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More nerve root injuries occur with minimally invasive lumbar surgery: Let's tell someone

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Abstract

Background: In a recent study entitled: "More nerve root injuries occur with minimally invasive lumbar surgery, especially extreme lateral interbody fusion (XLIF): A review", Epstein documented that more nerve root injuries occurred utilizing minimally invasive surgery (MIS) versus open lumbar surgery for diskectomy, decompression of stenosis (laminectomy), and/or fusion for instability.

Methods: In large multicenter Spine Patient Outcomes Research Trial reviews performed by Desai *et al*., nerve root injury with open diskectomy occurred in 0.13–0.25% of cases, occurred in 0% of laminectomy/stenosis with/without fusion cases, and just 2% for open laminectomy/stenosis/degenerative spondylolisthesis with/without fusion.

Results: In another MIS series performed largely for disc disease (often contained nonsurgical disc herniations, therefore unnecessary procedures) or spondylolisthesis, the risk of root injury was 2% for transforaminal lumbar interbody fusion (TLIF) versus 7.8% for posterior lumbar interbody fusion (PLIF). Furthermore, the high frequencies of radiculitis/nerve root/plexus injuries incurring during anterior lumbar interbody fusions (ALIF: 15.8%) versus extreme lumbar interbody fusions (XLIF: 23.8%), addressing disc disease, failed back surgery, and spondylolisthesis, were far from acceptable.

Conclusions: The incidence of nerve root injuries following any of the multiple MIS lumbar surgical techniques (TLIF/PLIF/ALIF/XLIF) resulted in more nerve root injuries when compared with open conventional lumbar surgical techniques. Considering the majority of these procedures are unnecessarily being performed for degenerative disc disease alone, spine surgeons should be increasingly asked why they are offering these operations to their patients?

Key Words: Extreme lateral interbody fusion (XLIF); minimally invasive surgery (MIS); nerve root injuires; lumbar surgery; percutaneous procedures; posterior lumbar interbody fusion (PLIF); posterolateral fusions (PLF); transforaminal lumbar interbody fusion (TLIF)

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INTRODUCTION

Frequency of root injuries with open lumbar surgery versus minimally invasive transforaminal lumbar interbody fusion (TLIF)

In this editorial, the higher incidence of nerve root injuries that occurs utilizing minimally invasive surgery

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(MIS) versus open lumbar surgical techniques addressing disc disease, stenosis, and instability is reviewed [Tables 1-3]. In Desai *et al*., Spine Patient Outcomes Research Trial (SPORT) studies, a 0.13–0.25% frequency of nerve root injuries followed open diskectomy, a 0% incidence occurred with open laminectomy/stenosis with/without fusion, whereas the frequency was 2% for laminectomy/stenosis/degenerative spondylolisthesis with/without fusion [Table 1].[4-8] Alternatively, in a MIS fusion study, 2% of patients sustained root injuries with MIS transforaminal lumbar interbody fusion (TLIF) versus 7.8% with posterior lumbar interbody fusion (PLIF) performed largely for degenerative disc disease or spondylolisthesis [Table 2].[18] When bone morphogenetic protein (BMP) was added to MIS TLIF, 45.8% (11/24 patients) of patients exhibited transient postoperative radiculitis [Table 2].[3] Notably, many of these patients undergoing MIS TLIF likely required no surgery or decompression alone without fusion to largely address degenerative disc disease. Nevertheless for the MIS TLIF or MIS PLIF operations often performed unnecessarily, patients sustained high frequencies of transient or permanent nerve root injuries.

