Outcome After Extreme Lateral Transpsoas Approach: Corpectomies Versus Interbody Fusion

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■ INTRODUCTION: **The lateral transpsoas approach (LTPA) has gained popularity in thoracolumbar spine surgery procedures; however, there is an insufficient amount of data pertaining to motor and sensory complications that arise when a corpectomy is performed through the LTPA approach.**

■ METHODS: **Patients who underwent a corpectomy through a LTPA at a single institution between 2006 and 2016 were analyzed. Demographics, neurological outcomes, and complications were recorded. The minimum follow-up was 6 months. Univariate analysis was performed to compare demographics, surgical characteristics, complications, and outcome scores. To compare categorical variables, the χ^2 test was used. For continuous outcomes, simple linear regression was used. Statistical significance was set at $P < 0.05$.**

■ RESULTS: **A total of 166 patients were included. The patients were divided into 2 groups; LTPA without corpectomy (n = 112) versus LTPA with corpectomy (n = 54). Patients without corpectomy showed a significantly lower rate of postoperative infections compared with patients with corpectomy (3.6% vs. 22.2%; $P < 0.000$). A higher percentage of postoperative complications was found in patients with corpectomy (31.5% vs. 13.4%; $P = 0.006$). The rate of neurologic complications at the 6-month follow-up and the reoperation rate (22.7% vs. 32.4%; $P = 0.256$) were higher in the corpectomy group (8.9% vs. 7.4%; $P = 0.741$), no significant difference was found between the groups.**

■ CONCLUSION: **Patients who underwent an LTPA corpectomy have a higher risk to suffer from postoperative complications. The results at the 6-month follow-up did not significantly differ between the groups.**

INTRODUCTION

Minimally invasive approaches to the spine are continually evolving to improve the effectiveness of treatment and reduce approach-related morbidity.[1] An example of this approach is the lateral transpsoas approach (LTPA), which was first described by Ozgur et al. in 2006.[2] The use of the LTPA has increased because of its advantages such as low tissue trauma, low blood loss, preservation of the posterior ligamentous elements, direct disc exposure allowing complete disc removal, and positioning of a large interbody implant with the engagement of the apophyseal ring leading to increases in disc height and indirect decompression.[3] One major drawback of the LTPA is that lumbar nerve root contributions to the lumbar plexus are located within the psoas muscle; therefore, neurological complications can be high. Several recommendations and techniques have been described to counteract against injury of the lumbar plexus nerves, which often are encountered because of a long surgical time with an increased retractor time or direct mechanical trauma. As the use of LTPA procedures continue to increase, it is important for surgeons to remain aware of procedural complications. The incidence of neurologic complications is well known and has been published and described extensively[4-13]; therefore, intraoperative fluoroscopy, direct visualization, and neuro-monitoring are essential to minimizing complications. Despite these precautions, the overall complication rate for the LTPA averages at 18% in the literature.[11] Hip flexion weakness is reported in 1%–8% of cases. Sensory nerve injury is 5%–49%. The most

Key words
- Complications
- Corpectomy
- Interbody fusion
- Lateral transposes approach

Abbreviations and Acronyms
LTPA: Lateral transpsoas approach

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common nerve occurs at the L4-5 level, involving the femoral nerve. Vascular injury and bowel injury as well as surgical site infection are other complications associated with LTPA.[14] Meanwhile, interbody fusion using LTPA is frequently used for the correction of scoliosis because it can assist with both sagittal and coronal deformity corrections with similar or better outcomes regarding pain and disability relief compared with direct posterior approaches.[14-17]

There is a lack of data regarding motor and sensory complications that arise when a corpectomy is performed through an LTPA. During that procedure, a retractor is inserted and expanded to perform 2 discectomies (above and below the vertebral body undergoing resection) followed by resection of the vertebral body and implant placement. This is often followed by posterior pedicle instrumentation of 1 or 2 levels above and below the resected vertebrae. In comparison to interbody fusion, performing a corpectomy results in a longer procedural time (the retractor is opened for an extended time) and needs a wide retractor opening to expose the area necessary for the procedure, which may result in a higher amount of postoperative motor and sensory complications compared to interbody fusion.

