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Editorial

Many Intraoperative Monitoring Modalities Have Been Developed To Limit Injury During Extreme Lateral Interbody Fusion (XLIF/MIS XLIF): Does That Mean XLIF/MIS XLIF Are Unsafe?

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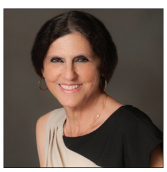

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Received : 18 November 19
Accepted : 19 November 19
Published : 29 November 19

DOI
10.25259/SNI_563_2019

Quick Response Code:

ABSTRACT

Background: Extreme lateral interbody fusions (XLIF) and Minimally Invasive (MIS) XLIF pose significant risks of neural injury to the; lumbar plexus, ilioinguinal, iliohypogastric, genitofemoral, lateral femoral cutaneous, and subcostal nerves. To limit these injuries, many intraoperative neural monitoring (IONM) modalities have been proposed.

Methods: Multiple studies document various frequencies of neural injuries occurring during MIS XLIF/XLIF: plexus injuries (13.28%); sensory deficits (0-75%; permanent 62.5%); motor deficits (0.7-33.6%; most typically iliopsoas weakness (14.3%-31%)), and anterior thigh/groin pain (12.5-25%.-34%). To avoid/limit these injuries, multiple IONM techniques have been proposed. These include; using finger electrodes during operative dissection, employing motor evoked potentials (MEP), eliminating (no) muscle relaxants (NMR), and using "triggered" EMGs.

Results: In one study, finger electrodes for XLIF at L4-L5 level for degenerative spondylolisthesis reduced transient postoperative neurological symptoms from 7 [38%] of 18 cases (e.g. without IONM) to 5 [14%] of 36 cases (with IONM). Two series showed that motor evoked potential monitoring (MEP) for XLIF reduced postoperative motor deficits; they, therefore, recommended their routine use for XLIF. Another study demonstrated that eliminating muscle relaxants during XLIF markedly reduced postoperative neurological deficits/thigh pain by allowing for better continuous EMG monitoring (e.g. NMR no muscle relaxants). Finally, a "triggered" EMG study" reduced postoperative motor neuropraxia, largely by limiting retraction time.

Conclusion: Multiple studies have offered different IONM techniques to avert neurological injuries following MIS XLIF/XLIF. Does this mean that these procedures (e.g. XLIF/MIS XLIF) are unsafe?

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

INTRODUCTION

Extreme lateral interbody fusions (XLIF) and Minimally Invasive (MIS) XLIF place the lumbar plexus, ilioinguinal, iliohypogastric, genitofemoral, lateral femoral cutaneous, and subcostal nerves at risk of injury during surgery [Table 1]. In 2016, Epstein reviewed the varying incidences of multiple nerve injuries occurring in various studies where XLIF/MIS XLIF were performed.[3,4] These included: sensory deficits (13.28%: 0-75%; permanent in 62.5%), motor deficits (0.7-33.6%), iliopsoas weakness (14.3%-31%), overall plexus injuries 13.28%, and anterior thigh/groin pain (12.5%-34%).[3,4] Here we reviewed several of the intraoperative neural monitoring (IONM) modalities that have been developed to reduce these injuries; the use of finger electrodes during operative dissection, employing motor evoked potentials (MEP), eliminating (no) muscle relaxants (NMR), and using "triggered" EMGs. If you need any or all of these monitoring modalities to avoid neurological injuries during XLIF/MIS XLIF, are they inherently unsafe?

Nerves at Risk with XLIF

The lumbar plexus includes the L1-L4 nerves, and the subcostal nerve (T12). The sensory portion of the ilioinguinal nerve innervates the genital regions and some of the upper anterior/-medial thigh, while motor branches subserve the internal oblique and transversus abdominis muscles. The iliohypogastric nerve contributes to sensation over the

Table 1: Different Monitoring Protocols for XLIF/MIS XLIF.