EVEN HIGHER FREQUENCY OF RADICULITIS WITH MINIMALLY INVASIVE ANTERIOR LUMBAR INTERBODY FUSION (ALIF) AND EXTREME LATERAL INTERBODY FUSION (XLIF)

Patients undergoing either anterior lumbar interbody fusion (ALIF) or extreme lateral interbody fusion (XLIF) cannot demonstrate a preoperative neurological deficit or significant radiographic neural or cauda equina compression as these procedures do not provide direct access to the spinal canal (at least not deliberately and therefore cannot include neural decompression). Therefore, many

Table 1: Nerve root injuries with lumbar surgery; series with 300 patients or more

Author (reference) year	Number of patients	Type of surgery Average follow-up duration Outcomes	Outcomes Complications	Nerve root injuries Frequency Type
Choi 2013[2]	233	MIS percutaneous transforaminal endoscopic diskectomy (measure exiting nerve root to the facet; working zone: If narrow choose another method)	213 no root injury 20 root injuries Smaller working zone for the latter	20 (4.3%)
Kaushal and Sen 2012[16]	300	Endoscopic diskectomy for lumbar discs (MIS); followed 12-24 months	1.7% discitis 1.7% durotomy	2 (0.7%) root injuries
Desai *et al.* 2012[6]	389	Lumbar laminectomy ± fusion/degenerative slip Followed 12 months	10.5% durotomy	Root injury 2% +durotomy 0% −durotomy
Desai *et al.* 2015[5]	409	Open lumbar laminectomy ± fusion for stenosis/ no slip Followed 43.8 months	37 (9%) durotomy longer LOS/surgery, higher EBL, younger surgeon	0% nerve root injuries with or without durotomy
Desai *et al.* 2011[4]	419	Open lumbar laminectomy with/without fusion for stenosis; Followed 43.8 months	38 (9%) durotomy	0% with or without durotomy
Evaniew *et al.* 2014[11]	431	MIS versus open diskectomy cervical/lumbar (4 cervical/10 lumbar trials) Followed average 12 months	Cervical durotomy 4 MIS/7 open Lumbar durotomy 25 MIS/16 open	1.39% cervical root injuries 3 MIS/3 open 2.25% lumbar root injuries 6 MIS/3 open
Verla *et al.* 2015[23]	1498	Primary lumbar fusion Follow-up average 24 months	115 (7.68%) complications 115 (49.18%): Durotomy 115 (13.11%) bleeding	11/115 (9.83%) nerve root injury
Desai *et al.* 2012[8]	792	Open lumbar diskectomy (13 centers - 11 states) Follow-up 41.3 months	Differences in duration of surgery, durotomy, LOS, reoperation rates	Comparable root injuries 2/792 (0.25%)
Desai *et al.* 2011[6]	799	Open diskectomy Average follow-up 12 months	25 (3.1%) durotomy Longer OR time; EBL, LOS	Root injuries 1/774 (0.13%) durotomy 0/25 (0%) no durotomy
Ahmadian *et al.* 2013[1]	2310	XLIF lumbar plexus/nerve root injuries: 18 MEDLINE studies	Deficits 0-3.4% root 7-33.6% motor 0-75% sensory	304 (13.2%) XLIF root/ plexus injuries Root injury 0-3.4%

MIS: Minimally invasive surgery, LOS: Length of stay, XLIF: Extreme lateral interbody fusion, EBL: Estimated blood loss

Table 2: Nerve root injuries with lumbar surgery: Series with 24-120 patients

Author (reference) year	Number of patients	Type of surgery Follow-up duration Outcomes	Outcomes Complications	Nerve root injuries Frequency Type
Corenman *et al.* 2013[3]	24	Disc pain: TLIF-BMP2 Follow-up 3.5 years	4 revisions 0 dural tears	11 radiculitis 0 root injuries
Hsiang *et al.* 2013[15]	40	TLIF unilateral pedicle screws/ contralateral percutaneous facet screws	2/40 (5%) contralateral facet screws misplaced	5% root injury contralateral facet screws
Wang *et al.* 2012[24]	50	Full endoscopic unilateral MIS diskectomy	5 reoperations (10%): Poor exposure, CSF leak	0% root injuries
Omidi-Kashani *et al.* 2014[19]	51	Instrumented TLIF Follow-up 31.4 months	100% fusion rate 0% instrument failure	1 (1.96%) partial L5 root injury
Lindley *et al.* 2011[17]	68	ALIF MIS fusions Followed average 34 months; 8.8% pseudarthrosis, 5.9% infection, 2.9% fracture	2.9% clot, 1.5% wound dehiscence, 2.0% rectal perforation	1.5% transient radiculitis
Duncan *et al.* 2012[10]	115	TLIF-study significant SEP changes/ no EMG Follow-up 2 years	5 (4.3%) SEP changes 3 resolved 2 root deficits	2 (1.7%) root deficits
Mehta *et al.* 2011[18]	119	TLIF (43) and PLIF (76) disc or spondylolisthesis disease Follow-up 5 years	Durotomy 17% PLIF versus 9% TLIF	Root injuries 7.8% PLIF 2% TLIF
Hrabalek *et al.* 2014[14]	120 ALIF 88 XLIF	Disc disease/failed back surgery Spondylolisthesis/retrolisthesis Posttraumatic disc injury T12-L5 level	ALIF 26.6% complications XLIF 25% complications	15.8% ALIF radiculitis 23.8% XLIF 1 L5 root 20 radiculitis