The purpose of this study was to describe 1) complications associated with LTPA corpectomies, 2) incidence of neurological complications, 3) reoperation rate, and 4) to compare the results with patients who underwent LTPA interbody fusion.

PATIENTS AND METHODS

From 2006 to 2016, all patients who underwent an LTPA at a single institution were analyzed. Institutional review board approval was obtained before data collection and analysis. Patients younger than 18 years and older than 75 years were excluded from the study. Demographics included age, gender, presenting symptoms, body mass index, smoking status, and comorbidities. Length of stay was recorded and pre- and postoperative opioid use was documented. Complications were assessed including the incidence of postoperative nerve root palsies, surgical complications, and reoperation rates in patients undergoing LTPA with interbody fusion or corpectomy listed above for trauma, tumor, infections, and degenerative conditions. Postoperative improvement in radiculopathy was documented. All patients had a minimum follow-up of 6 months. Patients were assessed using standard imaging with plain x-rays and computed tomography scans. Patients who underwent LTPA without corpectomy were compared with patients who underwent LTPA with corpectomy and vertebral body replacement. Univariate analysis was performed to compare demographics, surgical characteristics, complications, and pain outcomes. For categorical variables, frequency counts were computed and presented along with their percentages. For continuous variables, means were computed and presented along with their standard deviation. The χ^2 test was used to compare categorical variables. For continuous outcomes, simple linear regression was used. Statistical significance was set at $P < 0.05$.

RESULTS

A total of 166 patients were included. The mean age was 66.0 ± 10.4 years. The gender ratio was equal, with 50.0% male and 50.0% female patients. The patients were divided into 2 groups: LTPA without corpectomy (n = 112) and LTPA with corpectomy (n = 54). The groups were similar with respect to body mass index (30.2 ± 5.6 vs. 29.0 ± 6.0; P = 0.194), male gender (52.7% vs. 44.4%; P = 0.320), and comorbidities (smoking, chronic obstructive pulmonary disease, diabetes). There were significantly more patients in the corpectomy group with cardiovascular disease (64.8% vs. 42.9%; P = 0.008). Patients who underwent a corpectomy showed significant differences in the preoperative symptoms (P < 0.000) with more back pain and less radiculopathy as a single symptom. Demographics and preoperative symptoms are summarized in Table 1.

Indications for corpectomies included tumor (16.7%), degenerative disease (35.2%), trauma (29.6%), and infection (18.5%). Patients who underwent a corpectomy had a significantly higher length of stay (7.8 ± 4.3 days vs. 3.1 ± 4.3 days; P < 0.000). In 37.0% of cases, 4 levels or more (vs. 0.9%; P < 0.000) were addressed. The thoracolumbar junction was the most involved region in the LTPA corpectomy group (37.0% vs. 2.7%; P < 0.000). A total of 75.3% of the patients completed their 6-month follow-up. The results are summarized in Table 1.

Patients without corpectomy showed a significantly lower rate of postoperative infections (3.6% vs. 22.2%; P < 0.000). A higher percentage of postoperative complications was found in patients who underwent a corpectomy (31.5% vs. 13.4%; P = 0.006). The rate of neurologic complications at the 6-month follow-up was lower in the LTPA group without corpectomy (22.7% vs. 32.4%; P = 0.256), but without significant difference amongst the groups. The reoperation rate in the LTPA group with corpectomy group was higher (9.8% vs. 7.4%; P = 0.741), but did not vary at a significant difference (P = 0.741). Postoperative complications and follow-up results are summarized in Table 1.

