**Abstract**

Spinal stenosis and low-grade spondylolisthesis produce symptoms of neural compression that can be treated with XLIF via indirect decompression. This study aimed to investigate whether the restoration of disc dimensions would relieve symptoms of radiculopathy, claudication and back pain. In this retrospective study, patients undergoing XLIF surgery for relief of radicular symptoms or degenerative disc disease were included. Radiologically proven changes were used to assess the modes of degeneration. Objective measures such as the Visual Analogue Scale (VAS) for back and legs and the Oswestry Disability Index (ODI) were used. Complications were collated postoperatively from clinical notes and outpatient appointments. 23 consecutive patients were included, of whom 91% had spinal stenosis. The cohort presented with multiple comorbidities and 35% of the cohort had undergone previous lumbar surgery. There was a 61% improvement of coronal Cobb angle and an 11% correction of the lordosis sustained one year after surgery. Clinical outcomes at one year showed 39%, 50% and 60% improvements in the ODI, back and leg VAS scores respectively. 48% of patients had reduced sensation related to lumbosacral plexus manipulation and one retroperitoneal haematoma was conservatively managed. MIS XLIF resulted in effective restoration of disc dimensions via indirect decompression, providing good relief of clinical symptoms evidenced by significant improvement in clinical outcome scores. XLIF corrected scoliosis and improved lumbar lordosis significantly. Several plexopathies did not hinder long-term recovery. XLIF is highly suited to treating complex patients with multiple comorbidities and degenerative disease.

**Key words**

Extreme lateral interbody fusion (XLIF); spinal stenosis; spondylolisthesis; comorbidities; outcomes; sagittal balance

**Introduction**

XLIF is a minimally invasive surgical technique that allows access to the intervertebral disc space and vertebral bodies via the retroperitoneal transpsoas approach [[1](#_ENREF_1)]. The insertion of an implant, with opportunity for bony fusion, can provide indirect decompression of the neural elements at that level. As a result, XLIF is increasingly being used to treat degenerative disc disease with comorbid spondylolisthesis and scoliosis. These have a prevalence of 11.5% and 8.5% respectively, in the over 40 population [[2](#_ENREF_2), [3](#_ENREF_3)]. Such conditions, which are the result of asymmetric changes to the vertebral body and disc, can produce disc height loss and thecal or nerve root compression causing claudication or radiculopathy [[4](#_ENREF_4), [5](#_ENREF_5)]. MRI demonstrates best the spinal stenosis, defined as the narrowing of the lateral recess, neural foramen or central canal. Treatment for spinal stenosis with degenerative disc disease has traditionally been decompression surgery followed by fusion (i.e. posterior lumbar interbody fusion - PLIF) [[6](#_ENREF_6)]. XLIF however, is increasingly being used in these patient populations.

XLIF was originally developed as a way of overcoming the drawbacks of anterior and posterior lumbar interbody fusion (ALIF/PLIF), however it is increasingly being used in preference to traditional laminectomy. XLIF’s ability to indirectly decompress and thus restore disc and foraminal height resulting in symptomatic relief is its main advantage over more invasive decompression and interbody fusion surgeries. Indeed the minimally invasive XLIF approach can produce reduced postoperative pain, entry wounds, tissue trauma, operating, recovery and mobility times resulting in shorter hospital stays. A faster recovery facilitates greater adherence to rehabilitation programs and final symptom improvement [[1](#_ENREF_1)]. XLIF unlike traditional decompression surgery, such as laminectomy or foraminotomy, does not require the need to dissect the muscles surrounding the spine causing possible paraspinal muscle denervation [[7](#_ENREF_7)]. Furthermore, decompression by laminectomy can risk postoperative instability and increased functional recovery time or the need for concomitant fusion [[8](#_ENREF_8)].

XLIF is shown to have utility in complex patients with numerous comorbidities; especially diabetes mellitus and smoking that contribute to poor healing [[9](#_ENREF_9)]. Indeed, the extreme lateral approach can confer lower complications for patients who have undergone previous spinal surgeries, by avoiding the old scarred surgical plane and muscle denervation. Furthermore, larger interbody cages and more complete discectomy are possible than through a posterior approach [[10](#_ENREF_10)].

