ScientificScholar®
Knowledge is power
Publisher of Scientific Journals

www.surgicalneurologyint.com

Surgical Neurology International
Editor-in-Chief: Nancy E. Epstein, MD, NYU Winthrop Hospital, Mineola, NY, USA.
SNI: Spine
Editor
Nancy E. Epstein, MD
NYU Winthrop Hospital, Mineola, NY, USA

SNI
Open Access

Review Article

Review of Risks and Complications of Extreme Lateral Interbody Fusion (XLIF)

Nancy E. Epstein, M.D.

Professor of Clinical Neurosurgery, School of Medicine, State University of New York at Stony Brook, New York, and Chief of Neurosurgical Spine and Education, NYU Winthrop Hospital, NYU Winthrop NeuroScience/Neurosurgery, Mineola, New York 11501, United States.

E-mail: *Nancy E. Epstein, M.D. - nancy.epsteinmd@gmail.com

***Corresponding author:**
Nancy E. Epstein, M.D.,
NYU Winthrop Hospital,
NYU Winthrop NeuroScience/
Neurosurgery, 200 Old Country
Rd. Suite 485, Mineola, NY
11501, United States.

nancy.epsteinmd@gmail.com

Received : 16 November 19
Accepted : 16 November 19
Published : 06 December 19

DOI
10.25259/SNI_559_2019

Quick Response Code:

ABSTRACT

Background: Extreme lateral interbody fusions (XLIF) and Minimally Invasive (MIS) XLIF were developed to limit the vascular injuries associated with anterior lumbar interbody fusion (ALIF), and minimize the muscular/soft tissue trauma attributed to transforaminal lumbar interbody fusion (TLIF), posterior lumbar interbody fusion (PLIF), and posterolateral lumbar fusion (PLF).

Methods: Nevertheless, XLIF/MIS XLIF pose significant additional risks and complications that include; multiple nerve injuries (e.g. lumbar plexus, ilioinguinal, iliohypogastric, genitofemoral, lateral femoral cutaneous, and subcostals (to the anterior abdominal muscles: abdominal oblique), and sympathectomy), major vascular injuries, bowel perforations/postoperative ileus, seromas, pseudarthrosis, subsidence, and reoperations.

Results: The risks of neural injury with XLIF/MIS XLIF (up to 30-40%) are substantially higher than for TLIF, PLIF, PLF, and ALIF. These neural injuries included: lumbar plexus injuries (13.28%); new sensory deficits (0-75% (21.7%-40%); permanent 62.5%); motor deficits (0.7-33.6%-40%); iliopsoas weakness (9%-31%: permanent 5%), anterior thigh/groin pain (12.5-34%), and sympathectomy (4%-12%). Additional non-neurological complications included; subsidence (10.3%-13.8%), major vascular injuries (0.4%), bowel perforations, recurrent seroma, malpositioning of the XLIF cages, a 45% risk of cage-overhang, pseudarthrosis (7.5%), and failure to adequately decompress stenosis. In one study, reviewing 20 publications and involving 1080 XLIF patients, the authors observed "Most (XLIF) studies are limited by study design, sample size, and potential conflicts of interest."

Conclusion: Many new neurological deficits and other adverse events/complications are attributed to MIS XLIF/XLIF. Shouldn't these significant risk factors be carefully taken into consideration before choosing to perform MIS XLIF/XLIF?

Keywords: Extreme lateral interbody fusion (XLIF): Complications, Lumbar plexus injuries, Major injuries, Minor injuries, Nerve root injuries

INTRODUCTION

Extreme lateral interbody fusions (XLIFs) and Minimally Invasive (MIS) XLIF were devised to reduce the vascular injuries seen with anterior lumbar interbody fusions (ALIF), and limit the muscular/soft tissue trauma seen with transforaminal lumbar interbody fusion (TLIF), posterior lumbar interbody fusion (PLIF), and posterolateral lumbar fusion (PLF). Further, XLIF/MIS XLIF uniquely contributed to multiple new major neurological injuries(10%-40%) to the lumbar plexus, ilioinguinal, iliohypogastric, genitofemoral, lateral femoral cutaneous, and subcostal nerves