DISCUSSION

This study aimed to analyze complication rates and neurological outcomes after corpectomy using the LTPA approach. Previously published literature focused on postoperative nerve root palsies after single-level discectomies and interbody fusion using the LTPA and outlined the correlation of nerve root injuries dependent on the location of the lumbar plexus. The most challenging level, even for well-experienced LTPA surgeons, is L4-L5 because of a high incidence to femoral nerve palsies. Experienced LTPA surgeons recommend a short retractor insertion time to minimize lumbar plexopathy due to nerve compression or stretch injury.[18-20] Bendersky et al. demonstrated, in their retrospective review, that a retraction time of less than 20 minutes did not cause lumbar plexopathy; causing the recommendation, that retraction times be kept to a minimum, aiming to be less than 20–30 minutes per operative level.[21] Other recommendations include a minimal amount of psoas dissection, minimal retractor expansion, and the use of intraoperative monitoring to avoid nerve root transection or damage during retractor docking.[22]

Furthermore, the thickness of the psoas is inversely proportional to femoral nerve translation during retractor translation. Displacement and strain upon the lumbar plexus with subsequent translation may reduce blood flow of the vasa nervorum and could lead to injury.[23] A small psoas has been predicted to be a risk factor for the development of neurological deficits after LTPA.[24]

Table 1. Demographics, Surgical Characteristics, and Postoperative Complications

	Total N = 166	No Corpectomy n = 112	Corpectomy n = 54	*P* Value
Demographics				
Age	66.0 ± 10.4	67.0 ± 9.6	64.1 ± 11.6	0.094
BMI	29.8 ± 5.8	30.2 ± 5.6	29.0 ± 6.0	0.194
Male	50.0 (83)	52.7 (59)	44.4 (24)	0.320
Smoking	24.1 (40)	26.8 (30)	18.5 (10)	0.243
Cardiovascular	50.0 (83)	42.9 (48)	64.8 (35)	0.008
COPD	2.4 (4)	2.7 (2.7)	1.9 (1)	0.745
Diabetes	22.3 (37)	23.2 (26)	20.4 (11)	0.680
Preoperative symptoms				<0.000
Back pain only	16.9 (28)	8.0 (9)	35.2 (19)	
Radiculopathy only	15.7 (26)	20.5 (23)	5.6 (3)	
Both	67.5 (112)	71.4 (80)	59.3 (32)	
Preoperative opioids	55.4 (92)	56.3 (63)	53.7 (29)	0.757
Surgical characteristics				
Indication for corpectomy				<0.000
Tumor	5.4 (9)	0.0 (0)	16.7 (9)	
Degenerative	11.5 (19)	0.0 (0)	35.2 (19)	
Trauma	9.6 (16)	0.0 (0)	29.6 (16)	
Infection	6.0 (10)	0.0 (0)	18.5 (10)	
Length of stay (days)	4.6 ± 4.8	3.1 ± 4.3	7.8 ± 4.3	<0.000
No. of levels treated				<0.000
≤3	87.3 (145)	111 (99.1)	63.0 (34)	
≥4	12.7 (21)	0.9 (1)	37.0 (20)	
Level				<0.000
Lumbar	81.9 (136)	94.6 (106)	55.6 (30)	
Thoracolumbar	13.9 (23)	2.7 (3)	37.0 (20)	
Thoracic	4.2 (7)	2.7 (3)	7.4 (4)	
Postoperative opioids				0.043
Stop of opioids	5.4 (9)	4.5 (5)	7.4 (4)	
Decrease	12.1 (20)	17.0 (19)	1.9 (1)	
Continued	45.8 (76)	43.8 (49)	50.0 (27)	
Started opioids	36.8 (61)	34.8 (39)	40.7 (22)	
6-month follow-up	75.3 (125)	78.6 (88)	68.5 (37)	0.159
Postoperative complications				
1 or more postoperative complication	19.3 (32)	13.4 (15)	31.5 (17)	0.006
CSF leak	2.4 (4)	3.6 (4)	0.0 (0)	0.160
Infection	9.6 (16)	3.6 (4)	22.2 (12)	<0.000
Hardware complication	1.2 (2)	0.9 (1)	1.9 (1)	0.596
UTI	3.6 (6)	3.6 (4)	3.7 (2)	0.966
Ileus	1.2 (2)	0.9 (1)	1.9 (1)	0.596