This study aimed to investigate the efficacy of XLIF in treating the symptoms of a population with multiple medical comorbidities presenting with symptoms of degenerative disc disease and spinal stenosis with comorbid spondylolisthesis or scoliosis.

**Methods**

A cohort of 23 consecutive patients with back and/or leg pain undergoing XLIF surgery performed by a single surgeon (KL) at a single NHS hospital (Guy’s and St. Thomas’ NHS Foundation Trust, London, UK) over three years from September 2012 to September 2015 was studied retrospectively.

A proforma was produced which collated demographic data such as age, primary diagnosis, comorbidities, age at operation, previous lumbar spine surgery and levels fused. Clinical data was collected from casenotes, operation charts and radiological images. Radiological assessment entailed the measurement of parameters before and after surgery. Radiographs, computed tomography (CT) and MR scans were used for data collection and the measurement of radiological angles. Radiological measurements were performed using Surgimap software (Nemaris Inc, New York, USA). Such angles included the Cobb angles, segmental lordosis angle, lordotic angle, sacral slope, pelvic incidence and pelvic tilt. Fusion grade was also assessed on post-operative radiographs and CT where available, looking for bridging bone and absence of any halo around the implant. Operation details recorded included duration of surgery, fusion product used and type of surgery. Post-operative complications were recorded from inpatient notes and clinic letters. Clinical outcome was measured using Oswestry Disability Index (ODI), Visual Analogue Scale Back (VASB) and Visual Analogue Scale Leg (VASL) scores, which were recorded before and six weeks after surgery and at six monthly follow-up thereafter with one year outcomes analysed where available. The cohort was stratified into several groups during analysis - those with central canal, lateral recess and neural foramen stenosis with or without spondylolisthesis.

**Results**

A total of 23 patients received XLIF surgery during the three-year study period. Table 1 displays the patient demographics. There was an almost equal split between males and females (11:12) with a mean age of 61 years (27 - 82) at the time of the operation. Eight (35%) of the cohort had previous spinal surgery. Of these three had undergone decompression, another three underwent fusion and one case had received a transforaminal lumbar interbody fusion (TLIF) which did not resolve the pain. The average duration of stay was 7.7 days. There was an abundance of comorbidities with an average of two per patient. One patient had as many as six comorbidities. The most commonly described was hypertension followed by hypercholesterolaemia, smoking, transient ischaemic attacks and osteoarthritis.

The L4/5 disc was most commonly operated on in 74% of patients. This was followed by the L3/4 disc in 61%. 18 patients (78%) received XLIF intervention at two or less levels and 22% received intervention at three or more levels. The latter group had an average age of 71 years, whereas those that received intervention at two or less levels had an average age of 58 years at the time of surgery.

The most common material used as a bone graft was Attrax, followed by de-mineralized bone substitute (DBS). 35% of the patients had a second posterior operation a week later; such operations included multi-level fixation with percutaneous screws. Overall, 13 patients (57%) received percutaneous screws, nine (39%) had open posterior instrumentation surgeries to correct deformity and one patient (4%) received interfacetal spacers. No patient received a standalone XLIF. The mean operation time for both the XLIF and posterior fixation combined was 222 minutes. Figures 4 and 5 illustrate typical pre- and post-operative radiographs.

The most common primary diagnosis was sciatica; Table 2 illustrates the primary diagnoses for this cohort. Radiological evidence collated from CT and MRI scans showed evidence of spinal stenosis in 91%, spondylolisthesis in 70% and scoliosis in 43%. The most common pathology was spinal stenosis presenting in 55%, followed by 12%, 23% and 20% for central canal, foraminal and lateral recess stenosis (Table 3). The most commonly degenerate disc was L4/5 in 91%. 52% were found to have abnormalities at L5/S1.

Radiological outcomes at one year were available in all 23 patients and showed two main improvements. The Cobb angle, a measure of scoliosis, was improved by 60%. The lordotic angle, which directly influences sagittal balance, was improved by 11%. There was little change in the pelvic parameters, which are displayed in Table 4 and Figure 1. Further outcomes include the correction of Cobb angles synonymous with a diagnosis of scoliosis to <10o, in six scoliotic cases (67%), the maximum correction being 46o. Fusion was confirmed radiologically in 91% of patients at one year.