Author Ref. Year	Study Design	Findings	Findings	Findings	Conclusions
Chaudhary 2015[2]	EMG does not detect impending neural deficits MEP does= defines femoral N. injury for transpsoas XLIF.	Triggered EMG Predicts neuropraxia postop for 3 L45 XLIF	MEP defined changes during XLIF without EMG changes	MEPs lost during/ after retraction of 25, 27, and 61 minutes; No EMG Changes	Two MEP changes =postoperative quadriceps deficits One MEP loss resolved= no deficits
Uribe 2015[8]	Triggered electromyography (t-EMG) during psoas retraction for XLIF reduced postop neural deficits	323 L4-L5 MIS XLIF 21 Sites Helped predict postop deficits	t-EMG thresholds with posterior retractor blade stimulation Recorded q 5 min during operative retraction	Postop 13 (4.5 %) exhibited new motor deficits/ lumbar plexus nerve injuries	Prolonged retraction time /increases in t-EMG predictors declining nerve integrity
Narita 2016[6]	Finger Electrode for L4-L5 XLIF for DS Reduced AE	36 patients vs. 18 historical controls	Finger electrode thresholds before/ after psoas dissections	No Finger electrode group AE 7 (38%) of 18 cases	With Finger Electrode 5 (14%) of 36 cases
Epstein 2016[3] Epstein 2016[4]	High risk of XLIF for neural injury: Sensory/Motor	Sensory (13.28%: 0-75%; permanent in 62.5%),	Motor (0.7-33.6%), Iliopsoas weakness (14.3%-31%),	Anterior thigh/ groin pain (12.5%-34%).	Up to 75% sensory 33.6% motor 13.28% plexus injury
Abel 2018[1]	Femoral nerve lumbar plexus trauma due to 230 transpsoas MIS XLIF	Used NCS and EMG	Postop 6 (2.6%) new femoral or femoral/ obturator neuropathy	5 (2.2%) Included acute weakness".	Five of six (83%) demonstrated axonotmesis
Riley 2018[7]	tcMEPs << risk surgeon-induced postop deficits following XLIF EMG only equals high risk deficits	3 Protocols: SD-EMG NC-EMG NC-MEP	Sensory deficits NC-MEP 20.5% NC-EMG 34.3% SD-EMG 36.9%	Motor deficits NC-MEP 5.7% SD-EMG 17.0% NC-EMG 17.1%	<<Permanent/long-term motor deficits NC-MEP 0.9% NC-EMG 6.9% SD-EMG 11.0%
Fogel 2018[5]	74 patients 150 levels XLIF No Muscle Relaxants NMR	Vs. 124 XLIF (238 levels) with Muscle Relaxants	< Neural Injury without NMR 8/74 =0.8% vs. With MR 3(6/125=28.8%)	Eliminating MRs-free running EMG more reliable and accurate	NMR better predicts proximity neurologic structures-reduces injury with XLIF

VB=Vertebral Body, DLS=Degenerative Lumbar Scoliosis, DLSt-Degenerative Lumbar Stenosis, AE=Adverse Event, DS=Degenerative Spondylolisthesis, NCS=Nerve Conduction Studies, EMG=Electromyography, MEP=Motor Evoked Potentials, LLIF=Lateral Lumbar Interbody Fusions, SD=EMG=Surgeon Directed EMG Monitoring, NC-EMG=Neurophysiologist-Controlled EMG monitoring, NC-MEP=Neurophysiologist-controlled T-EMG monitoring supplemented with MEP monitoring, NMR=No Muscle Relaxants , Ref=References, q=every, MR=Muscle relaxants lateral gluteal region, and provides motor innervation to the external/internal oblique, and transverse abdominus muscles. Sensation to the upper anterior thigh and genital regions is provided by the genitofemoral nerve, while sensation to the skin inferior to the iliac crest and gluteal regions is attributed to the lateral femoral cutaneous nerve. Lastly, the subcostal nerve (origin ventral ramus of T12 thoracic nerve) supplies motor innervation to the transversus abdominis, rectus abdominis, and pyramidalis.

Intraoperative Neural Monitoring to Avoid Neurological Deficits with XLIF/MIS XLIF

Use of Nerve Conduction Studies (NCS) and Electromyography (EMG)

Abel *et al*. (2018) evaluated the extent of trauma to the femoral nerve and lumbar plexus occurring during 230 transpsoas MIS XLIF procedures utilizing different electrodiagnostic protocols [Table 1].[1] Immediately postoperatively, "… 6 *patient*s (2.5%) had new postoperative femoral or femoral/obturator neuropathy, 5 (2.2%) of which included acute weakness". At six postoperative weeks, 5 (83%) demonstrated fixed/permanent axonotmesis.