TLIF: Transforaminal lumbar interbody fusion, BMP2: Bone morphogenetic protein 2, MIS: Minimally invasive surgery, ALIF: Anterior lumbar interbody fusion, PLIF: Posterior lumbar interbody fusion, XLIF: Extreme lateral interbody fusion, PELD: Percutaneous endoscopic lumbar discectomy, EMG: Electromyography, SEP: Somatosensory evoked potentials

Table 3: Review articles and other studies: Root injuries with MIS versus open procedures

Author (reference) year	Number of patients	Type of surgery Follow-up duration Outcomes	Outcomes Complications	Nerve root injuries Frequency Type
Valone *et al.* 2014[22]	Review	TcMEP and EMG assess nerve roots (porcine model)	TcMEP responded to greater compression	Mechanical EMG's were not sensitive to root compression
Tannoury and An 2014[21]	Review	BMP-2 for cervical or lumbar fusions	Root injury Radiculitis	BMP-2 contributes to root injury
Spivak *et al.* 2013[20]	Review	MIS XLIF 12 cadavers 24 lumbar plexus	From L2 to L4	Safe zone avoids plexus/root injury; anterior half-disc

XLIF: Extreme lateral interbody fusion, TLIF: Transforaminal lumbar interbody fusion, ALIF: Anterior lumbar interbody fusion, BMP: Bone morphogenetic protein, MIS: Minimally invasive surgery, EMG: Electromyography, SEP: Somatosensory evoked potential, TcMEP: Transcranial motor evoked potential

of us argue from the get-go that these procedures are not warranted. Here, additionally, the argument is that they are also not safe. In a study by Ahmadian *et al*. in 2013, XLIF resulted in a 13.2% incidence of plexus injuries versus a 0–3.4% incidence of root injuries [Table 1].[1] A study by Hrabalek *et al*. in 2014 showed an even higher rate (23.8%) of radiculitis following MIS XLIF versus a 15.8% incidence of radiculitis after MIS ALIF [Table 2].[14] When assessing these frequencies of root injuries/radiculitis, one has to ask whether MIS ALIF or MIS XLIF are worth it? What about the high frequencies of these permanent nerve root deficits? Is there a "value added" for unnecessary surgery, which is associated with increased risks to previously normal neural function. As spine surgeons, we should be better monitoring the lack of safety/efficacy of MIS ALIF and XLIF MIS procedures, and not condone those operations that clearly "do harm."

ROOT INJURIES FOR OPEN LUMBAR LAMINECTOMIES WITH/WITHOUT FUSIONS

The frequency of lumbar root injuries with open surgical procedures remains very low whether performed

for disc disease, stenosis, or spondylolisthesis. The Desai *et al*. SPORT report in 2011, for 419 patients undergoing initial open decompressive laminectomies for stenosis with/without fusions, revealed that none sustained nerve root injuries (0%) [Table 1].[4] In a later SPORT trial by the same author, the 389 patients undergoing decompressive lumbar laminectomy for degenerative spondylolisthesis with/without fusion (not a MIS study) exhibited a durotomy rate of 10.5%, and the frequency of nerve root injuries was comparably low with durotomy (2%) or without (0%) durotomy [Table 1].[6] Desai *et al*. in the 2015, SPORT evaluation for patients undergoing open surgery for spinal stenosis without spondylolisthesis (e.g., 1st-time laminectomies with/without fusions) also revealed that durotomy occurred in 9% of patients, but there were no root injuries (0%) with/without durotomy [Table 1].[5] Of interest, in these three SPORT studies, the higher incidence of dural tears was correlated with more operations being performed by less experienced surgeons. It was unfortunate that they did not keep track of the use of the operating microscope that was left to "surgeon discretion," as its absence likely contributed to the incidence of both dural and neural injuries in everyones' hands.