Patient reported outcome measures were universally improved at one year follow-up where available. Figures 2 and 3 display these scores. Six patients (26%) had no one year outcome scores on record. Of the remaining 17 patients, the mean post-operative ODI score was reduced from 56 to 35 whilst ranging between 0 and 70, showing an improvement of 39% (s.d. 21%) in the cohort. A greater improvement was seen in the VASB and VASL scores; with an improvement of 50% (s.d. 3%) and 60% (s.d. 3%) seen respectively. The mean pre-operative VASB score decreased from 7.3 to 3.6 (s.d. 51%) following surgery and the VASL score from 7.8 to 3.1 (+60%). Patient symptoms were improved in 86% of cases; there was only one patient who reported worsening of symptoms following surgery. 50% of the 14 patient VASL and 40% of the 15 patient VASB scores collected scored their pain 2 or less at one year follow-up.

As shown in table 5, 25 non-medical post-operative complications were recorded, the most common of which was numbness, which accounted for 44%. 18% of the numbness was localised around the surgical site, a further 27% and 18% affecting the thigh and buttocks respectively. There was also back pain in 24% of cases with numerous causes, of which a psoas haematoma was notable. Other complications included one failure of preoperative footdrop to resolve, one case of dysaesthesia and one case of Staphylococcus epidermis metalwork infection. Imbalance due to altered feet sensation was recorded in 12% of patients post-operatively during clinical outpatient follow-up.

**Discussion**

XLIF is an intervention that can successfully be used in complex patients with numerous pathologies of neural compression. Its ability to treat multilevel disc disease in patients with multiple comorbidities via a minimally invasive approach is largely supported by the literature.

Regarding lumbar scoliosis, Akbarnia *et al.* report the use of XLIF in cases of severe scoliosis, with a Cobb angle of over 30o [[11](#_ENREF_11)]. McAfee et al. review the use of XLIF in treating three-dimensional deformities with two or more levels of translation whilst Gabel et al. examine the success of indirect compression in patients with spinal stenosis [[10](#_ENREF_10), [12](#_ENREF_12)]. Indeed XLIF has been used widely in our patient cohort for numerous indications from correction of a lumbar scoliosis to symptom relief in low-grade spondylolisthesis to treating spinal stenosis, vertebral fractures and failed instrumentation. XLIF can be a suitable intervention for degenerative disc disease affecting the ageing population that present with numerous pathologies.

The main aims of XLIF surgery revolve around the relief of pain and symptoms thus ultimately improving the quality of life. Rodgers *et al*. report similar patient outcomes to our cohort with nearly 90% of the 66 patients being “satisfied or very satisfied” with the outcomes of their XLIF surgery [[13](#_ENREF_13)]. The ODI score improvement in Ozgur *et al’s* series of 62 patients was akin to that of our cohort at 39% [[14](#_ENREF_14)].  Dangelmajer et al highlights the desirability of the minimally invasive approach of XLIF in its ability to reduce postoperative pain and morbidity [[15](#_ENREF_15), [16](#_ENREF_16)].

Radiographic analysis of our cohort revealed further deformities whose correction was desirable, namely spondylolisthesis or scoliosis. There was significant improvement, of 60%, in the Cobb angle following surgery. Indeed the mean angle before surgery was 15o, which is synonymous with a mild scoliosis diagnosis; this was seen to decrease to 5.7o. Cobb angles synonymous with a diagnosis of scoliosis were corrected to <10o in 67% of cases, with the maximum correction being 46o. Although there was no direct compression as a result of the scoliosis in 87% of cases, this additional effect of XLIF is beneficial and can prevent lumbar scoliosis progression, given the degenerative background of this patient population. Tormenti et al. showed a postoperative mean Cobb angle of 10o from 38.5o [[17](#_ENREF_17)]. Acosta et al. too noted excellent corrections in the coronal and sagittal plane following XLIF [[18](#_ENREF_18)].

