



Minimally invasive surgery procedure in isthmic spondylolisthesis

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Abstract

Purpose The aim of the study was to evaluate the efficacy and safety of the direct lateral approach to the lumbar spine in the treatment of painful isthmic spondylolisthesis in adults.

Methods Twenty-one patients affected by isthmic spondylolisthesis and treated with extreme lateral interbody fusion and posterior percutaneous pedicle screw fixation were enrolled. All included patients were clinically evaluated with Oswestry Disability Index, SF36 and Visual Scale Anatomy (VAS) for back pain at 1, 3 months and at 1 year.

Results The mean correction of vertebral slippage measured on lateral lumbar X-ray was 56.3% ($p=0.002$). The average preoperative VAS score was 7.1, at 1 year decreasing to 2.2 ($p=0.001$). The patients had an average preoperative “Oswestry Disability Index” of 36.8 and 24.1% after 1 year ($p=0.02$). The preoperative Short-Form 36 Physical Health was equal to 33.8, 72.1% after 1 month, to 76.3% after 3 months and to 83.2% ($p=0.001$) after 1 year of follow-up. There were no signs of implant loosening at 1-year CT scan examination in any of the patients.

Conclusion The study showed that the extreme lateral approach to the lumbar spine in case of isthmic spondylolisthesis is a reliable and safe option to the most common open procedures. In the authors’ opinion, XLIF procedures allow a good correction of the listhesis associated with good clinical and radiographic results.

Graphical abstract These slides can be retrieved under Electronic supplementary material.

The graphical abstract consists of three panels. The left panel, titled 'Key points', lists: 1. XLIF; 2. Extreme Lateral Interbody Fusion; 3. Isthmic spondylolisthesis; 4. MIS; 5. Spondylolysis. The middle panel shows two lateral X-ray images of a lumbar vertebra, labeled 'pre' and 'post', with red lines indicating the correction of vertebral slippage. Below the images is a caption: 'Comparison between pre and post operative lateral views in a 57-year-old male with L4/L5 isthmic spondylolisthesis that shows the amount of correction achievable with minimally invasive lateral approach to the lumbar spine. The amounts of correction has been calculated as the variation of the percentage of slippage before and after the operation. In this case 31% of slippage before the operation decreased to 12% due to the effect of the indirect correction that occurs during the positioning of the intervertebral disc cage.' The right panel, titled 'Take Home Messages', lists: 1. Extreme lateral approach to the lumbar spine in case of isthmic spondylolisthesis is a reliable and safe option to the most common open procedures. 2. XLIF procedures allow a good correction of the listhesis associated with good clinical outcome and radiographic results. 3. XLIF technique in spondylolisthesis allows the reduction of peri- and post operative complications, early hospital discharge, and earlier physical and functional recovery. Each panel includes the Springer logo.

Keywords XLIF · Extreme lateral interbody fusion · Isthmic spondylolisthesis · MIS · Spondylolysis

Introduction

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In the adult population, spondylolisthesis is one of the most frequent causes of disabling lumbar pain with or without neurologic claudication. An anterior vertebral body slippage can take place in elderly people because of degenerative spine modifications or as a consequence of pars interarticularis defect in young people. Unilateral or bilateral spondylolysis is a pathologic bone defect of the pars interarticularis of

the vertebra much more frequent in young people at L5 level than in the upper lumbar vertebrae because of the peculiar biomechanics of the lumbosacral junction [1–3].

Isthmic lysis and relatedolisthesis of the vertebral body typically cause disabling lumbar pain rarely associated with neurogenic claudication because the slippage of the vertebral body does not cause lumbar stenosis. Conservative treatment is the standard therapeutic indication. Many options are available such as physical therapy, medications (use of muscle relaxers and narcotics may be appropriate for managing the initial acute pain) or drug seepage. Whenever a long-lasting conservative treatment fails, a surgical approach is advisable [4]. A surgical stabilization of the segment of motion is widely accepted as the gold standard for surgical treatment of isthmic spondylolisthesis, although the techniques are still debatable [5]. Different surgical procedures can be performed but, nowadays, the concept of adopting the least invasive procedure to obtain the same positive results as in traditional open procedures is becoming even more widely accepted.