Root injuries for open diskectomy

In the SPORT study by Desai *et al*. in 2011, out of 799 patients undergoing initial open lumbar surgery for diskectomy alone, the frequency of neural injury was 1/774 (0.13%) without durotomy, and 0/25 (0%) with durotomy [Table 1].[7] In Desai *et al*.'s second SPORT study in 2012 focusing on open surgery for lumbar disc herniations alone, the frequency of nerve root injuires still remained a very low 0.25% (2/792 patients) [Table 1].[8]

Root injuries with endoscopic minimally invasive diskectomy

Multiple studies cited varying frequencies of root injuries occurring with MIS endoscopic diskectomies.[11,16] In Kaushal and Sen in 2012, out of a series of 300 posterior lumbar MIS endoscopic diskectomies, 5 patients sustained dural tears, 5 had discitis, and 2 exhibited new nerve root injuries [Table 1].[16] Choi *et al*. cited root injuries occurring in 20 (4.3%) of 233 MIS percutaneous transforaminal endoscopic diskectomies and correlated these with a narrowed "working zone" (e.g., distance on magnetic resonance imaging between the existing root and the facet at the lower disc level) [Table 1].[2] In 2014, Evaniew *et al*. described a 2.25% root injury rate for different types of MIS versus open lumbar diskectomy procedures; rates were substantially higher with the MIS procedures [Table 1].[11] In the latter study, the authors themselves could not support the routine use of MIS for cervical or lumbar diskectomies due to their greater major and minor morbidities. Why should we?

HIGHER INCIDENCE OF ROOT INJURIES WITH MINIMALLY INVASIVE LUMBAR FUSIONS (ALIF, TLIF, XLIF, PLF)

Multiple MIS lumbar fusion (ALIF, TLIF, XLIF, posterolateral fusion (PLF)) series cite high frequencies of nerve root injuries (up to 9.83%) sustained in patients undergoing surgery for degenerative (disc disease, stenosis, and degenerative spondylolisthesis).[12,15,23] In Hsiang *et al*.'s modification of the MIS TLIF utilizing ipsilateral pedicle screws, but contralateral percutaneous transpedicular facet screws, the latter resulted in a 5% (2 patients) incidence of root injuries warranting screw removal [Table 2].[15] Nevertheless, how could the authors conclude that this modified technique was safe and effective? Furthermore, Mehta *et al*. in 2011 concluded that any MIS interbody device applied to address disc disease or spondylolisthesis, resulted in a high incidence or nerve root injury whether utilizing the TLIF (2%) or PLIF (7.8%) approaches [Table 2].[18] Here, the authors themselves concluded MIS interbody fusions should only be performed where posterolateral traditional decompressions/fusions will not suffice. Why not take their advice? As several studies cite high frequencies of pseudarthrosis with TLIF (including a pseudarthrosis rate for bilateral screws from 2.5% to 23.1%), why should one believe Omidi-Kashani *et al*.'s 100% TLIF fusion rate or their minimal 1 of 51 frequency of partial L5 root injury rate?[12,13,19]

Minimally invasive anterior lumbar interbody fusion (ALIF): 1.5% rate of radiculitis

Lindley *et al*. in 2011 found a 26.5% complication rate and 1.5% incidence of transient nerve root irritation for 68 MIS ALIF performed at the L4–L5 and L5–S1 levels [Table 2].[17] Noting that ALIF are typically indicated in patients with pain alone, without focal neurological deficits or significant radiographic findings (e.g., no focal nerve root/cauda equina compression), one should conclude that the overall complication rate and even relatively small nerve root complication rates were too high.