Several spinal surgical techniques can be used to achieve either direct or indirect neural decompression. The advantage of XLIF ahead of decompressive laminectomy is that it does not destroy posterior elements and risk late kyphosis. Dangelmajer et al. suggest that in an elderly population traditional decompressive surgeries may cause recurrent radiculopathies and sagittal imbalance can be exacerbated and so XLIF is encouraged [[15](#_ENREF_15)]. Dakwar and colleagues provided evidence to support a correction of sagittal imbalance in two-thirds of patients treated [[19](#_ENREF_19), [20](#_ENREF_20)]. Furthermore, following a relatively short operation; patients recover quickly, require less hospital stay thus reducing the chance of any hospital acquired infection or medical problems which can hugely affect recovery and rehabilitation. The MIS technique has been directly credited for this improvement, especially in the elderly patient population [[15](#_ENREF_15), [21](#_ENREF_21)].

Another advantage of XLIF is its ability to restore lumbar lordosis, which can further stabilise gait and reduce sagittal imbalance. There was an increase in lumbar lordosis of 8.8% bringing the average lordotic angle to 35.0 ± 9.8o, which is closer to the mean lordotic angle in the general population of 33.2 ± 12.1o [18]. Tormenti reports an average post-operative lumbar lordotic angle of 40.4° from 47.3°, again closer to that of the normal angle, further evidencing the increase in sagittal balance as a result of XLIF intervention [[17](#_ENREF_17)]. Further evidence can be drawn from two other studies, which also reported an increase in lumbar lordosis, whereas Johnson et al. described no change at all [[22](#_ENREF_22)]. Phan et al. concludes that MIS XLIF is a favourable intervention for correction of sagittal balance and lumbar lordosis [[23](#_ENREF_23)].

In comparison to laminectomy, which is traditionally used to directly decompress symptomatic spinal stenosis, XLIF relies on the insertion of an implant and indirect compression to relieve compression symptoms, restoring disc and foraminal height, as seen in Figure 1 and 2. Gabel et al review several authors’ use of indirect compression ahead of traditional decompressive surgeries. They show significant improvements to disc dimensions and improved symptoms. This has been supported by Malham who concludes that significant indirect neural decompression is possible with XLIF and Arnold et al whose review produced evidence to show adequate neural decompression and substantial dimensional improvement on all radiological parameters for patients presenting with spinal stenosis [[24](#_ENREF_24), [25](#_ENREF_25)]. Oliveira et al. demonstrated XLIF’s ability to provide the necessary decompression to relieve symptoms, with significant improvements in central canal diameter, disc height, foraminal height and area [[26](#_ENREF_26)]. Their clinical outcomes reflected the radiological improvements with 96% of patients reporting an improvement of symptoms postoperatively and 100% of patients reporting an improvement of symptoms by the most recent follow up. It can therefore be concluded that XLIF may indirectly decompress the neural element carrying spinal spaces to produce significant benefit in patient outcome and radiological parameters.

Regarding patient outcomes, XLIF showed promising results. Malham et al. matched the outcomes of our cohort showing an ODI improvement from 55.3 to 30.7 (44.4%) at 12 months [[25](#_ENREF_25)]. Youssef *et al.* report good patient and surgical outcomes in their 84 patient series [[21](#_ENREF_21)]. Phillips et al. showed a mean ODI score improvement from 48 to 26 (+46%) post-operatively [[27](#_ENREF_27)]. The improvement in XLIF was not limited to just the ODI scores but universally across both VAS scores. Our cohort showed a decrease in the VASB and VASL scores after surgery. Malham and his colleagues showed greater reductions with mean VASB and VASL scores improving from 8.5 to 3.5 (+56.8%) and 8.7 to 2.6 (+60%) [[25](#_ENREF_25)]. Phillips showed improvements in VASB and VASL scores which were decreased from 7.4 to 3.8 and 6.2 to 2.6 [[27](#_ENREF_27)]. Alimi et al. also showed a postoperative drop of 5.6 and 4.5 points for the VASB and VASL scores [[4](#_ENREF_4)]. Although pain free outcomes are highly unlikely due to the elderly patient population and complex degenerative nature often with concomitant deformity of the conditions treated, several studies show objective measures of symptom improvement with XLIF.