Among the minimally invasive surgery procedures, the XLIF is becoming more frequently adopted in the case of lumbar degenerative diseases and a safe and reliable alternative procedure to the most widely used open techniques [6]. Based on extensive personal experience with the lateral access to the lumbar spine, the authors aimed to make the procedure available even in cases of high segmental instability such as in isthmic spondylolisthesis. Clinical and radiographic outcomes have been evaluated in cases of adult isthmic spondylolisthesis to prove the reliability and safety of the XLIF.

Materials and methods

Twenty-one patients, affected by lumbar spondylolisthesis due to isthmic lysis and treated by extreme lateral transposas approach arthrodesis and posterior pedicle screw fixation, were enrolled in this study. All the patients were surgically treated in our institution from 2014 to 2016 by two senior surgeons with consolidated experience in minimally invasive spinal surgery. The mean age was 52 years (min 44–max 63), 13 M and 8F, with a mean BMI of 27.2 (24–30.1) (Table 1).

The main exclusion criteria were anatomical abnormalities such as the disposition of the nerve and vascular trunks especially at L4–L5 level, previous abdominal surgery and the L5–S1 level due to the surgical method's inherent limitations. All the patients had a history of long-lasting back pain, not responsive to conservative treatment. A comprehensive radiologic preoperative investigation was carried out with standing plain radiograph of the lumbosacral spine in anteroposterior and lateral views, with a dynamic study (flexion and extension). To evaluate the anatomy of the site, with

Table 1 Demographic and clinical characteristics of patients

Characteristics	Patient data
Age (year)	52 * (range 44–63)
Sex (M:F)	13:8
BMI	27.2* (24–30.1)
Comorbidities	
Arterial hypertension	3
Smoker	5
Diabetes	1
Degree of spondylolisthesis	3
Grade I	6
Grade II	15
Grade III	0
Grade VI	0
Level	
L3–L4	10
L4–L5	11
Complication	
Transient hypoaesthesia	3

*Values shown are mean

particular attention to the neurologic and vascular structures and the feasibility of the procedure, MRI with a high magnetic field was carried out in all patients. The vertebral slippage was calculated on standing plain radiograph and according to the Meyerding classification (Fig. 1).

The direct lateral approach to the lumbar spine was performed according to the procedure first described by Pimenta et al. [7]. We used the intraoperative nerve monitoring system (NVM5[®]) to avoid iatrogenic injuries to the nerve fibres of lumbosacral plexus. The risk of neurologic lesions is higher at L4–L5 level because the nerve roots, in case of spondylolisthesis, may be more anterior than normal so the entry point into the disc space becomes a crucial step in the procedure [8].

Normally, if two adjacent vertebrae are properly aligned, the correct entry point is located at the junction between the anterior two-thirds and posterior one-third of the disc space. In spondylolisthesis, because of the slippage of the superior endplate with respect to the lower one, the entry point must be correctly targeted by examining the exact position of both the superior and lower vertebrae. An entry point that might seem correct with respect to the lower vertebra could be too posterior for the upper vertebra. In this case, the access point would need to be moved forward, more anteriorly when compared to the access point usually used for properly aligned vertebrae (Figs. 2 and 3). To prevent neurological complications, even reversible ones such as neuroapraxia, it is mandatory to minimize the time of action of the muscle retractor that could stress nerve fibres in a time-dependent correlation [9].

