic outcomes at 1 year: a preliminary report. *J Spinal Disord Tech* 2011;24(4):242-50. doi: https://doi.org/10.1097/BSD.0b013e3181ecf995
31. Youssef JA, McAfee PC, Patty CA, Raley E, DeBauche S, Shucosky E, et al. Minimally invasive surgery: lateral approach interbody fusion: results and review. *Spine (Phila Pa 1976).* 2010;35(26 Suppl):S302-11. doi: https://doi.org/10.1097/BRS.0b013e3182023438
32. Dakwar E, Cardona RF, Smith DA, Uribe JS. Early outcomes and safety of the minimally invasive, lateral retroperitoneal transpsoas approach for adult degenerative scoliosis. *Neurosurg Focus* 2010;28(3):E8. doi: https://doi.org/10.3171/2010.1.FOCUS09282
33. Tormenti MJ, Maserati MB, Bonfield CM, Okonkwo DO, Kanter AS. Complications and radiographic correction in adult scoliosis following combined transpsoas extreme lateral interbody fusion and posterior pedicle screw instrumentation. *Neurosurg Focus* 2010;28(3):E7. doi: https://doi.org/10.3171/2010.1.FOCUS09263
34. Fontes RB, Traynelis VC. Transpsoas approach and complications. *J Neurosurg Spine* 2011;15(1):9-10; author reply p. 10. doi: https://doi.org/10.3171/2010.12.SPINE10741
35. Ahmadian A, Deukmedjian AR, Abel N, Dakwar E, Uribe JS. Analysis of lumbar plexopathies and nerve injury after lateral retroperitoneal transpsoas approach: diagnostic standardization. *J Neurosurg Spine* 2013;18(3):289-97. doi: https://doi.org/10.3171/2012.11.SPINE12755
36. Moller DJ, Slimack NP, Acosta FL Jr, Koski TR, Fessler RG, Liu JC. Minimally invasive lateral lumbar interbody fusion and transpsoas approach-related morbidity. *Neurosurg Focus* 2011;31(4):E4. doi: https://doi.org/10.3171/2011.7.FOCUS11137
37. Spivak JM, Paulino CB, Patel A, Shanti N, Pathare N. Safe zone for retractor placement to the lumbar spine via the transpsoas approach. *J Orthop Surg (Hong Kong)* 2013;21(1):77-81. doi: https://doi.org/10.1177/230949901302100120
38. Dakwar E, Le TV, Baaj AA, Smith WD, Akbarnia BA, Uribe JS. Abdominal wall paresis as a complication of minimally invasive lateral transpsoas interbody fusion. *Neurosurg Focus* 2011;31(4):E18. doi: https://doi.org/10.3171/2011.7.FOCUS11164
39. Karikari IO, Grossi PM, Nimjee SM, Hardin C, Hodges TR, Hughes BD, et al. Minimally invasive lumbar interbody fusion in patients older than 70 years of age: analysis of peri- and postoperative complications. *Neurosurgery* 2011;68(4):897-902. doi: https://doi.org/10.1227/NEU.0b013e3182098bfa
40. Dua K, Kepler CK, Huang RC, Marchenko A. Vertebral body fracture after anterolateral instrumentation and interbody fusion in two osteoporotic patients. *Spine J* 2010;10(9):e11-5. doi: https://doi.org/10.1016/j.spinee.2010.07.007
41. Brier-Jones JE, Palmer DK, Inceoglu S, Cheng WK. Vertebral body fractures after transpsoas interbody fusion procedures. *Spine J* 2011;11(11):1068-72. doi: https://doi.org/10.1016/j.spinee.2011.07.020
42. Essig DA, Cho W, Hughes AP, Huang RC, Sama AA, Girardi FP, Cammisa FP Jr. Risk factors for implant subsidence after stand-alone lateral interbody fusión. *Spine J* 2014;14(11 Suppl):S114. doi: https://doi.org/10.1016/j.spinee.2014.08.284
43. Rodgers WB, Cox CS, Gerber EJ. Early complications of extreme lateral interbody fusion in the obese. *J Spinal Disord Tech* 2010;23(6):393-7. doi: https://doi.org/10.1097/BSD.0b013e3181b31729