The patient demographic for whom XLIF is used varies in the literature. XLIF as an intervention for primarily age related spinal disease was universal, with one study quoting a mean patient age of 65 with a range of 56 to 68 years [[15](#_ENREF_15)]. Our patient ages ranged from 27 to 82 years without the presence of any statistical outliers. The primary diagnoses in our study showed spinal stenosis with sciatic symptoms to be the most common mode of presentation. 91% (21) of patients in this cohort had evidence of degenerative disease on radiological imaging. Malham et al shows similar results with the primary diagnosis of all 40 patients treated with XLIF being degenerative [[25](#_ENREF_25)]. The patient population selected for XLIF is therefore emerging as elderly and complex with multiple pathologies and comorbidities.

Gabel et al’s development of an algorithm that can be used to select patients for maximal benefit from indirect decompression was founded on the failure of XLIF following the presence of bony lateral recess stenosis or unstable spondylolisthesis [[12](#_ENREF_12)]. They concluded that the presence of osteoporosis amongst others was detrimental to the success of XLIF intervention. This was highlighted in our study with the case of an 82-year-old woman suffering from multilevel degenerative disc disease with a diagnosis of osteopenia. Her VASB score improvement following XLIF was half of the average improvement; furthermore this woman experienced a 140% increase in her VASL score. However, with multiple comorbidities and previous lumbar surgery it is hard to be certain of causation.

The presence of comorbidities favoured XLIF over more invasive decompressive surgery, although there is evidence to suggest that certain comorbidities produce worse prognoses. Lee explores the risks associated with diabetes, such as that of poor healing, and whether such comorbidity would favour XLIF due to the minimally invasive approach. Lee goes further to suggest that diabetes may even be a risk factor for screw loosening and poor long term outcomes. Old age was identified as another risk factor [[28](#_ENREF_28)]**.** This complication was not observed after two years of clinic follow up in a 75-year-old patient in our cohort, who was diabetic. Isaacs *et al*. report that the presence of one or more comorbidity increased the incidence of complications following XLIF. 28% of patients in the Isaacs study were found to have at least one comorbidity [[29](#_ENREF_29)]. This strongly contrasted our study, in which 74% of patients had at least one comorbidity. This high comorbidity rate could not be explained by a significant difference in age. Our high rate of comorbidity did not however affect our incidence of complications, which mainly consisted of pain and numbness from presumed neuropraxias.

The complication rate for MIS XLIF was largely lower than any other open decompression surgery both intra and postoperatively. Intraoperatively, the surgery is shorter with a reduced risk of blood loss, muscle denervation, nerve injury and dural tear. Isaacs et al. described a 12.1% major complication rate in his study, which compares well to corrective degenerative surgery from other studies [[29](#_ENREF_29)]. Dangelmajer et al. produced an average complication rate of 18.7% (0-30%) for the studies analysed [[15](#_ENREF_15)]. Ozgur et al. reports a 19% minor complication rate, of which hip flexion weakness was the most common and typically resolved six weeks post-surgery [[14](#_ENREF_14)]. Berjano et al. described 97 XLIF cases in which only 9% reported transient numbness and 7% reported transient neurological symptoms within the first month post operatively [[11](#_ENREF_11)]. Berjano acknowledges a 92% post-operative success rate and goes to affirm the safety and efficacy of MIS XLIF technique. Papanastassiou et al. reported two cases that developed contralateral femoral nerve compression, which was explained by overzealous endplate removal during surgery [[30](#_ENREF_30)]. Le et al. observed 6 complications in 101 patients (6%) who underwent XLIF surgery; three vertebral body fractures and three cases of hardware failure [[31](#_ENREF_31)]. Some literature presents a low rate of complications for XLIF surgery. The current cohort did not share this; there were a total of 25 complications in 18 patients (78%). This difference may be due to the definition of a complication. Of the 25 complications 44% (11) were transient numbness found at follow up, 24% (6) were non-resolving pain and only 24% (6) were significant other complications. Indeed it must be reiterated that in such a heterogeneous and elderly patient population it is unrealistic to expect pain free outcomes, this is further reflected in the post-operative patient outcome scores across the literature. Nonetheless, a major complication rate of 24% is high. Three of the six complications related to reduced confidence walking due to reduced ipsilateral leg sensation. Of the other three, one was the failure to improve a case of preoperative footdrop; the development of a psoas haematoma and a Staphylococcus epidermis infection of the metal work. The psoas haematoma was completely resolved with the patient reporting an ODI score of 0 at six weeks’ follow up, whereas the infection necessitated a revision ALIF surgery.