Fig. 1 a, b Comparison between pre- and postoperative lateral views in a 57-year-old male with L4–L5 isthmic spondylolisthesis that shows the amount of correction achievable with minimally invasive lateral approach to the lumbar spine. The amounts of correction have been calculated as the variation of the percentage of slippage before and after the operation. In this case, 31% of slippage before the operation decreased to 12% due to the effect of indirect correction that occurs during the positioning of the intervertebral disc cage

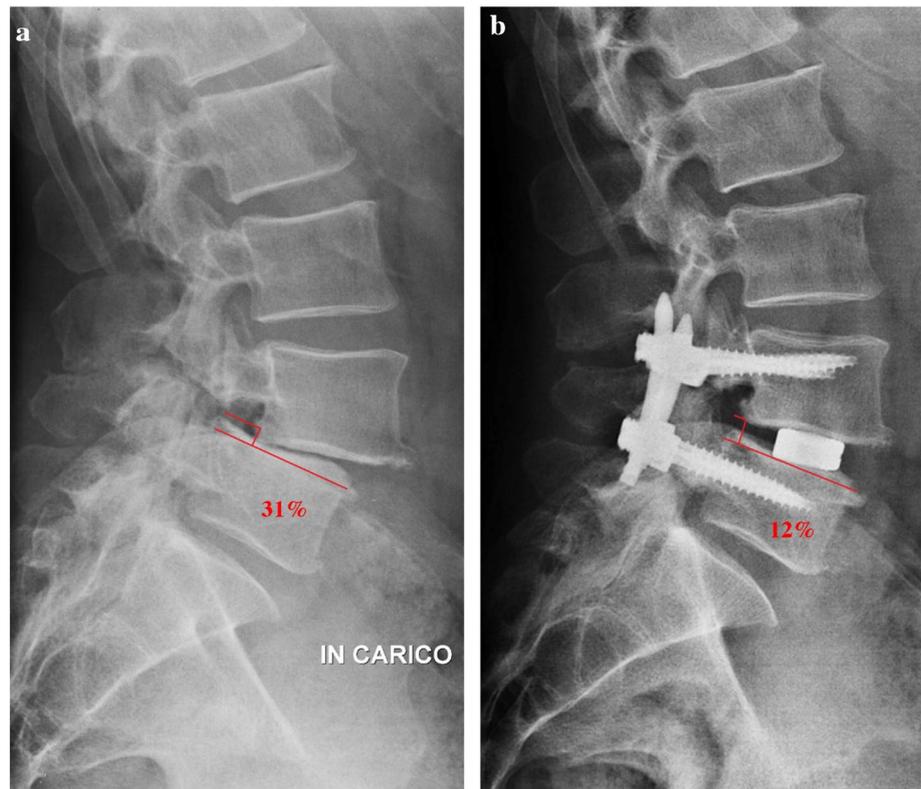


Fig. 2 a 53-year-old man. Pre-operative lateral view X-ray of a high instability, L4–L5 isthmic spondylolisthesis with foraminal distortion due to L4 vertebral body slippage. **b** Postoperative lateral view shows the reduction in the L4–L5 olisthesis with restoration of the height of the intervertebral disc space and the recovery of the normal shape of the foramina