Minimally invasive extreme lateral interbody fusion (XLIF): The high frequency of root/plexus injuries is unacceptable

The biggest problem with XLIF is that they are not only unnecessarily being performed for patients with pain alone without focal neurological or neuroradiological abnormalities, but that they are also resulting in many lumbar plexus and nerve root injuries.[1,14,20] In the cadaveric study performed by Spivak *et al*. in 2013, they noted the lumbar plexus and nerve roots from the L2–L3 through the L4–L5 levels were at great risk of injury during

XLIF procedures [Table 3].[20] Corroborating this pathoanatomical finding, Ahmadian *et al*. study in 2013, involving a review of 18 series, found that 304 (13.2%) of 2310 patients sustained root/plexus injuries during XLIF [Table 1].[1] When Hrabalek *et al*. in 2014 further compared the complication rates of MIS ALIF (120 patients; overall 26.6% complication rate) versus the newer MIS XLIF (88 patients: overall 25% complication rate) addressing disc herniations from the T12 to L5 levels, 15.8% of ALIF versus 23.8% having XLIF exhibited new postoperative radiculitis [Table 2].[14] The high incidence of plexus/nerve root injuries with XLIF should prompt spinal surgeons to strongly questions why these procedures should still be offered.

INADEQUATIES OF MINIMALLY INVASIVE LUMBAR SURGICAL APPROACHES; 10% CONVERT TO OPEN SURGERY

Wang *et al*. in 2012 observed a 10% conversion rate (5 of 50 patients) for patients initially undergoing full endoscopic unilateral, interlaminar lumbar diskectomies.[24] These failures were attributed to MIS affording, poor placement of the MIS retractor, inadequate exposure particularly with lateral recess stenosis, poor hemostasis, and a higher incidence of cerebrospinal fluid fistulas. All of these shortcomings can certainly contribute to the risk of nerve root injury [Tables 1-3].

ELECTROPHYSIOLOGICAL MONITORING OF LUMBAR SURGERY TO HELP AVOID ROOT INJURIES

Many spine surgeons routinely use intraoperative neural monitoring. Modalities utilized include; electromyography [EMG], often including sphincter function, and somatosensory-evoked potentials [SEPs]. Motor-evoked potentials [MEPs] are typically reserved for higher lesions (e.g. involving up to the T12-L2 levels during lumbar operaitons).[10,22] We obtain real-time feedback in the operating room as our monitoring physiologist/interpreter is present. We are immediately alerted if there is any neural and/or cauda equina compromise. If changes occur, they are typically very transient and are immediately acted upon (e.g. cessation of dissection/manipulation). Duncan *et al*. in 2012 underscored the need to monitor TLIF as the placement of the interbody device resulted in significant SEP changes, providing clear physiological evidence that these procedures can result in significant cauda equina compression and are not really "safe" [Table 2].[10] In addition, Valone *et al*. in 2014 observed that lumbar nerve root injury/weakness, variously attributed to operative manipulation/decompression, occurs in up to 30% of spinal deformity cases [Table 3].[22]

NERVE ROOT INJURIES DUE TO BONE MORPHOGENETIC PROTEIN IN LUMBAR FUSIONS

Several studies now document that the application of recombinant human BMP-2 (rhBMP-2) in lumbar fusion procedures can produce neural injury not only documented clinically, but also histopathologically.[3,9,21] Dmitriev *et al*., in their 2011 article, demonstrated the significant negative impact of applying rhBMP-2 near neural structures.[9] In another study, Corenman *et al*. retrospectively evaluated the results of TLIF performed with BMP-2 for patients with discogenic pain syndromes; 11 (30.6%) patients exhibited unexplained postoperative radiculitis, whereas 4 needed additional surgery [Table 2].[3] In the review article by Tannoury and An in 2014, they noted that rhBMP-2 resulted in adverse events including nerve root injury/radiculitis when utilized to perform cervical or lumbar fusions.[21] Although all of these authors cite "real concerns" about the off-label use of BMP in spinal surgery, where is the momentum to remove this product from the shelves?

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