Other noteworthy complications include dyaesthesia which is a known complication due to lumbar plexus irritation intraoperatively. One episode of pain presented post-operatively on the contralateral side to the original side of complaint, which mirrors Papanastassiou’s observations. Furthermore, one patient, who was therefore excluded from this study, had the XLIF surgery aborted due to the obstruction of the disc space by the femoral nerve. Le et al remarked on three cases of hardware failure. Indeed there was one case of a repeated XLIF within our cohort.

In the face of all the aforementioned potential virtues of XLIF, it is limited in several regards. XLIF is not able to access the L5/S1 disc space. This was significant given the abundance of pathology present in that disc space, 14% of all pathology observed, a problem also highlighted by Arnold et al. Arnold goes further to highlight the unsuitability of the approach for congenital stenosis [[24](#_ENREF_24), [26](#_ENREF_26)].

This study had several limitations of which the heterogeneity of the patient population was the greatest. The complexity of the patients combined with the multiple comorbidities and prevalence of previous lumbar spinal surgery is a common issue within the literature [[15](#_ENREF_15)]. Further annual follow-up beyond one year is desirable to assess long-term clinical outcomes and radiological parameters of sagittal balance and fusion.

To conclude, MIS XLIF has produced results that show effective restoration of disc dimensions via indirect decompression, thus providing good relief of clinical symptoms evidenced by significant improvement in clinical outcome scores. The radiological evidence produced supports this statement, highlighting the responsiveness of scoliosis to XLIF intervention and suggesting restoration of lumbar lordosis and high fusion rate. XLIF produced largely transient complications with no effect on long-term recovery and morbidity. As a result, XLIF is highly suited to treating complex patients with multiple comorbidities and degenerative disease, namely spinal stenosis and spondylolisthesis.

**References**

[1] Ozgur BM, Aryan HE, Pimenta L, Taylor WR. Extreme Lateral Interbody Fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion. The spine journal : official journal of the North American Spine Society. 2006;6:435-43.

[2] Kalichman L, Kim DH, Li L, Guermazi A, Berkin V, Hunter DJ. Spondylolysis and spondylolisthesis: prevalence and association with low back pain in the adult community-based population. Spine. 2009;34:199-205.

[3] Kebaish KM, Neubauer PR, Voros GD, Khoshnevisan MA, Skolasky RL. Scoliosis in adults aged forty years and older: prevalence and relationship to age, race, and gender. Spine. 2011;36:731-6.

[4] Alimi M, Hofstetter CP, Tsiouris AJ, Elowitz E, Härtl R. Extreme lateral interbody fusion for unilateral symptomatic vertical foraminal stenosis. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society. 2015;24 Suppl 3:346-52.

[5] Di Silvestre M, Lolli F, Bakaloudis G. Degenerative lumbar scoliosis in elderly patients: dynamic stabilization without fusion versus posterior instrumented fusion. The spine journal : official journal of the North American Spine Society. 2014;14:1-10.

[6] Gibson JNA, Depreitere B, Pflugmacher R, Schnake KJ, Fielding LC, Alamin TF, et al. Decompression and paraspinous tension band: a novel treatment method for patients with lumbar spinal stenosis and degenerative spondylolisthesis. The spine journal : official journal of the North American Spine Society. 2015;15:S23-32.

[7] Hsu H-T, Li H-Y, Tu C-W, Huang K-F. Surgical outcomes of a modified Marmot operation with transverse cutting of the spinal process in patients with degenerative lumbar spinal stenosis. Tzu Chi Medical Journal. 2015;27:79-82.

[8] Gelalis ID, Stafilas KS, Korompilias AV, Zacharis KC, Beris AE, Xenakis TA. Decompressive surgery for degenerative lumbar spinal stenosis: long-term results. International orthopaedics. 2006;30:59-63.