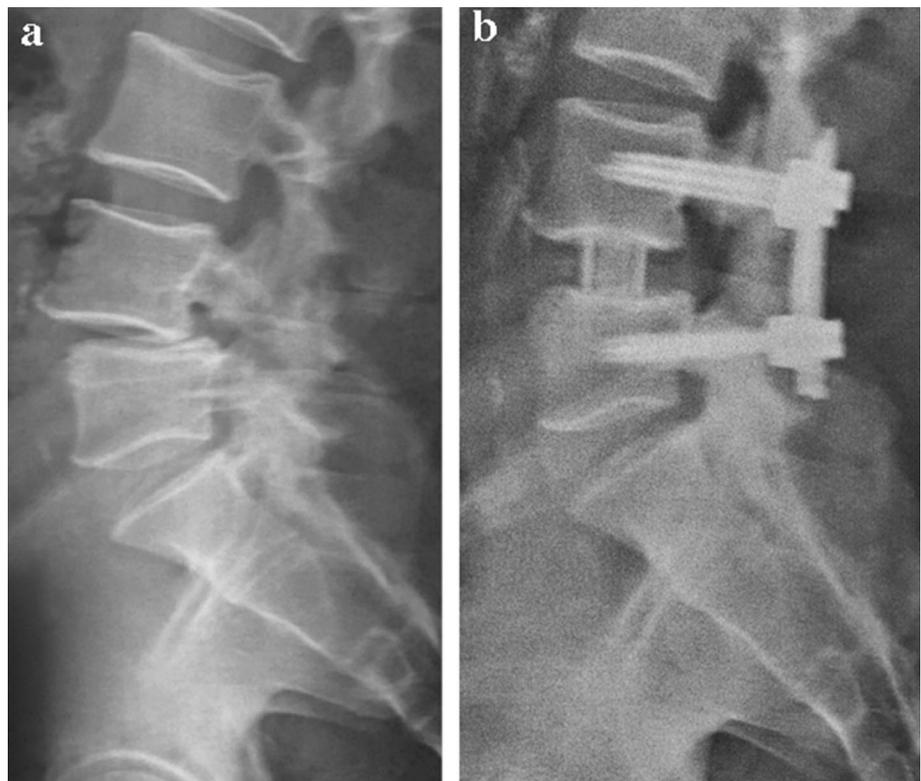
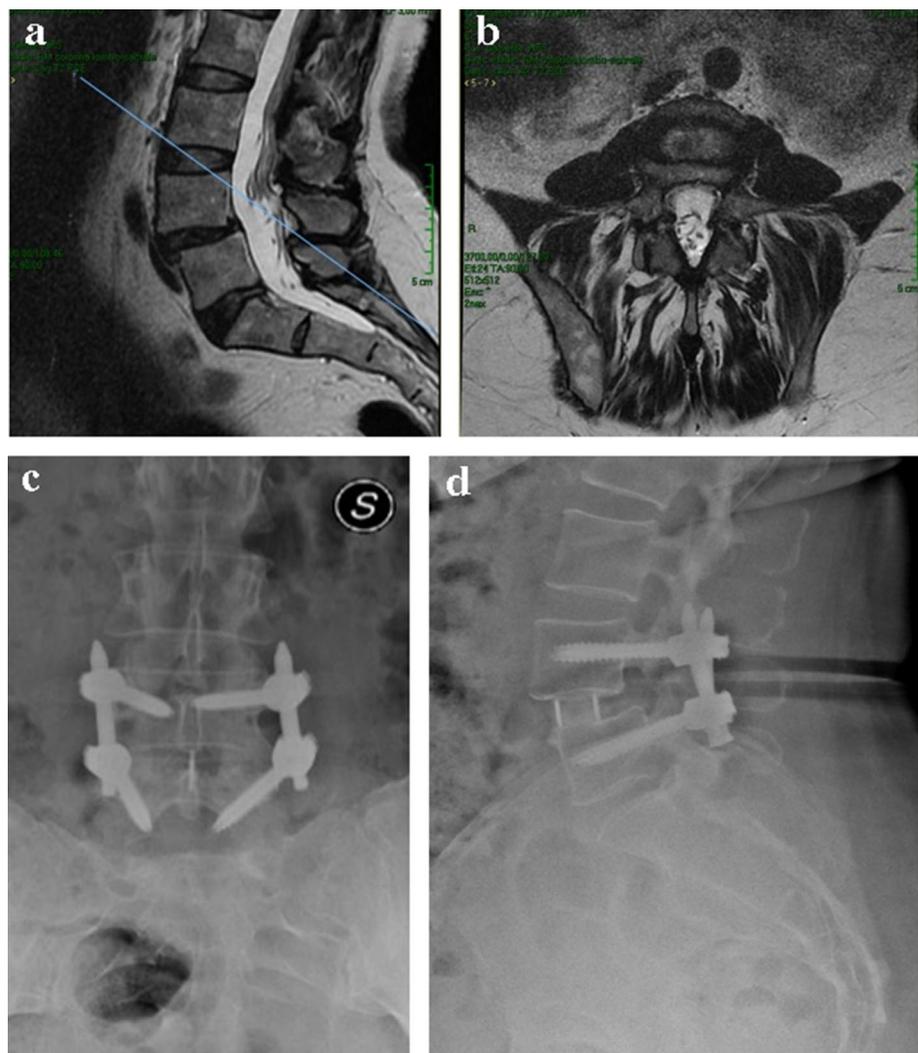