[Tables 1 and 2].[10,11,5-7,14,24] These resulted in; new sensory deficits (0-75% (21.7%-40%); permanent 62.5%); new motor deficits (0.7-40%; most typically iliopsoas weakness (9%-31%: 5%)), sympathectomy (4%), and anterior thigh/groin pain (12.5%-34%).[10,11,5-7,14,24] Further multiple non-neurological complications included; subsidence (10.3%-13.8%), failure to adequately decompress stenosis, major vascular injuries (0.4%), bowel perforations, postoperative ileus, recurrent seroma, pseudarthrosis (7.5%), and malpositioning of XLIF cages including a 45% risk of cage-overhang.[5-7,15]

Arguments Favoring XLIF/MIS XLIF with/without Supplemental Posterior Instrumentation

XLIF/MIX XLIF With/Without Instrumentation

Minimally Invasive (MIS) Extreme Lateral Interbody Fusion and XLIF (XLIF" NuVasive Inc San Diego CA) were developed to provide interbody fusion, indirect neural decompression, and stabilization. These XLIF/MIS XLIF approaches would theoretically limit the major vascular/visceral injuries seen with ALIF, and avoid the paraspinal/soft tissue trauma observed with TLIF, PLIF, and PLF. Further, potential benefits included; smaller incisions, reduced blood loss, shorter operative time, increased disc space height, reduced infection rates, shorter length of stay (LOS), higher fusion rates, reduced subsidence rates, less postoperative pain, and lower reoperation rates [Table 1].[2,4,8,16-18] In several studies, MIS XLIF performed without instrumentation (stand-alone) increased disc space height (41.9%), resulted in clinical improvement in back (58.6%)/leg pain (60.0%), improved Oswestry Disability Index Scores (ODI 44%), and lowered subsidence rates (7.5%) [Table 1].[16-18] Instrumented MIS XLIF/XLIF increased; neuroforaminal height (80.3%), foraminal width (7.4%), disc height (116.7%), segmental lordosis at L4-L5 (14.1%), and global lordosis (11.5%) [Table 1].[4] Goodnough *et al.* (2019) additionally documented reduced estimated blood loss (EBL) for instrumented MIS XLIF vs. ALIF treating L4-L5 degenerative spondylolisthesis (DS) [Table 2].[8]

Anatomic Studies Showing Nerves at Risk with XLIF

However, multiple anatomic/cadaveric studies demonstrated how MIS XLIF/XLIF involving dissection through the psoas muscle, placed the lumbar plexus, ilioinguinal, iliohypogastric, genitofemoral, lateral femoral cutaneous, and subcostal nerves at risk.[1,9,23] The lumbar plexus is comprised of nerves L1-L4, and also receives input from the subcostal nerve (T12; last thoracic nerve). The ilioinguinal nerve is a branch of the anterior ramus of L1 (lumbar plexus) that provides sensation to the anterior surface of the scrotum/labia majora, base of the penis/mons pubis, and a small portion of the upper anterior/medial thigh; motor branches also innervate the internal oblique, and transversus abdominis muscles. The iliohypogastric nerve, also a branch of L1, contributes to skin sensation to the lateral gluteal region, and motor function to the external/internal oblique muscles, and transverse abdominus. The genitofemoral nerve, including both genital and femoral branches, provides sensation to the upper anterior thigh, and skin of the anterior scrotum/mons pubis. Exiting the lumbar plexus, between the L2-L3 vertebrae, the lateral femoral cutaneous nerve provides sensation to the skin inferior to the iliac crest and gluteal regions. Finally, the subcostal nerve, originating from the ventral ramus of T 12 (e.g. thoracic nerve), supplies motor innervation to the transversus abdominis, rectus abdominis, and pyramidalis musculature.

Definition of Safe Working Zone for XLIF

In 2010, Uribe *et al.* attempted to define the "safe working zones" for MIS XLIF in a series of 20 cadavers [Table 1].[23] They divided the lumbar vertebrae into 4 zones, and dissected the psoas muscle, lumbar plexus, and nerve roots at each of these sites. **"**All parts of the lumbar plexus, including nerve roots, were found within the substance of the psoas muscle dorsal to the posterior fourth of the VB (vertebral body; Zone IV)". They found the safe anatomical zones from L1-2 to L3-4 were "at the middle posterior quarter of the VB (midpoint of Zone III), and the " the safe anatomical zone at the L4-5 disc space was at the midpoint of the VB (Zone II-Zone III demarcation)."

