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Editorial

Learning curves for minimally invasive spine surgeries: Are they worth it?

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Abstract

Background: Minimally invasive surgery (MIS) spine procedures were developed to limit operative time, the extent of dissection, and reduce perioperative morbidity. Here, we asked what are the "learning curves" for these MIS spine procedures?

Methods: We reviewed studies in the literature that discussed the "learning curves" attributed to performing different MIS spine surgical procedures. Of interest, the majority were single-surgeon series.

Results: Very few articles assessed the learning curves for different MIS spine procedures. One study reported no learning curve for open vs. MIS discectomy/laminotomy. Another study indicated that 20–30 cases were required for a surgeon to become proficient in performing a variety of MIS spine fusions [e.g., cervical MIS fusions, MIS anterior lumbar interbody fusions (ALIF), MIS transforaminal lumbar interbody fusions (TLIF), and MIS pedicle/screw placement in the thoracic/lumbar spine]. Several other studies specifically cited that, to become proficient in the performance of TLIF, surgeons had to have performed between 10, to 32, to 40, to 44 such cases.

Conclusions: There is a very limited literature available that focuses on the "learning curves" associated with the performance of different types of MIS spine procedures. The number of cases required to satisfy the "learning curves" for different operations varied from 0 for MIS vs. open discectomy/laminotomy, to 20-30 for a variety of cervical-thoracic-lumbar procedures, and up to 44 cases for TLIF. Shouldn't we ask whether better oversight measures and/or mentoring programs could limit the morbidity/AE occurring during these "learning curves" in the future?

Key Words: Adverse events, learning curve, minimally invasive spine surgery, minimizing, morbidity, mortality, under-reporting

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INTRODUCTION

Minimally invasive spine surgery (MIS) theoretically limits operative time/dissection, and reduces perioperative morbidity and mortality. Here, we focused on the "learning curves," defined as the number of cases required to become proficient (e.g., reduce operative time, estimated blood loss, morbidity/adverse events) for performing various MIS

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spinal procedures. As some studies documented comparable long-term outcomes for open vs. MIS spinal operations, how do we determine wheter (not if) the "learning curve' is "worth it"?

MIS SPINE SURGERY ASSOCIATED WITH SIGNIFICANT ADVERSE EVENTS

The adverse events (AE) attributed to MIS spine surgery need to be better recognized [Table 1].[2-4] In 2008, Epstein reported major complications of 4 MIS Met/RX diskectomies performed by other surgeons (MED/METRx, Medtronic, Memphis, TN, USA) and 2 major complications of MIS X-Stops devices (infection, hematoma) also performed by outside surgeons.[2] Epstein quoted another study in 2011 that observed AE increased with the greater complexity/extent of MIS spinal surgery performed in largely geriatric patients (e.g., 10% AE for decompression alone, 40% AE for decompression/limited fusions, and 56% AE for full curve fusions).[3] As of 2016, Epstein observed that the literature quoted higher frequencies of nerve root injuries occurring with MIS vs. open spine surgery.[4] Higher rates of nerve root injuries were reported during MIS fusions; posterior lumbar interbody fusions (PLIF 7.8%), transforaminal lumbar interbody fusions (TLIF 2%), anterior lumbar interbody fusions (ALIF 15.8%), and extreme lateral interbody fusions (XLIF 23.8%). Lower rates of nerve root injuries were confirmed in different reports for open procedures; from 0.13–0.25% for laminectomy/discectomy alone, 0–2% for laminectomy/stenosis with/without fusion, and up to 2% for laminectomy/stenosis/degenerative spondylolisthesis (DS) with/without fusion. Phan *et al*. in 2016 reviewed 29 studies involving 1228 patients, and defined higher incidences of motor/sensory deficits for patients undergoing MIS LLIF (lateral lumbar interbody fusions: motor 3.6%/sensory 3.3%) and TLIF (0.7%/0.7%), vs. open decompression alone for adult degenerative scoliosis (0.5%/0.5%) [Table 1].[11]

MINIMAL TO STEEP LEARNING CURVES FOR MIS SPINE SURGERY

Several studies, most of which were single-surgeon series, identified "steep" learning curves for MIS spinal surgery [Table 2].[3,5-9,12,13] In 2003, Guyer *et al*. observed that learning curves for MIS spine surgery had to be better assessed.[3] Lau *et al*. in 2011, in a single-surgeon series, evaluated/compared the learning curve for 12 open TLIF vs. 10 MIS TLIF (e.g., for lumbar spondylolisthesis and lysis) over 1 postoperative year [Table 2].[7] Those undergoing MIS TLIF exhibited lower transfusion rates, fewer drains/shorter drainage periods, shorter time duration for bed rest, but "tended" to have higher complication rates that they attributed to the learning curve.[7]

In 2013, Silva *et al*., in another single-surgeon series, noted MIS-TLIF correlated with "a steep learning curve."[13] Procedures included; 110 one-level and 18 two-level MIS-TLIF. They observed a 50% learning curve by case 12 (defined by a complication rate of 33%), but a 90% learning curve by case 39 (defined by a complication rate 20.51%). They concluded that the learning curve for MIS TLIF was therefore, approximately 40 cases.