Fig. 3 **a, b** MRI images of a 54-year-old female with L4 and L5 isthmic spondylolisthesis without narrowing of the spinal canal or roots compressions at the slipped level. **c, d** Postoperative a-p and lateral view X-rays show the correct placement of pedicle screws and PEEK cage between L4 and L5. On lateral view, a quite complete correction of the olisthesis is appreciable. The position of the cage results more anterior than the normal respect to the end plate of the caudal vertebra although it is perfectly positioned respect to the lower end plate of the slipped vertebra. It depends to the choice of the entry point to the intervertebral disc that, in case of spondylolisthesis, can be more anterior than the normal due to the position of the neurological structures and the femoral nerve in particular



Despite the high stability achievable with XLIF cages, we never carried out a stand-alone procedure. All patients enrolled for XLIF procedure underwent, at the same stage, a posterior percutaneous approach with bilateral pedicle screws fixation performed in prone position except for two cases in which the posterior approach was carried out in the same lateral position. No patients underwent any direct open or minimally invasive laminectomy decompression. In 14 cases, PEEK cages were implanted as they were the only ones available at that moment. In seven cases, titanium cages were implanted. Currently we prefer to use titanium cages with lordotic angulation when restoration of segmental lordosis is desirable.

Non-standardized rules were adopted in choosing the size of the cage to be implanted but this was chosen empirically, case by case, comparing the height of the adjacent disc space and verifying, on the surgical site, the amount of correction achievable using fluoroscopy. In all cases, a

lumbar X-ray was performed after surgery. On lateral view radiograph, we calculated the reduction in anterolisthesis, pre- and postoperative spinopelvic parameters such as pelvic index (PI), pelvic tilt (PT), sacral slope (SS), lumbar lordosis and pelvic incidence–lumbar lordosis (PI–LL) mismatch. All patients were clinically evaluated before the operation and at follow-up examination at 1, 3 months and 1 year, with Oswestry Disability Index (ODI), Short-Form 36 Physical Health and Visual Analogue Scale (VAS) for back pain. All subjects completed the minimum follow-up end-point at 12 months and all underwent CT examination at a minimum of 1 year later, to evaluate the grade of arthrodesis. Statistical analyses were conducted using χ^2 test and verified with Fisher's exact test for Oswestry Disability Index, Short-Form 36 Physical Health and Meyerding Percentage change. Student's t test was used for Visual Analogue Scale data and spinopelvic parameters variation. Significance was established for $p < 0.05$.

Results

The mean follow-up was 16 months (12–18). The anterior displacement of the upper vertebra, according to the Meyerding classification, was Grade I in six patients and Grade II in 15 patients. The affected levels of spondylolisthesis were L3–L4 (10) and L4–L5 (11). The average surgical time for lateral procedure only was 123 min (min 102–max 156). The average time of divarication was 26 min (min 21–max 29). The mean intraoperative blood loss was 135 ml (min 107 ml–max 168 ml). No complications were reported during surgery. No wound infections were found. None of the patients needed blood transfusions. Only three patients had a temporary hypoaesthesia on the left thigh due to the stretching of the lumbar plexus. All the patients were able to walk the first day after surgery, and the mean length of hospital stay was 3.4 days. No early implant failure or cage displacements were recorded on the first X-ray postoperative evaluation. The mean correction of vertebral slippage, obtained with the procedure, calculated as a percentage variation on lateral lumbar X-ray before and after operation, was 56.3% (47.2–59.5%) ($p = 0.002$) (Table 2).