[9] Takahashi S, Suzuki A, Toyoda H, Terai H, Dohzono S, Yamada K, et al. Characteristics of diabetes associated with poor improvements in clinical outcomes after lumbar spine surgery. Spine (Phila Pa 1976). 2013;38:516-22.

[10] McAfee PC, Shucosky E, Chotikul L, Salari B, Chen L, Jerrems D. Multilevel extreme lateral interbody fusion (XLIF) and osteotomies for 3-dimensional severe deformity: 25 consecutive cases. International journal of spine surgery. 2013;7:e8-e19.

[11] Berjano P, Lamartina C. Far lateral approaches (XLIF) in adult scoliosis. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society. 2013;22 Suppl 2:S242-53.

[12] Gabel BC, Hoshide R, Taylor W. An Algorithm to Predict Success of Indirect Decompression Using the Extreme Lateral Lumbar Interbody Fusion Procedure. Curēus. 2015;7:e317-e.

[13] Rodgers WB, Gerber EJ, Patterson JR. Fusion after minimally disruptive anterior lumbar interbody fusion: Analysis of extreme lateral interbody fusion by computed tomography. SAS journal. 2010;4:63-6.

[14] Ozgur BM, Agarwal V, Nail E, Pimenta L. Two-year clinical and radiographic success of minimally invasive lateral transpsoas approach for the treatment of degenerative lumbar conditions. SAS journal. 2010;4:41-6.

[15] Dangelmajer S, Zadnik PL, Rodriguez ST, Gokaslan ZL, Sciubba DM. Minimally invasive spine surgery for adult degenerative lumbar scoliosis. Neurosurgical focus. 2014;36:E7-E.

[16] McAfee PC, Garfin SR, Rodgers WB, Allen RT, Phillips F, Kim C. An attempt at clinically defining and assessing minimally invasive surgery compared with traditional "open" spinal surgery. SAS journal. 2011;5:125-30.

[17] 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. Neurosurgical focus. 2010;28:E7-E.

[18] 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.

[19] 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:E8.

[20] Lin RM, Jou IM, Yu CY. Lumbar lordosis: normal adults. Journal of the Formosan Medical Association = Taiwan yi zhi. 1992;91:329-33.

[21] 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. 2010;35:S302-11.

[22] Johnson RD, Valore A, Villaminar A, Comisso M, Balsano M. Pelvic parameters of sagittal balance in extreme lateral interbody fusion for degenerative lumbar disc disease. J Clin Neurosci. 2013;20:576-81.

[23] Phan K, Rao PJ, Scherman DB, Dandie G, Mobbs RJ. Lateral lumbar interbody fusion for sagittal balance correction and spinal deformity. Journal of clinical neuroscience : official journal of the Neurosurgical Society of Australasia. 2015;22:1714-21.

[24] Arnold PM, Anderson KK, McGuire RA. The lateral transpsoas approach to the lumbar and thoracic spine: A review. Surgical neurology international. 2012;3:S198-215.

[25] Malham GM, Ellis NJ, Parker RM, Blecher CM, White R, Goss B, et al. Maintenance of Segmental Lordosis and Disc Height in Standalone and Instrumented Extreme Lateral Interbody Fusion (XLIF). Journal of spinal disorders & techniques. 2014.

[26] 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. 2010;35:S331-7.

[27] Phillips FM, Isaacs RE, Rodgers WB, Khajavi K, Tohmeh AG, Deviren V, et al. Adult degenerative scoliosis treated with XLIF: clinical and radiographical results of a prospective multicenter study with 24-month follow-up. Spine. 2013;38:1853-61.

[28] Lee YS, Park SW, Kim YB. Direct lateral lumbar interbody fusion: clinical and radiological outcomes. Journal of Korean Neurosurgical Society. 2014;55:248-54.

[29] 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. 2010;35:S322-30.

[30] Papanastassiou ID, Eleraky M, Vrionis FD. Contralateral femoral nerve compression: An unrecognized complication after extreme lateral interbody fusion (XLIF). Journal of clinical neuroscience : official journal of the Neurosurgical Society of Australasia. 2011;18:149-51.