Continues

Table 1. Continued

	Total N = 166	No Corpectomy n = 112	Corpectomy n = 54	*P* Value
Pneumonia	1.8 (3)	0.9 (1)	3.7 (2)	0.196
Wound complication	1.2 (2)	0.9 (1)	1.9 (1)	0.596
Pneumothorax/pleural effusion	1.8 (3)	0.9 (1)	3.7 (2)	0.203
Pneumoperitoneum	0.6 (1)	0.9 (1)	0.0 (0)	0.486
DVT/pulmonary embolism	1.2 (2)	0.0 (0)	3.7 (2)	0.040
6-month neurological complications*				
Any neurologic complication	25.6 (32)	22.7 (20)	32.4 (12)	0.256
Sensory	20.0 (25)	18.2 (16)	24.3 (9)	0.433
Motor	6.4 (8)	5.7 (5)	8.1 (3)	0.613
Reoperation				
Reoperation	8.4 (14)	8.9 (10)	7.4 (4)	0.741
Reason for reoperation				0.303
Tumor growth	1.2 (2)	0.9 (1)	1.9 (1)	
Decompress/foraminotomy	3.6 (6)	5.4 (6)	0.0 (0)	
Pseudarthrosis	1.8 (3)	0.9 (1)	3.7 (2)	
Cage revision	1.2 (2)	1.8 (2)	0.0 (0)	
Wound complication	1.2 (2)	0.9 (1)	1.9 (1)	

Results presented as either % (n) or mean ± SD.
BMI, body mass index; COPD, chronic obstructive pulmonary disease; CSF, cerebrospinal fluid; DVT, deep vein thrombosis; UTI, urinary tract infection.
*In patients who attended 6-month follow-up (n = 125, 75.3% follow-up).

Approach-related complications such as groin and anterior thigh pain are described in 10%–30% of cases[25-27] as a result of upper lumbar plexopathy caused by stretch injury through retraction or sensory nerve injury on approach. Short-term thigh dysesthesia and hip flexor weakness often occur because of direct trauma to the psoas muscle but resolve quickly in most cases.[21] Groin and thigh hyperesthesia is likely the result of injury of the iliohypogastric or ilioinguinal nerve during preparation through the abdominal wall, usually resolving spontaneously.[28] Dakwar et al. and Oliveira et al. reported transient postoperative anterior thigh numbness, ipsilateral to the side of approach in 12% and 14.3% of cases respectively.[3,29]

Nerve root injury or ureteral injury is uncommon in LTPA procedures.[30] Motor deficits are 1 of the biggest challenges among spinal surgeons and have been discussed frequently in relation to the LTPA. There is a theoretical increased risk of developing motor complication at the L4-5 level as the neurovascular structures are located more anteriorly and in the "operative zone" in 44% of cases.[28] Knight et al. reported 2 cases (3.4%) of permanent motor deficits thought to be due to injury to the L4 root.[31] The largest series in literature by Rodgers et al. found motor deficits in 4 of 600 patients (0.7%).[32] Overall, the data support a low risk of motor deficit for LTPA with interbody fusion performed at L4/5. Rodgers et al. reported that 600 patients who underwent LTPA interbody fusion had no vascular or intraoperative visceral injuries.