Subcostal Nerve Injury with XLIF

In a cadaveric study, Alonso *et al*. (2017) observed how the subcostal nerve that typically innervates the anterolateral abdominal muscles (e.g. abdominal oblique muscle), if injured during XLIF, could contribute to abdominal wall hernias [Table 1].[1] Utilizing 10 cadavers, dissection of the subcostal nerve revealed its typical 8 branches, and its location midway between the 12th rib and the iliac crest. They found; "The subcostal nerve is the dominant nerve in both size and innervation of the oblique muscles in the lateral position, transpsoas approach."

XLIF Results in Complete or Partial Nerve Transections

In a cadaver study (15 cadavers, 26 sides), Grunert *et al*. (2017) analyzed complete/partial nerve injuries/transections to the lumbar plexus occurring during L1-L5 XLIF [Table 1].[9] "At L1/2, the iliohypogastric, ilioinguinal, and subcostal nerves were injured within the psoas major muscle, while in the retroperitoneal space, both nerves plus the genitofemoral nerve were at risk." As they were located outside the psoas muscle in the lateral retroperitoneal transpsoas approach, they could be readily injured during blunt retroperitoneal dissection, or by the retractor blades themselves.

Clinical Injuries with XLIF

Multiple neurological and other injuries were clinically observed following XLIF/MIS XLIF.[2] Khajavi *et al.* (2015) noted that with

Table 1: Studies for XLIF 2010-2017.

Author Reference Year	Study Design	Data	Data	Findings	Conclusions
Oliveira 2010[18]	MIS XLIF interbody fusions	43 levels	21 Patients	Increased disc height (41.9%):	Increased disc height (41.9%):
Uribe 2010[23]	Cadaver XLIF: Lumbar Plexus, Psoas Muscle, Retroperitoneal Exposure	20 Cadavers Divided 4 Vertebral Body Zones Studied Plexus, Roots in Psoas Muscle	Dorsal to Posterior IV of Vertebral Body	Safe Zone from L12-L34 Mid posterior quarter body (midpoint of Zone III)	Safe area for L45: mid-point of VB Zones II-III
Arnold 2012[2]	Review of AE thoracic/ lumbar XLIF Pros: <tissue dissection, smaller incisions, < operative time	Pros: <blood loss, < hospital stay, <postop pain, >fusion rates/ instrumentation	Pros: larger interbody device vs. TLIF or PLIF	Cons: " … lumbar spine, including L4-5 and L4-S1 often inaccessible"	Cons: XLIF unique s complications- neural injuries, psoas weakness, thigh numbness\
Caputo 2013[4]	30 MIS XLIF+posterior instrumented fusion Rx DLS	Postop X-rays->> neuroforaminal height (80.3%)	> Width (7.4%) >> disc height (116.7%)\	>segmental lordosis at L4-L5 (14.1%)/	>>Global lordosis (11.5%).
Khajavi 2015[11]	MIS XLIF 197 Levels avg. 1.2/patient Followed avg. 19 mos	Indications 68 DS Discs 20 Post-Lam 46	0% Pseudarthroses	14% Anterolateral thigh/groin sensory deficits	9% Hip Flexor weakness.
Alonso 2017[1]	10 Cadavers XLIF	Subcostal N to oblique muscles At Risk with XLIF	Subcostal N: Midway between 12th rib -iliac crest 75%	Need to know subcostal nerve location -avoid injury XLIF	Injury subcostal Nerve -sensory deficit abdominal wall and hernias
Epstein 2016[6]	AE-XLIF/MIS XLIF AE Lumbar plexus (13.28%) New sensory deficits (0–75% (permanent 62.5%)	New motor deficits (0.7–33.6%) Thigh pain (12.5–25%)	Sympathectomy (4%), Vascular injuries	Bowel perforations Failure Stenosis decompression	Poor Position XLIF cages 45% Risk cage overhang
Malham 2017[17]	2D- CT scans 52 patients- 79-level MIS XLIF	Increased postoperative disc height (89%),	Increased foraminal height (38%)/	Increased area (45.1%) in	79 Levels of XLIF Disc Height Foraminal height Area
Lang 2017[13]	PubMed, Cochrane, ScienceDirect databases 1080 Patients 20 articles	XLIF Indirect decompression stenosis	Disc disease, spinal stenosis, DS, DLS, DLSt	Efficacy XLIF "Low", and "Inconsistent	Limited study design, sample size, potential conflicts of interest."
Grunert 2017[9]	Cadaver Study XLIF L1-L5 Complete-partial nerve transections nerves/lumbar plexus	L1/2, Iliohypogastric, Ilioinguinal, Subcostal nerves injured psoas muscle	L1-L2 injuries Retroperitoneal outer abdominal muscles	L1-L2 N injuries: subcutaneous tissues	Genitofemoral nerve injuries occurring in the retroperitoneal space.