The spinopelvic parameters changed as follows: LL from 45.1° preop to 49.8° postop ($p = 0.07$), SS from 31.5° to 32.6° ($p = 0.61$) PT from 19.2° to 16.3° ($p = 0.56$) and PI–LL mismatch from 7.2° to 4.2° ($p = 0.03$). The average preoperative VAS score was 7.1 (6–9), at 1 month decreased to 4.3 (3–7), at 3 months to 3.9 (2–6) and at 1 year to 2.2 (1–4) ($p = 0.001$). The patients had an average preoperative “Oswestry Disability Index” of 36.8% (28–62%), of 32.3% (18–44%) after 1 month, of 29.8% (16–42%) after 3 months and of 24.1 (16–36) after 1 year ($p = 0.02$). The preoperative Short-Form 36 Physical Health was equal to 33.8% (25.5–50.1%), to 72.1% (59.9–84.7%) after 1 month, to 76.3% (66.1–87.3%) after 3 months and to 83.2% (69.6–91%) ($p = 0.001$) after 1 year of follow-up. At 1-month clinical follow-up, each patient resumed his/her normal daily life activities. At 1-year CT scan examination, there was no sign of implant loosening in any patient.

Discussion

An isthmic lysis of the vertebral arc is one of the causes of segmental instability of the lumbar spine that can develop in every stage of life with different clinical, anatomic and radiologic features. On rare occasions, it can occur in the paediatric population with a peculiar condition known as “developmental dysplasia” which involves the pars interarticularis of L5 and needs an early surgical stabilization. In the adult patients, a painful lumbar disease is generally due to an acquired isthmus lysis or to a late deterioration of a preexisting lysis. Unlike dysplastic types, the acquired form is localized in the upper lumbar vertebrae, mainly L4 and L3 rather than L5 [10]. Some authors have shown through cadaveric and biomechanical studies that, for its shape and position, the pars interarticularis is subjected to the greatest strength of any structure in the lumbar spine; these same authors have suggested that pars interarticularis is the weakest part of the neural arc [11]. Lumbar pain is caused by the instability of the affected segment and its abnormal, not constrained, movements. Radicular pain and neurologic symptoms seem to be caused by irritation and/or tension of the nerve roots rather than stenosis of the spinal canal and foramina. Typically lumbar and radicular pain improves with conservative treatment due to the immobilization of the involved segments [10]. Sometimes pain relief is unsatisfactory and not long lasting with conservative treatment, thus forcing to consider surgical stabilization in case of disabling syndrome. Although the concept of surgical stabilization is universally accepted as the main goal in cases of segmental instability what is not univocally accepted is the need for a reduction in the lysis as an essential step in the procedure [12]. Some authors affirm that long-term outcomes are quite the same in cases of stabilization with or without reduction especially in the case of minor slippage while others support the need for the reduction in every case [13, 14]. Until now a lot of surgical procedures have been commonly used to reach stabilization, reduction and solid interbody arthrodesis with positive outcomes [5].

Since the introduction of PLIF (posterior lumbar interbody fusion) in the 50s and TLIF (transforaminal interbody fusion) later, the effect of the intervertebral space

Table 2 Measurements of vertebral slippage on lateral lumbar X-ray according to Meyerding before and after surgical correction. ODI, VAS Back AND SF36 before surgery and at clinical follow-up

Meyerding %	Preoperatively	Postoperatively		Percentage change	<i>p</i> value
	36.2	15.8			
	Preoperatively	1-month follow-up	3-months follow-up	1-year follow-up	
ODI	36.8%	32.3%	29.8%	24.1%	0.02
VAS	7.1	4.3	3.9	2.2	0.001
SF36	33.8%	72.1%	76.3%	83.2%	0.001

distraction in conferring a stiffer primary stability of the segment of motion became evident. Both the techniques in fact allow a solid interbody vertebral arthrodesis compared to the simple posterolateral fusion (PLF). A further important biomechanical aspect related to the reduction in the slippage and the retention of the ligaments by placement of interbody cages is the redistribution and transmission of the loading forces on the anterior column of the spine. Cecchinato et al. demonstrated that 80% of weight is carried through the anterior spine [15]. PLF gives support only on the posterior column of the spine that carries less than 20% of the weight.

The extreme lateral approach to the lumbar spine allows the choice of a truly less invasive technique able to produce the same positive results achievable with the older, though nevertheless effective, open procedures.