Our results showed a significantly higher rate of complications in patients who underwent an LTPA with corpectomy, which might be explained by the fact that patients frequently underwent a more invasive surgery—with level 4 or more. This may also play a role in the significantly higher length of stay, more pulmonary embolism, and less decrease in postoperative opioid use. Furthermore, there were significantly more patients suffering from cardiovascular disease in the corpectomy group. Smith et al. reported a complication rate of 15.4% in 52 patients who underwent a mini-open lateral corpectomy for a traumatic pathology (T7-L4).[33] Similar results were observed by Baaj et al. with a reported complication rate of 12.5%.[34] A study of 19 patients by Tan et al., who performed an LTPA for corpectomies in the thoracolumbar spine supplemented with percutaneous posterior pedicle fixation in metastatic disease, found an average procedural time of 188 minutes for single-level corpectomies. Their overall complication rate was 15.8%, with 1 perioperative mortality. They observed a significant increase in vertebral body height, with improvements in lumbar lordosis and thoracic kyphosis. The levels performed included L1 (8 patients), L2 (2 patients), and L3 (2 patients). Four patients had preoperative

neurologic deficits, and all improved postoperatively. Three patients required chest tube placement for violation of the pleura, and 1 patient required hardware revision. Their overall postoperative complication rate was 25% with a reoperation rate of 17% and an average length of surgery of 288 minutes. A study of 16 patients undergoing an LTPA with a supplemental posterior fixation for acute (within 24 hours) and hyperacute (within 8 hours) thoracolumbar traumatic burst fractures reported an average procedure time of 2.7 hours with an average blood loss of 646 mL. Almost all patients had near or complete recovery of neurological function with 1 ASIA grade improvement in 73% of patients, and 2 grade improvements in 20% (Smith et al.).

There were more pneumothorax and/or pleural effusion in the corpectomy group, which might be associated with the fact that those patients underwent significantly more often a surgery at the thoracolumbar junction.

At the 6-month follow-up, we observed no differences between the groups with regard to the neurological outcome. Corpectomy should be performed carefully and may require the use of angled retractor blades or resection of a rib in the thoracic/thoracolumbar spine. As stated by Malham et al., the exposure of the thoracolumbar spine via a minimally invasive LTPA approach for a corpectomy is almost identical to the regular exposure utilized for single-level lateral interbody fusions.[35]

The observed reoperation rate was 7.4% in the LTPA group with corpectomy and 8.9%, respectively, without corpectomy. Reason for reoperation included tumor growth, decompression/foraminotomy, cage revision, and wound complication. Our nonunion rate was 1.8%. A high fusion rate (Malham. 85.3%; Berjano. 98.0%; Rodgers. 93.2%) for the LTPA has been reported in several studies.[36-38]

This study is limited by its retrospective nature, the limited subanalysis, the short follow-up, and patients lost to follow-up. Nevertheless, our results are comparable with those found in the available literature.

CONCLUSION

Patients who undergo an LTPA corpectomy have a higher risk of suffering from postoperative complications. The results at 6 months did not differ between groups. This study suggests that lateral lumbar corpectomies may be performed safely with the use of intraoperative monitoring. A prospective study is necessary to provide stronger evidence.