Fusion, ALIF=Anterior Lumbar Interbody Fusion, TLIF=Transforaminal Lumbar Interbody fusion, PLIF=Posterior Lumbar Interbody Fusion, PLF=Posterolateral Lumbar Fusion, N=Nerves, AE=Adverse Events, Rx=Treating, avg.=average, SLIF=Subsidence Lumbar Interbody Fusion, OLIF=Oblique Lumbar Interbody Fusion, Post-Lam=Post Laminectomy Syndrome, N=Nerve

Table 2: Studies for XLIF 2018-2019.

Author Reference Year	Study Design	Data	Data	Findings	Conclusions
Paterakis 2018[21]	Retrospective series (2008-2017) 12 patients Efficacy XLIF for DLS	Avg. 64.5 years old Followed avg. 28 months.	Back-related disability improved by 26% (ODI scale) in 6-months	3 AE: 2 meralgia paresthetica (resolved 3 months),	3 AE: 1 intraoperative bowel perforation (requiring bowel anastomosis).
Macki 2019[15]	Meta analysis	Subsidence XLIF	Subsidence 10.3% SLIF	141/1362 patients in 14 articles	2.7% reoperations for subsidence 41/1470 in 16 articles
Hah 2019[10]	AE XLIF vs. OLIF	Sensory and motor to the thigh (ipsilateral)	Deficits XLIF/LLIF 30-40%.	5% Permanent XLIF deficits -	Better monitoring may decrease this complication in the future.
Walker 2019[24]	Meta-analysis AE of XLIF with Prepsoas (1874) vs. Transpsoas (4607) Approaches	Prepsoas Approaches: >sympathetic N AE injuries (5.4%) >More major neurovascular injuries (1.8% vs. 0.4%).	Transpsoas Group: > temporary sensory (21.7% vs 8.7%,) >Hip flexor weakness (19.7% vs 5.7%,),	Transpsoas >infections (3.1% vs 1.1%,). 2.8% permanent neurological weakness (2.8% vs 1.0%,).	Both Equal Prepsoas vs. Transpsoas Urological, peritoneal/bowel injuries, postop ileus, hematomas =subsidence (12.2% vs. 13.8% =pseudarthrosis (9.9% vs 7.5%),
Li 2019[14]	Retrospective analysis of learning curves for OLIF vs. XLIF	First 30 OLIF and First 30 XLIF	<Complications for XLIF (10%) vs. > AE OLIF (33.3%;	XLIF showed increased neurovascular trauma	XLIF approach complications 10%

VB = Vertebral Body, DS = Degenerative Spondylolisthesis, DLS = Degenerative Lumbar Scoliosis, DLSt-Degenerative Lumbar Stenosis, AE = Adverse Event, MIS = Minimally Invasive, XLIF = Extreme Lumbar Interbody Fusion, ALIF = Anterior Lumbar Interbody Fusion, TLIF = Transforaminal Lumbar Interbody fusion, PLIF = Posterior Lumbar Interbody Fusion, PLF = Posterolateral Lumbar Fusion, N = Nerves, AE = Adverse Events, Rx = Treating, avg.=average, SLIF = Subsidence Lumbar Interbody Fusion, OLIF = Oblique Lumbar Interbody Fusion, Post-Lam = Post Laminectomy Syndrome

XLIF, there was a 4% incidence of anterolateral thigh/groin/sensory complaints, and a 9% incidence of hip flexor weakness [Table 1].[11] In 2016, Epstein summarized the following neurological risks/complications of XLIF/MIS XLIF: injuries to the lumbar plexus (13.28%), new sensory deficits (0–75% (irreversible 62.5%)), new motor deficits(0.7–33.6%), thigh pain (12.5–25%), and sympathectomy (4%), [Table 1].[5,7] Other injuries included; major vascular injuries, bowel perforations, seromas, subsidence, failure to decompress disc disease/stenosis/spondylolisthesis/degenerative scoliosis, mispositioning of the XLIF cages, and a 45% risk of cage-overhang [Table 1].[6] In 2019, Hah and Kang found that for XLIF, the most common postoperative sensory and motor deficits involved the ipsilateral thigh in 30-40% of patients; further, these injuries were permanent in 5% of patients [Table 2].[10] Additionally, Arnold *et al*. (2012) emphasized the potential difficulty in accessing the L4-L5 and L5-S1 levels with the XLIF approach [Table 1].