Use of Finger Electrodes to Avoid Neurological Complications of XLIF

In 2016, Narita *et al*. studied whether using a finger electrode while performing L4-L5 XLIF for DS (degenerative spondylolisthesis) would reduce the incidence of new postoperative neurological deficits [Table 1].[6] The results of 36 monitored XLIF patients (before and after psoas muscle dissection) were contrasted with 18 of their own previous unmonitored historical controls (XLIF performed without this device). They found the finger electrodes significantly reduced the transient neurological symptoms (e.g. a lesser 5 [14%] of 36 cases) vs. unmonitored controls (7 [38%] of 18 controls).[6]

Motor Evoked Potential Monitoring (MEP) Decreases Deficits with XLIF

Several authors demonstrated that adding intraoperative MEP monitoring to EMG for XLIF, where EMG's typically showed no changes, could reduce or limit the incidence of new postoperative neurological deficits [Table 1].[2,7] Chaudhary *et al*. (2015) evaluated whether changes in transcranial MEP monitoring could help reduce the incidence of femoral nerve injuries occurring during transpoas L4-L5 XLIF where no EMG changes occurred [Table 1].[2] MEPs were lost but EMG's were maintained in these 3 procedures with respective retraction times of 25, 27, and 61 minutes; 2 patients had new postoperative quadriceps deficits, while one with a transient MEP loss (e.g. recovered intraoperatively), remained intact. They concluded that adding MEP to EMG monitoring of XLIF could reduce future neurological deficits, particularly by prompting surgeons to reduce retraction times. In 2018, Riley *et al*. also analyzed the efficacy of MEP and/or EMG monitoring for XLIF. They used 3 treatment groups (followed for 12 months); (1) surgeon-directed EMG monitoring ("SD-EMG"), (2) neurophysiologist-controlled EMG monitoring ("NC-EMG"), and (3) neurophysiologist-controlled EMG with MEP monitoring ("NC-MEP") [Table 1].[7] Both sensory and motor deficits following XLIF were reduced with NC-MEP monitoring, (sensory 20.5%, motor 5.7%) vs. NC-EMG (sensory 34.3%, motor 17.0%), and SD-EMG monitoring (36.9% sensory, motor 17.1%). They concluded that MEPs (adductor longus, quadriceps, and tibialis anterior muscles) reduced the risk of surgeon-induced postoperative sensory/motor deficits following XLIF, and should be used routinely.

No Muscle Relaxants (NMR) Avoids Neurological Injuries with XLIF

A typical complication of XLIF performed with muscle relaxants is proximal thigh pain and weakness involving the L3-L4, and L4-L5 levels. In 2018, Fogel *et al*. asked whether eliminating muscle relaxation during XLIF would reduce the risk of neural injury.[5] They studied 74 consecutive patients undergoing 150 level XLIF with no muscle relaxants (NMR) vs. 124 patients undergoing XLIF at 238 levels performed with muscle relaxation (MR); the incidence of thigh pain/motor deficits was lowered in the NMR (8/74 =0.8%) vs. MR 3(6/125=28.8%) groups [Table 1]. They concluded; "Eliminating MRs altogether appears to have allowed the evoked and free running EMG to be more reliable and accurate in predicting the proximity of the neurologic structures."

Use of Triggered EMG to Predict Neuropraxia After MIS XLIF

Uribe *et al*. (2015) evaluated whether triggered EMG utilized during 323 L4-L5 MIS XLIF (from 21 study sites) during psoas retraction and XLIF would reduce postoperative neurological dysfunction [Table 1].[8] Original t-EMG thresholds were obtained utilizing posterior retractor blade stimulation, and also every 5 min during operative retraction. After surgery, 13 (4.5 %) patients exhibited new motor deficits/lumbar plexus nerve injuries (e.g. symptomatic neuropraxia (SN)), and concluded; "Prolonged retraction time and coincident increases in t-EMG thresholds are predictors of declining nerve integrity." Therefore, routinely using t-EMG during retraction, and limiting retraction time could limit postoperative neurapraxia.

CONCLUSION

Here we have presented multiple intraoperative neural monitoring (IONM) modalities developed to reduce nerve injuries following XLIF/MIS XLIF, including; finger electrodes, motor evoked potentials (MEP), no muscle relaxants (NMR), and using "triggered" EMGs [Table 1]. We ask again, if you need so many monitoring techniques to limit neural injuries incurred during XLIF/MIS XLIF, are these procedures inherently unsafe?

Financial support and sponsorship

None.

Conflicts of interest

There are no conflicts of interest.

Disclaimer

The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Journal or its management.

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How to cite this article: Epstein NE. Many Intraoperative Monitoring Modalities Have Been Developed To Limit Injury During Extreme Lateral Interbody Fusion (XLIF): Does That Mean XLIF Are Unsafe? Surg Neurol Int 2019;10:233.