Subsequently, in 2014, Nandyala *et al*., again in a single-surgeon study, evaluated the learning curve for the first 32 cases of MIS TLIF vs. the latter 33 MIS TLIF performed for disc disease/lumbar spinal stenosis

Table 1: Complications for minimally invasive vs. open spinal surgical procedures

Author Reference Year	Case number Type	Surgery	Treatment/Other	Outcomes/Other	% Adverse events
Epstein[2] 2008	AE MIS spine surgery	4 MET/Rx discectomies 2 X-Stop Devices	4 MIS Diskectomies: 1 Far lateral disc missed 1 CSF leak – no discectomy	4 MIS Diskectomies: 1 infection, 1 CSF leak/cauda equina syndrome	2 X-Stops: 1 Infection 1 Epidural hematoma
Epstein[3] 2011	>65 years of age	Many Comorbid Factors	10% AE Decompressions	40% AE Decompressions limited fusions	56% AE decompression full curve fusions
Epstein[4] 2016	More root injuries XLIF	Root Injuries Open discectomy 0.13%-0.25%	0% Open laminectomy/ Fusions +/- 2% Stenosis/+/- fusion	MIS PLIF 7.8% MIS TLIF 2%	Root Injuries MIS ALIF 15.8% 23.8% XLIF
Phan[11] 2016	1228 Patients 29 Studies LLIF TLIF Decompression only	95.9% Fusion rates (all) 4.3% Hardware complications 4 4.3% Pseudarthrosis 4	Motor deficits 3.6% LLIF 0.7% TLIF 0.5% decompression	Sensory deficit 3.3% LLIF 0.7% TLIF 0.5% decompression	Similar rates of infection Dural tears Medical Similar X-ray results

LLIF/XLIF: Extreme Lateral Lumbar Interbody Fusion, TLIF: Transforaminal lumbar interbody fusion, MIS: Minimally invasive surgery, LOS: Length of stay, PLIF: Posterior lumbar interbody fusion, ALIF: Anterior lumbar interbody fusion, DS: Degenerative Spondylolisthesis, MET/Rx: Metrix System (Medtronic, Memphis, TN, USA), AE: Adverse events

Table 2: Learning curve for minimally invasive spine procedures

Author Reference Year	Case number Type	Surgery	Treatment/Other	Outcomes/Other	% Adverse events
Guyer[5] 2003	Review Article	MIS surgery aims: Less exposure	MIS surgery: Reduced dissection	MIS surgery; Completion surgery without >morbidity	MIS Must not increase morbidity
Lau[7] 2011	MIS TLIF Learning Curve	12 Open TLIF vs. 10 MIS TLIF	MIS TLIF Lower intraoperative Transfusions	MIS TLIF <Postop drains Shorter drainage <Time to ambulation	MIS TLIF More AE >Learning Curve
Silva[13] 2013	150 MIS TLIF 1 Surgeon	110 1-level 18 2-level MIS TLIF 22 had additional procedures	Average OR time 140 minutes 50% learning curve 12 cases 90% learning curve 39 cases	Overall complications 12.67% Most frequent dural tear 5.32% Complications 33% and 20.51%	MILESTEON 40 cases (90%)
Parker[10] 2014	MI TLIF (50 patients	Open TLIF for DS (50 patients	MIS reduced LOS Time to return to work	Comparable short and long term outcomes Comparable morbidity	Similar 2 year direct costs and QALY
Nandyala[9] 2014	65 MIS 1-Level TLIF 1 Surgeon Learning Curve/AE Early 32 Late 33	DJD/Stenosis Grade I-II Olisthy No revisions Only 1-level surgery	Early 32 patients: Longer surgery >Blood Loss >IV fluids >Anesthesia Similar CT fusion 2 Groups 1 year AE: 11 vs. 9	AE Early 32 patients 2 Pseudarthrosis 1 Graft migration 1 Medial pedicle breech 2 revisions AE Late 33 patients: 2 pseudarthrosis 2 infection 3 revisions	Similar AE Events Same number durotomies (2 each) same LOS
Sclafani[12] 2014	Learning Curves MIS TLIF Pedicle Screws	MIS ALIF MIS Cervical	15 Studies 966 patients AE decompressions – durotomy	AE Fusions: Implant malposition, Neural injury. Nonunion Overall AE rates 11% (109/966)	Learning Curve 20-30 cases for all techniques
Lee[8] 2014	Learning curve MIS TLIF 1 surgeon 44 1st vs. Latter 46 cases	First 44: >OR Time, >Fluoro time, >Pain <VAS <Outcomes	Early AE: 1 durotomy 2 cage migrations Later 46 AE 1 cage migration	Both Groups Similar: Neurological symptoms X-ray-fusion rates No MIS TLIF converted to open	Learning Curve for MIS TLIF 44 Cases
Jin-Tao[6] 2015	MIS vs. Open PLIF/TLIF	MIS TLIF similar fusion and complication rates	Deep learning curve	MIS-TLIF surgeons require many years of training + More experience necessary	MIS TLIF vs. Open Similar fusion/AE Rates
Ahn[1] 2016	Learning Curve 1-2 Level Surgery	Lumbar laminectomy Laminotomy +/- Discectomy	Secondary Analysis: 50 MIS vs. 50 Open lumbar discectomy (LD) patients	Open LD >OR time >EBL >LOS Same Reoperation Readmission rates	Similar learning curve 1-2 Level LD Procedures