Meta-analysis of Complications of XLIF with Prepsoas vs. Transpsoas Approaches

In 2019, Walker *et al*. performed a meta-analysis of the complications of XLIF utilizing the prepsoas (1874 patients) vs. transpsoas (4607 patients) approaches.[24] For the prepsoas vs. transpsoas group, there were more sympathetic nerve injuries (5.4% prepsoas vs. 0% transpsoas), and more major neurovascular injuries (1.8% prepsoas vs. 0.4% transpsoas) [Table 2].[24] For the transpsoas vs. prepsoas group, there were higher rates of temporary sensory deficits (21.7% vs 8.7%), hip flexor weakness (19.7% vs 5.7%; permanent weakness 2.8% vs. 1.0%), and a higher infection rate (3.1% vs 1.1%). Notably, for both groups, there were comparable rates of urological, peritoneal/bowel injuries, postoperative ileus, hematoma, subsidence (12.2% prepsoas vs 13.8% transpsoas), and pseudarthrosis (9.9% prepsoas vs 7.5% transpsoas).

XLIF Unreliable Extent of Decompression

Using the PubMed, Cochrane, and ScienceDirect databases, Lang *et al*. (2017) determined that XLIF failed to provide adequate indirect decompression of central and lateral recess stenosis (e.g. decompression for disc disease, spinal stenosis, spondylolisthesis, and degenerative scoliosis) [Table 1].[13] Indeed, in the 20 publications they reviewed involving 1080 patients, the efficacy of XLIF for decompressing stenosis was "low", and "inconsistent". They further concluded: "Most studies are limited by study design, sample size, and potential conflicts of interest."

XLIF Resulting in Meralgia Paresthetica and Bowel Perforation

In 2018, Paterakis *et al*. (study years 2008-2017) retrospectively studied the efficacy of XLIF for treating degenerative scoliosis involving 12 patients averaging 64.5 years of age, and followed for 28 months [Table 2].[21] Although they found the back-related Oswestry Disability Scales (ODS) improved by 26% at 6 postoperative months, there were three major complications; 2 instances of meralgia paresthetica, and one intraoperative bowel perforation (requiring resection/anastomosis).

XLIF Subsidence Rate

In a meta-analysis of XLIF, reviewing 14 articles and involving 1362 patients, Macki *et al*. (2019) found a 10.3% subsidence rate (141/1362 patients) that warranted a 2.7% incidence of reoperations (N = 41/1470 patients in 16 articles) [Table 2].[15]

Learning Curve for XLIF

In a retrospective analysis of the learning curve (e.g. complications/outcomes) for the first 30 oblique lumbar interbody fusion (OLIF) vs. the first 30 XLIF, Li *et al*. (2019) found there were fewer complications for XLIF (10%) vs. OLIF (33.3%; increased neurovascular trauma). Nevertheless, XLIF still resulted in a 10% significant complication rate [Table 2].[14]

Adjacent Segment Disease/Post Laminectomy Syndrome with XLIF

XLIF/MIS XLIF were often utilized to address adjacent segment disease and/or post laminectomy syndromes. When Khajavi *et al*. (2015) evaluated outcomes of MIS XLIF (197 levels; average 1.2/patient) at 19 postoperative months addressing degenerative spondylolisthesis ($n = 68$) and disc disease ($n = 20$), they found 26 new instances of adjacent segment disease, and 46 cases of post-laminectomy syndrome [Table 1].[11] On the other hand, Ono *et al*. (2019) reviewed 21 patients who underwent spinal deformity surgery, and at one postoperative year, XLIF demonstrated a strong ability to reconstruct the deformity [Table 2].[19]

