Lateral lumbar interbody fusion. Surgical technique and current concepts

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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 evidence: IV

ARTRODEISIS INTERSOMÁTICA LATERAL DE COLUMNÁ 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
Introduction

Lumbar interbody fusion can be carried out through a direct posterior approach (posterior lumbar interbody fusion [PLIF] or transforaminal lumbar interbody 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. 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.

This (unpublished) technique was introduced by Pimenta in 2001 and formally spread by Ozgur et al. in 2006. On the other hand, Bertagnoli et al. 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 with preservation of posterior elements such as paraspinal muscles, articular facets and the posterior ligament complex. It was described for interbody spaces from T5 through L4-L5.

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.

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. Retrograde ejaculation is a complication exclusively associated with lumbosacral interbody fusion through transperitoneal or retroperitoneal anterior approach. 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. At the time of restoring the disc height it is possible to indirectly carry out decompression by increasing the central and foraminal areas (Figure 1), and to correct deformities.

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, traumaism, tumors, infection, conversion of total disc arthroplasty and, sometimes, thoracic spinal disc herniation. Moreover, this approach can be used to conduct anterior vertebral body removal if need be.

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.

Relative contraindications are: L4-L5 interbody disc below the intercrest line, high grade spondylolisthesis due to the location of the lumbar plexus and also rotational deformity. 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 canal 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 spondylodisitis, 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 retro-

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 techniques15 (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 bending and 41.7% in axial rotation), followed by the LLIF technique with unilateral pedicular fixation.7

The preservation of the anterior common vertebral liga-

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 stabiliz-
ing 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-L5 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 the 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);

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 pneumoperitoneum3 (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 interbody 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

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Segment</th>
<th>Supplied muscle</th>
<th>Cutaneous branches</th>
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<tbody>
<tr>
<td>Lumbar plexus</td>
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<tr>
<td>Iliohypogastric</td>
<td>T12-L1</td>
<td>Transverse</td>
<td>Anterior cutaneous branch</td>
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<td></td>
<td></td>
<td>Internal Oblique</td>
<td>Lateral cutaneous branch</td>
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<tr>
<td>Ilioinguinal</td>
<td>L1</td>
<td>Internal Oblique</td>
<td>Anterior scrotal branches in males</td>
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<tr>
<td>Genitofemoral</td>
<td>L1,L2</td>
<td>Cremaster (males)</td>
<td>Femoral branch</td>
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<td></td>
<td></td>
<td></td>
<td>Genital branch</td>
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<tr>
<td>Lateral femoral cutaneous</td>
<td>L2,L3</td>
<td>External oblique</td>
<td>Lateral femoral cutaneous</td>
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<tr>
<td>Obturator</td>
<td>L2-L4</td>
<td>Adductor longus</td>
<td>Cutaneous branch</td>
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<td>Gracilis</td>
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<td></td>
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<td>Pectineus</td>
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<td></td>
<td></td>
<td>Adductor magnus</td>
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<tr>
<td>Femoral</td>
<td>L2-L4</td>
<td>Iliopsoas</td>
<td>Anterior cutaneous branch</td>
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<td>Pectineus</td>
<td>Saphenous</td>
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<td>Sartorius</td>
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<td>Quadriceps</td>
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<tr>
<td>Muscular branches</td>
<td>T12-L4</td>
<td>Psoas</td>
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<td>Quadratus</td>
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<td>Iliacus</td>
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<td>Lumbar intertransverse</td>
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▲ **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 interbody 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.
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.14 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 dose,\textsuperscript{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.\textsuperscript{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.\textsuperscript{32} 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 Disability Index and the physical component of the SF-12,\textsuperscript{14,22} although not in its psychological component. Moreover, the disc height, the coronal angle and lordosis were significantly restored in degenerative scoliosis.\textsuperscript{11,22,23} Acosta et al. did not show improvement in the sagittal balance.\textsuperscript{14} Fusion rates were 88\% and the most frequent complication was thigh pain (36\%).\textsuperscript{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\textsuperscript{11,12} and even thoracolumbar and thoracic deformities, although to a lesser extent than formal posterior approaches associated with osteotomies.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{14} Tornetti 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.\textsuperscript{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 instrumenta-

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.\textsuperscript{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 spondylolysis. They evaluated 1266 levels in 476 patients analyzing 14 publications. They concluded that this technique is especially effective when the correction goal is <10° of lumbar lordosis and <5 cm of global sagittal balance.\textsuperscript{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.\textsuperscript{8}

**Complications**

The first publication by the Pimenta’s team, in 2006,\textsuperscript{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 over-pressure by retractors, by indirect ischemia or ischemia due to hematoma.\textsuperscript{1,4,19,20,22,24,30,34,35} These complications rates oscillate between 23\%\textsuperscript{36} and 39\%\textsuperscript{28}. Rodgers et al.\textsuperscript{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,\textsuperscript{37} and the time of their use is directly related to the rates of postoperative neurologic injuries.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{6}
Published rates of deficit in muscular strength for hip flexion vary between 1% and 36%.\textsuperscript{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.\textsuperscript{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.\textsuperscript{38}

There are reports on 14.3% of complication rates associated with the subsidence of the implant (34 of 237 intervened levels),\textsuperscript{4} and with the fracture of the vertebral endplate.\textsuperscript{30,39,41} According to Essing et al.,\textsuperscript{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.\textsuperscript{4}

In a study conducted on 156 obese and 157 non-obese patients,\textsuperscript{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.

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