REFERENCES

1. Wang MY, Mummaneni PV. Minimally invasive surgery for thoracolumbar spinal deformity: initial clinical experience with clinical and radiographic outcomes. *Neurosurg Focus*. 2010;28:E9.
2. Ozgur BM, Aryan HE, Pimenta L, Taylor WR. Extreme lateral interbody fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion. *Spine J*. 2006;6:435-443.
3. 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.
4. Bergey DL, Villavicencio AT, Goldstein T, Regan JJ. Endoscopic lateral transpsoas approach to the lumbar spine. *Spine (Phila Pa 1976)*. 2004;29: 1681-1688.
5. Nakamura H, Ishikawa T, Konishi S, Seki M, Yamano Y. Psoas strapping technique: a new technique for laparoscopic anterior lumbar interbody fusion. *J Am Coll Surg*. 2000;191:686-688.
6. Cahill KS, Martinez JL, Wang MY, Vanni S, Levi AD. Motor nerve injuries following the minimally invasive lateral transpsoas approach. *J Neurosurg Spine*. 2012;17:227-231.
7. Tubbs RI, Gabel B, Jeyamohan S, et al. Relationship of the lumbar plexus branches to the lumbar spine: anatomical study with application to lateral approaches. *Spine J*. 2017;17:1012-1016.
8. Smith WD, Wohns RN, Christian G, Rodgers EJ, Rodgers WB. Outpatient minimally invasive lumbar interbody: fusion predictive factors and clinical results. *Spine (Phila Pa 1976)*. 2016;41(Suppl 8):S106-S122.
9. Winder MJ, Gambhir S. Comparison of ALIF vs. XLIF for L4/5 interbody fusion: pros, cons, and literature review. *J Spine Surg*. 2016;2:2-8.
10. Smith WD, Christian G, Serrano S, Malone KT. A comparison of perioperative charges and outcome between open and mini-open approaches for anterior lumbar discectomy and fusion. *J Clin Neurosci*. 2012;19:673-680.
11. Khajavi K, Shen A, Lagina M, Hutchison A. Comparison of clinical outcomes following minimally invasive lateral interbody fusion stratified by preoperative diagnosis. *Eur Spine J*. 2015;24(Suppl 3):322-330.
12. Dakwar E, Vale FL, Uribe JS. Trajectory of the main sensory and motor branches of the lumbar plexus outside the psoas muscle related to the lateral retroperitoneal transpsoas approach. *J Neurosurg Spine*. 2011;14:290-295.
13. Cummock MD, Vanni S, Levi AD, Yu Y, Wang MY. An analysis of postoperative thigh symptoms after minimally invasive transpsoas lumbar interbody fusion. *J Neurosurg Spine*. 2011;15:11-18.
14. Youssef JA, McAfee PC, Patty CA, et al. Minimally invasive surgery: lateral approach interbody fusion: results and review. *Spine (Phila Pa 1976)*. 2010;35(26 Suppl):S302-S311.
15. Saraph V, Lerch C, Walochnik N, Bach CM, Krismer M, Wimmer C. Comparison of conventional versus minimally invasive extraperitoneal approach for anterior lumbar interbody fusion. *Eur Spine J*. 2004;13:425-431.
16. Sembrano JN, Tohmeh A, Isaacs R, SOLAS Degenerative Study Group. Two-year comparative outcomes of MIS lateral and MIS transforaminal interbody fusion in the treatment of degenerative spondylolisthesis: part i: clinical findings. *Spine (Phila Pa 1976)*. 2016;41(Suppl 8):S123-S132.
17. Isaacs RE, Sembrano JN, Tohmeh AG, SOLAS Degenerative Study Group. Two-year comparative outcomes of MIS lateral and MIS transforaminal interbody fusion in the treatment of degenerative spondylolisthesis: part ii: radiographic findings. *Spine (Phila Pa 1976)*. 2016;41(Suppl 8):S133-S144.
18. Pumberger M, Hughes AP, Huang RR, Sama AA, Cammisa FP, Girardi FP. Neurologic deficit following lateral lumbar interbody fusion. *Eur Spine J*. 2012:2111192-2111199.
19. Isaacs RE, Hyde J, Goodrich JA, Rodgers WB, Phillips FM. A prospective, nonrandomized, multicenter evaluation of extreme lateral interbody fusion for the treatment of adult degenerative scoliosis: perioperative outcomes and complications. *Spine (Phila Pa 1976)*. 2010;35(26 Suppl): S322-S330.
20. Uribe JS, Isaacs RE, Youssef JA, et al. Can triggered electromyography monitoring throughout retraction predict postoperative symptomatic neuropraxia after XLIF? Results from a prospective multicenter trial. *Eur Spine J*. 2015;24(Suppl 3): 378-385.
21. Bendersky M, Solá C, Muntadas J, et al. Monitoring lumbar plexus integrity in extreme lateral transpsoas approaches to the lumbar spine: a new protocol with anatomical bases. *Eur Spine J*. 2015; 24:1051-1057.
22. Härtl R, Joeris A, McGuire RA. Comparison of the safety outcomes between two surgical approaches for anterior lumbar fusion surgery: anterior lumbar interbody fusion (ALIF) and extreme lateral interbody fusion (ELIF). *Eur Spine J*. 2016;25: 1484-1521.
23. Mandelli C, Colombo EV, Sicuri GM, Mortini P. Lumbar plexus nervous distortion in XLIF. *Eur Spine J*. 2016;25:4155-4163.