3 Cases of L1-L2 Disc Herniations Treated with MIS XLIF Utilizing CT Guidance

Oyelese *et al*. (2018) evaluated three MIS XLIF performed at the L1-L2 level addressing disc disease and stenosis.[20] They utilized intraoperative CT to facilitate "A safe corridor of direct visualization to the ventral thecal sac with minimal bony resection…", and anticipated this "…could, in principle, reduce neurological injury and biomechanical instability, which likely contribute to poor outcomes (*e.g. for MIS XLIF*) at this level." [Table 2].[20]

Modifications and Surgical Alternatives to XLIF

Endoscopic XLIF

Schonauer *et al*. (2017) noted the following risks for the classical XLIF: (the XLIF) "deep and tight surgical corridor

makes visual identification of important landmark structures, as well as sufficient endplate and contralateral preparation, challenging" [Table 1].[22] Their endoscopic XLIF, alternatively performed in 41 patients (mean age, 66.7 years old; 22 males (53.7%)), provided better visualization, and fewer intraoperative, and postoperative complications.

XLIF: Open vs. Percutaneous Screw Fusion in Adult Degenerative Scoliosis

Attenello *et al*. (2018) retrospectively evaluated 22 XLIF performed with open vs. percutaneous screws fixation for the management of adult degenerative scoliosis (ADScoli) over an average of 22 postoperative months [Table 2].[3] Open laminectomy/posterior pedicle-screw instrumentation vs. percutaneous pedicle screw instrumentation without decompression resulted in comparable clinical improvement, but the open procedure had higher complication rates. They, therefore, recommended using percutaneous posterior fixation alone without decompression.

Comparing Mini Open TLIF vs. XLIF for Degenerative Lumbar Spondylolisthesis

Kono *et al*. (2018) demonstrated the comparable safety/efficacy of XLIF (XLIF: 20 patients) vs. mini-open transforaminal lumbar interbody fusion (TLIF: 20 patients) for treating lumbar degenerative spondylolisthesis [Table 2].[12] They found comparable surgical duration and length of stay(LOS), but the XLIF showed decreased EBL, and greater alignment correction.

CONCLUSION

There are multiple neurological and other surgical risks associated with MIS XLIF/XLIF. The resultant nerve injuries included; the lumbar plexus, iliohypogastric, ilioinguinal, genitofemoral, subcostal, lateral femoral cutaneous nerves, meralgia paresthetica and sympathectomy [Tables 1 and 2]. The non-neurological injuries included; major vascular injuries, bowel perforations, seromas, subsidence, failure to adequately decompress stenosis, malpositioning of MIS XLIF/XLIF cages, and a high risk of cage-overhang [Tables 1 and 2]. Shouldn't these significant risks/complications be carefully considered before choosing to perform MIS XLIF/XLIF?