[31] Le TV, Smith DA, Greenberg MS, Dakwar E, Baaj AA, Uribe JS. Complications of lateral plating in the minimally invasive lateral transpsoas approach. Journal of neurosurgery Spine. 2012;16:302-7.

**Table 1. Patient demographics, common comorbidities and levels treated.**

|  |  |
| --- | --- |
| Mean age at surgery | 61 (s.d. 13) years |
| Gender (M:F) | 11:12 |
| Diabetes | 13.0% |
| Smoking | 13.0% |
| Hypertension | 47.8% |
| Previous spine surgery | 34.8% |
| Pure XLIF | 65.2% |
| Total number of levels fixed | 42 |
| * L1/2 | 3 |
| * L2/3 | 8 |
| * L3/4 | 14 |
| * L4/5 | 17 |

**Table 2. Frequency of primary diagnoses.**

|  |  |
| --- | --- |
| Primary diagnoses | Frequency |
| Sciatica | 13 |
| Degenerative scoliosis | 8 |
| Disc failure | 4 |
| Degenerative spondylolisthesis | 2 |
| Broken metal work | 1 |
| Presence of back pain | 18 |
| Presence of leg pain | 16 |

**Table 3. Frequency of pre-operative radiological abnormalities.**

|  |  |
| --- | --- |
| Radiological evidence | Frequency |
| Spinal stenosis (CC, LR, NF) | 21 |
| Spondylolisthesis | 17 |
| Scoliosis | 10 |
| No pathology | 1 |
| * 1 pathology | 4 |
| * 2 pathologies | 11 |
| * 3 pathologies | 7 |
| Disc Height Loss | 11 |
| * L1/2 | 1 |
| * L2/3 | 3 |
| * L3/4 | 3 |
| * L4/5 | 5 |
| * L5/S1 | 2 |

**Table 4. Frequency of MRI findings of stenosis or other abnormalities.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | L1/2 | L2/3 | L3/4 | L4/5 | L5/S1 | TOTAL |
| Neural Foramen | 2 | 4 | 2 | 12 | 5 | **25** |
| Central Canal |  | 1 | 6 | 6 |  | **13** |
| Lateral Recess | 1 | 2 | 5 | 12 | 1 | **21** |
| Disc Bulge | 1 | 2 | 1 | 6 | 4 | **14** |
| Fracture # | 1 | 2 | 1 |  |  | **4** |
| Facet Degeneration | 1 | 1 | 1 | 1 | 1 | **5** |
| Spondylolisthesis |  | 2 | 5 | 7 | 2 | **16** |
| Pars defect |  |  | 1 |  |  | **1** |
| Pseudoarthritis |  |  |  | 1 |  | **1** |
| Fusion |  |  |  | 1 | 1 | **2** |
| Cyst |  |  | 1 | 3 |  | **4** |
| Schmorl’s Nodes |  |  |  | 1 | 1 | **2** |
| TOTAL | **6** | **14** | **23** | **50** | **15** | **108** |

**Table 5. Frequency of complications after surgery.**

|  |  |
| --- | --- |
| **Complication** | **Frequency** |
| Numbness | 11 |
| Pain | 6 |
| Imbalance from altered sensation | 3 |
| Infection | 1 |
| Footdrop | 1 |
| Dysaesthesia | 1 |
| Psoas haematoma | 1 |
| Anaemia needing blood transfusion | 1 |

**Figure 1. Changes in radiological measures one year after surgery.** COB, cobb angle; SEG, segmental lordosis; LOR, overall lordosis; SS, sacral slope; PT, pelvic tilt; PI, pelvic incidence

**Figure 2. Pain improvements one year after surgery.** VASB, back visual analog score; VASL, leg visual analog score.

g**Figure 3. Oswestry Disability Index improvements one year after surgery**

**Figure** **4.** Pre-operative posteroanterior and lateral spinal radiographs for a 51-year-old man who underwent XLIF for consistent back pain and left sided sciatica, scoring 7 for both VASL and VASB.

**Figure 5.** Postoperative posteroanterior and lateral spinal radiographs for a 51 year old gentleman who underwent XLIF for consistent back pain and left sided sciatica and scored 3 for VASB and 1 for VASL one year after surgery.