24. Buric J. Relationship between psoas muscle dimensions and post operative thigh pain. A possible preoperative evaluation factor. *Int J Spine Surg*. 2015;9:27.

25. 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 J*. 2010;4:41-46.

26. Rodgers J, Gerber EJ, Lehmen J, Rodgers WB. Clinical and radiographic outcome in less invasive lumbar fusion: XLIF at two year follow-up. *J Spine Neurosurg*. 2013;2:1-6.

27. Hrabalek L, Adamus M, Gryga A, Wanek T, Tucek P. A comparison of complication rate between anterior and lateral approaches to the lumbar spine. *Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub*. 2014;158:127-132.

28. Tormenti MJ, Maserati MB, Bonfield CM, Okonkwo DO, Kanter AS. Complications and radiographic correction in adult scoliosis following combined transpsoas extreme lateral interbody fusion and posterior pedicle screw instrumentation. *Neurosurg Focus*. 2010;28:E7.

29. Oliveira L, Marchi L, Coutinho E, Pimenta L. A radiographic assessment of the ability of the extreme lateral interbody fusion procedure to indirectly decompress the neural elements. *Spine (Phila Pa 1976)*. 2010;35:S331-S337.

30. Brau SA. Mini-open approach to the spine for anterior lumbar interbody fusion: description of the procedure, results and complications. *Spine J*. 2002;2:216-223.

31. Knight RQ, Schwaegler P, Hanscom D, Roh J. Direct lateral lumbar interbody fusion for degenerative conditions: early complication profile. *J Spinal Disord Tech*. 2009;22:34-37.

32. Rodgers WB, Gerber EJ, Patterson J. Intraoperative and early postoperative complications in extreme lateral interbody fusion: an analysis of 600 cases. *Spine (Phila Pa 1976)*. 2011;36:26-32.

33. Smith WD, Dakwar E, Le TV, Christian G, Serrano S, Uribe JS. Minimally invasive surgery for traumatic spinal pathologies: a mini-open, lateral approach in the thoracic and lumbar spine. *Spine (Phila Pa 1976)*. 2010;35:S338-S346.

34. Baaj AA, Dakwar E, Le TV, et al. Complications of the mini-open anterolateral approach to the thoracolumbar spine. *J Clin Neurosci*. 2012;19:1265-1267.

35. Malham GM. Minimally invasive direct lateral corpectomy for the treatment of a thoracolumbar fracture. *J Neurol Surg A Cent Eur Neurosurg*. 2015;76:240-243.

36. Berjano P, Langella F, Damilano M, et al. Fusion rate following extreme lateral lumbar interbody fusion. *Eur Spine J*. 2015;24:369-371.

37. Rodgers WB, Gerber EJ, Patterson JR. Fusion after minimally disruptive anterior lumbar interbody fusion: analysis of extreme lateral interbody fusion by computed tomography. *SAS J*. 2010;4:63-66.

38. Malham GM, Parker RM, Bliecher CM, Chow FY, Seex KA. Choice of approach does not affect clinical and radiological outcomes: a comparative cohort of ALIF and XLIF patients at 12 months. *Spine J*. 2014;14:S54.

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