REFERENCES

1. Alonso F, Graham R, Rustagi T, Drazin D, Loukas M, Oskouian RJ, *et al*. The Subcostal Nerve During Lateral Approaches to the Lumbar Spine: An Anatomical Study with Relevance for Injury Avoidance and Postoperative Complications Such as Abdominal Wall Hernia. World Neurosurg. 2017;104:669-673.
2. Arnold PM, Anderson KK, McGuire RA Jr. The lateral transpsoas approach to the lumbar and thoracic spine: A review. Surg Neurol Int. 2012; 3(Suppl 3):S198-215.
3. Attenello J, Chang C, Lee YP, Zlomislic V, Garfin SR, Allen RT. Comparison of lateral lumbar interbody fusion (LLIF) with open versus percutaneous screw fixation for adult degenerative scoliosis. J Orthop. 2018;15(2):486-489.
4. Caputo AM, Michael KW, Chapman TM, Jennings JM, Hubbard EW, Isaacs RE, *et al*. Extreme lateral interbody fusion for the treatment of adult degenerative scoliosis. J Clin Neurosci. 2013; 20:1558–63.
5. Epstein NE. Extreme lateral lumbar interbody fusion: Do the cons outweigh the pros? Surg Neurol Int. 2016;7(Suppl 25):S692-S700.
6. Epstein NE. Non-neurological major complications of extreme lateral and related lumbar interbody fusion techniques. Surg Neurol Int. 2016;7(Suppl 25):S656-S659.
7. Epstein NE. High neurological complication rates for extreme lateral lumbar interbody fusion and related techniques: A review of safety concerns. Surg Neurol Int. 2016;7(Suppl 25):S652-S655.
8. Goodnough LH, Koltsov J, Wang T, Xiong G, Nathan K, Cheng I. Decreased estimated blood loss in lateral trans-psoas versus anterior approach to lumbar interbody fusion for degenerative spondylolisthesis. J Spine Surg. 2019;5(2):185-193.
9. Grunert P, Drazin D, Iwanaga J, Schmidt C, Alonso F, Moisi M, *et al*. Injury to the Lumbar Plexus and its Branches After Lateral Fusion Procedures: A Cadaver Study World Neurosurg. 2017;105:519-525.
10. Hah R, Kang HP. Lateral and Oblique Lumbar Interbody Fusion-Current Concepts and a Review of Recent Literature. Curr Rev Musculoskelet Med. 2019 22:305-310.
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 3:322-30.
12. Kono Y, Gen H, Sakuma Y, Koshika Y. Comparison of Clinical and Radiologic Results of Mini-Open Transforaminal Lumbar Interbody Fusion and Extreme Lateral Interbody Fusion Indirect Decompression for Degenerative Lumbar Spondylolisthesis. Asian Spine J. 2018;12(2):356-364.
13. Lang G, Perrech M, Navarro-Ramirez R, Hussain I, Pennicooke B, Maryam F, *et al*. Potential and Limitations of Neural Decompression in Extreme Lateral Interbody Fusion-A Systematic Review. World Neurosurg. 2017;101:99-113.
14. Li J, Wang X, Sun Y, Zhang F, Gao Y, Li Z, *et al*. Safety Analysis of Two Anterior Lateral Lumbar Interbody Fusions at the Initial Stage of Learning Curve. World Neurosurg. 2019;127:e901-e909.
15. Macki M, Anand SK, Surapaneni A, Park P, Chang V. Subsidence Rates After Lateral Lumbar Interbody Fusion: A Systematic Review. World Neurosurg. 2019;122:599-606.
16. Malham GM, Parker RM, Goss B, Blecher CM, BaX. Indirect foraminal decompression is independent of metabolically active facet arthropathy in extreme lateral interbody fusion. Spine. 2014;39:E1303–10.
17. Malham GM, Ellis NJ, Parker RM, Blecher CM, White R, Goss B, Seex KA. Maintenance of Segmental Lordosis and Disk Height in Stand-alone and Instrumented Extreme Lateral Interbody Fusion (XLIF). Clin Spine Surg. 2017;30(2):E90-E98.
18. 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(26 Suppl):S331–7.
19. Ono K, Ohmori K, Hori T. Clinical and Radiological Outcomes of Corrective Surgery on Adult Spinal Deformity Patients: Comparison of Short and Long Fusion. Adv Orthop. 2019;2019:9492486.
20. Oyelese AA, Fridley J, Choi DB, Telfeian A, Gokaslan ZL. Minimally invasive direct lateral, retroperitoneal transforaminal approach for large L1-2 disc herniations with intraoperative CT navigational assistance: technical note and report of 3 cases. J Neurosurg Spine. 2018;29(1):46-53.
21. Paterakis KN, Brotis AG, Paschalis A, Tzannis A, Fountas KN. Extreme lateral lumbar interbody fusion (XLIF) in the management of degenerative scoliosis: a retrospective case series.J Spine Surg. 2018;4(3):610-615.
22. Schonauer C, Stienen MN, Gautschi OP, Schaller K, Tessitore E. Endoscope-Assisted Extreme-Lateral Interbody Fusion: Preliminary Experience and Technical Note. World Neurosurg. 2017;103:869-875.e3.
23. Uribe JS, Arredondo N, Dakwar E, Vale FL. Defining the safe working zones using the minimally invasive lateralretroperitoneal transpsoas approach: an anatomical study. J Neurosurg Spine. 2010;13(2):260-6.
24. Walker CT, Farber SH, Cole TS, Xu DS, Godzik J, Whiting AC, *et al*. Complications for minimally invasive lateral interbody arthrodesis: a systematic review and meta-analysis comparing prepsoas and transpsoas approaches. J Neurosurg Spine. 2019; 25:1-15.

How to cite this article: Epstein NE. Review of Risks and Complications of Extreme Lateral Interbody Fusion (XLIF). Surg Neurol Int 2019;10:237.