LLIF/XLIF: Extreme lateral lumbar interbody fusion, TLIF: Transforaminal lumbar interbody fusion, MIS: Minimally invasive surgery, LOS: Length of Stay, PLIF: Posterior lumbar Interbody fusion, ALIF: Anterior lumbar interbody fusion, DS: Degenerative spondylolisthesis, MET/Rx: Metrix system (Medtronic, Memphis, TN, USA), AE: Adverse events, OR: Operating room time, DJD: Degenerative joint/lumbar Disease, LD: Lumbar diskectomy

with grade I or II spondylolisthesis.[9] Those in the first MIS TLIF group required significantly longer surgery with higher EBL; however, each group had comparable complication rates (e.g., 2 durotomies, and similar CT documented complications at one year; 11 vs. 9, respectively), with comparable LOS [Table 2]. They concluded that there should be "methods to minimize the complications associated with the learning curve."

Lee *et al*. in 2014 assessed the learning curve for 90 one-level MIS TLIF performed by one surgeon.[8] Although the first 44 patients showed poorer VAS and neurogenic symptom scores vs. the latter 46 patients, both groups demonstrated comparable radiologic fusion, and complication/AE rates. They concluded that "the asymptote (the number of cases needed to approach the complication rate of standard surgical techniques) of the

surgeon's learning curve for MIS TLIF was achieved at the 44th case."

In 2015, Jin-Tao *et al*. summarized the findings of 14 studies (12-month follow-up) involving MIS TLIF vs. open PLIF/TLIF.[6] They concluded that MIS TLIF led to similar fusion and complication rates, however, higher revision/readmission rates were attributed to the deep learning curve. They observed that for MIS TLIF, surgeons require "many of training and experience is necessary. Otherwise, MIS TLIF may yield unsatisfactory results upon patients."

Sclafani and Kim in 2014 also discussed the learning curves found in 14 studies involving 966 MIS procedures that included MIS TLIF, percutaneous pedicle screw insertion (thoracic/lumbar), MIS anterior lumbar interbody fusion, and MIS cervical fusions.[12] The most common complication/AE attributed to the "learning curve" for decompressions alone was durotomy, while for fusions, complications/AE included implant malposition, instrumented-related neural injury, and nonunion. Their total complication rate was 11% (109 of 966 cases). They concluded that the learning curve, largely based on operative time and complications, required 20 to 30 consecutive cases in each group. They also noted that "the field of MIS (spine surgery) would benefit from a standardization of study design and collected parameters in future learning curve investigations."

NO LEARNING CURVE FOR MIS LUMBAR DISKECTOMY OR MIS TLIF

Two studies claimed no significant learning curves were associated with performing MIS vs. open lumbar discectomy, and MIS vs. open TLIF [Table 2].[1,10] Ahn *et al*. evaluated one-surgeon's leaning curve for performing 50 MIS vs. 50 open lumbar discectomy (LD patients); MIS procedures were shorter, involved less blood loss, and shorter LOS. However, both groups demonstrated comparable 30-day readmission rates/AE.[1] Parker *et al*. found comparable safety/efficacy and cost effectiveness of 50 MIS-TLIF vs. 50 open procedures for degenerative spondylolisthesis [Table 1].[10] Although MIS reduced the length of stay (LOS) and time to return to work, both offered comparable outcomes/quality-adjusted life year QALY, AE, readmission rates, and 2-year health care costs.

CONCLUSION

The spine literature documents different learning curves (e.g., complications/AE) for performing various types of MIS spinal surgical procedures.[1,5-9,12,13] Two studies stipulated there were no learning curves necessary to perform MIS vs. open discectomy/laminotomy.[1,10] Another study found that an average of 20–30 cases were warranted to satisfy learning curves for TLIF, MIS Pedicle Screws, MIS ALIF, and MIS cervical surgery.[12] Several other studies described learning curves for MIS TLIF requiring from 10 to 44 cases [Table 2].[7-9,13] Shouldn't we ask whether better oversight measures and/or mentoring programs would/should limit the morbidity/AE occurring during these "learning curves" in the future?

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