One of the most relevant advantages in approaching the disc through retroperitoneal, transpsoas access is the availability of larger, taller and more lordotic cages that allow greater primary stability to the anterior spine compared with the stability achievable with PLIF and TLIF [16]. The footprint of a lateral cage is, in fact, greater than TLIF or PLIF cages allowing the spreading of the loading forces over a wider surface. This provides an increased biomechanical support and a smaller risk of subsidence. Furthermore, this procedure allows extensive discectomy without disruption of the anterior or posterior ligaments [17].

With regard to isthmic spondylolisthesis, the primary aim to adopt the transpsoas approach to the disc is to obtain a high grade of primary stability to a very unstable segment: the restoration of the disc height, in fact, allows an indirect correction of the slippage through the effect of the ligamentotaxis. This effect is due to the retension of the anterior and posterior longitudinal ligaments and is the same effect that occurs during the indirect reduction in bony fragments in cases of vertebral body fracture [18]. The introduction of the dilators during the disc preparation and the positioning of the appropriate height cage cause the stretching of the ligaments that draw back the upper vertebral body. An high rate of correction of the olisthesis, estimated at 56% comparing pre- and postoperative lumbar X-rays, was observed in all the cases treated with direct lateral approach.

An increasing number of papers in the literature confirms the reliability of minimally invasive procedure with transpsoas approach in the treatment of lumbar spine diseases minimizing the risks related to the open procedures [19]. Our clinical and radiographic results clearly prove that stabilization, decompression and fixation, the main goals of a surgical procedure for lumbar instability, can be easily achieved with this minimally invasive procedure. As regards the efficacy, the procedure proved reliable on lumbar pain as shown by the decreasing of the VAS (at 1-month postop), improving of ODI values already at 3-month follow-up

and patients outcome satisfaction at 1-year follow-up and beyond.

A further consideration, that strongly supports our choice of a minimally invasive approach to the spine in selected cases of isthmic spondylolisthesis, is the absence of the indication for decompressive laminectomy. In the case of isthmic spondylolisthesis, generally, there is no secondary canal stenosis as in the degenerative pathology and, even the stretched nerve roots, can easily be treated with the indirect decompression ensured by sagittal misalignment restoration (Fig. 3). In view of the above considerations, we believe that it may not be useful to perform an open procedure if a neurologic decompression is not necessary. Extensive laminectomy could be dangerous for neurologic injuries; it increases operating time and the risks of infection.

Conclusion

The availability of minimally invasive procedures could be a stimulus to change the way we have treated specific diseases of lumbar spine until now.

One of the best indication for XLIF procedure is the treatment of degenerative spondylolisthesis that typically causes stenosis of the lumbar vertebral canal. The indirect decompression of nerve roots achievable with large cages that causes a certain degree of canal and foramina enlargement is well known. Although much less frequent, a good indication for XLIF, in our opinion, is the isthmic spondylolisthesis of the lumbar spine in which a very solid implant allows a good correction of the lysis with restoration of a normal sagittal curvature.

Restoration of the disc height, achievable with large-size cages, in fact, fulfil two contemporary effects through the mechanism of ligamentotaxis: reduction in the olisthesis and neurologic decompression, avoiding the need to adopt an open, higher risk approach. A simple bilateral percutaneous posterior approach, sometimes performed in the same lateral position, is enough to complete a high rigid fixation.

Our results clearly demonstrated the efficacy of the minimally invasive surgery. In our opinion, the use of XLIF technique in spondylolisthesis allows the reduction in peri- and postoperative complications, early discharge and earlier physical and functional recovery. The long-term radiographic and clinic results show that XLIF technique produces the same mechanical stability obtained with an open procedure with a lower rate of surgically related complications. However, minimally invasive techniques require good knowledge of topographic anatomy, the ability to work safely in confined spaces and a specific training learning curve. In fact it has been shown that, during the learning curve, the extreme lateral interbody fusion associated with a minimally invasive posterior pedicle instrumentation requires longer

operative time than traditional open surgery that decreases with the surgeon's increasing ability and confidence with the technique [20].

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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