International Journal of Spine Surgery, Vol. 12, No. 6, 2018, pp. 680–688
https://doi.org/10.14444/5085

Evidence Based Medicine Review of Posterior Thoracolumbar Minimally Invasive Technology

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ABSTRACT

Background: Evaluate the current evidence in meta-analyses on posterior thoracolumbar minimally invasive surgery techniques and outcomes for degenerative conditions.

Methods: A systematic review of the literature from 1950 to 2015.

Results: The review of the literature yielded 34 meta-analysis studies evaluating posterior thoracolumbar minimally invasive techniques and outcomes for degenerative conditions. There were 11 studies included which investigated minimally invasive surgery (MIS) versus open posterior lumbar decompressions. There were 14 studies included which investigated MIS versus open posterior lumbar interbody fusions. Finally, there were 9 studies focused on navigation techniques and radiation safety within MIS procedures.

Conclusions: There are 34 meta-analysis studies evaluating minimally invasive to open thoracolumbar surgery for degenerative disease. The studies show a trend toward decreased estimated blood loss, decreased length of stay, decreased complications, similar fusion rates, improved accuracy, and decreased radiation when minimally invasive techniques are used.

Minimally Invasive Surgery

Keywords: minimally invasive spine surgery, minimally invasive decompression, MIS TLIF, navigation, radiation safety

INTRODUCTION

Minimally invasive surgery (MIS) techniques for spine have gained popularity as surgeons across this specialty have embraced advancements in access systems and imaging technologies. Minimally invasive surgery techniques are currently applied to a variety of spinal pathologies including degenerative disc disease, disc herniation, instability, deformity, fracture, and tumor. Advocates for MIS cite minimal muscle and soft tissue dissection, excellent visualization, and faster recovery time as advantageous when compared to open procedures.[1] However, despite the initial evidence supporting MIS techniques, traditional open approaches remain the standard of care among spine surgeons, prompting numerous studies dedicated to proving the effectiveness of MIS.

Lumbar microdiscectomy is the most common procedure performed in the United States for patients presenting with low back or leg pain.[2] Traditionally, these procedures require a significant amount of paraspinal muscle dissection with the exposure maintained by displacing the musculature from the bony elements.[3] On the contrary, MIS procedures, which use tubular retractor systems, minimize the amount of muscular dissection and thereby have been associated with faster recovery time and decreased intraoperative blood loss.[4] Similarly, in lumbar fusion surgery, MIS transforaminal lumbar interbody fusion (TLIF) has been shown to have comparable short- and long-term clinical outcomes to its open counterpart with added benefits such as decreased postoperative pain, decreased blood loss, faster recovery times, and shorter length of stay (LOS).[5]

Despite the apparent upsides, MIS surgery is not fully adopted within the spine surgery community. Open surgery advocates cite the increased radiation exposure to patients and providers as their chief criticism of MIS surgery. Certainly, radiation exposure increases with the use of intraoperative fluoroscopy[6]; however, Bindal et al found patient exposure during MIS spine surgery to be low when compared to other common interventional fluoroscopically guided procedures.[7] Furthermore, technological advancements providing intraoperative 3-dimensional computed tomography (3D CT) alter-

Table 1. Posterior lumbar microdiscectomy or laminectomy.

Authors	n	Surgical Technique	MIS Better, With $P < .05$	MIS = Open	Open Better, With $P < .05$
Rasouli et al[8] (Cochrane)	1172	MIS versus open microdiscectomy	Shorter LOS, lower SSI	None	None
Chang et al[9]	2139	MIS versus open microdiscectomy	Shorter LOS, shorter incision, less EBL	VAS, hospital costs, surgical costs, radiation exposure	Risk of recurrent HNP
Ji et al[10]	1913	MIS versus Open microdiscectomy	Decreased EBL, smaller incision shorter LOS, less complications, outcomes	OR time	
Shriver et al[11]	5390	Open versus MIS versus percutaneous microdiscectomy	Lower n root injury in MIS versus percutaneous		
Wang et al[12]	1012	MIS versus open microdiscectomy	Shorter LOS, less EBL	Short/long-term back pain, short/long-term leg pain, ODI, complications	
Kamper et al[13]	4472	Openvs. intralaminar MIS versus transforaminal MIS	Intralaminar has less EBL and shorter LOS		
He et al[14]	501	Microendodiscectomy	Decreased EBL, decreased EBL	VAS, ODI, complications	OR time
Cong et al[15]	1092	Endoscopic	Patient satisfaction, lower EBL, shorter LOS		
Phan et al[16]	28, 487	Open versus full endoscopic versus microendoscopic	Both endoscopic techniques had less EBL, shorter OR time for full endoscopic	ODI, leg pain, overall complications, recurrence or reoperation rates, dural tears, root injury, wound infections, and spondylodiscitis	
Ruan et al[17]	1389	Endoscopic	Shorter OR time, shorter LOS		Back pain, ODI, complications, reoperations
Phan et al[18]	841	MIS versus open RCT laminectomies	Higher satisfaction, lower VAS, shorter LOS, lower EBL, decreased LOS	Durotomy	OR time

Abbreviations: EBL, estimated blood loss; HNP, text; LOS, length of stay; MIS, minimally invasive surgery; ODI, Oswestry Disability Index; OR, operating room; RCT, text; SSI, text; VAS, visual analogue scale.

natives to fluoroscopy show promising results not only with regards to radiation safety, but in implant placement accuracy as well. Additional research is necessary to validate these initial studies.

The purpose of this systematic review is to evaluate relative meta-analyses pertaining to the outcomes of posterior lumbar decompression and posterior lumbar fusion surgeries. We will directly compare open and MIS techniques, focusing on operative and patient-reported outcomes. Finally, a complete review of all available literature covering navigation versus fluoroscopy techniques will be conducted, centering on implant accuracy and radiation safety.

METHODS

A comprehensive search of the literature was performed to identify meta-analysis and high level systematic review studies directly comparing the outcomes of minimally invasive versus open techniques within spine surgery. An electronic search of PubMed (MEDLINE), Ovid MEDLINE, and Cochrane for the past 5 years was conducted using the following search terms: meta-analyses AND lumbar AND minimally invasive or lateral or navigation or radiation safety. The search yielded 8604 original articles, and a reviewer screened all titles and abstracts for inclusion.

During the screening process, any articles meeting the following criteria were excluded from the review: (1) animal studies; (2) literature reviews; (3) biomechanical studies; (4) English available; (5) full text available; (6) nonclinical outcomes studies; (7) nondegenerative conditions such as spinal deformity, trauma, and tumor; (8) nongold standard surgical techniques; (9) nonsurgeon-based treatment (such as endoscopic microdiscectomy by pain management). Kyphoplasty and vertebroplasty were not included due to being part of the treatment for traumatic injuries. The search exclusion strategy yielded 74 articles from the screened literature. Further screening of the titles and abstracts of the studies produced 34 articles included in the review, as shown in Tables 1–3.

The relevant information from each study was extracted and input into tabular form. The follow-

Table 2. Posterior lumbar fusion.

Authors	n	Surgical Technique	MIS Better, $P < .05$	MIS = Open	Open Better, $P < .05$
Khan et al[19]	952	MIS TLIF versus open	EBL, LOS, late VAS back pain	Fusion rate, OR time, early VAS back, early ODI, and late ODI	Radiation exposure
Jin-tao et al[20]		MIS TLIF/PLIF versus open		Complication, fusions	Readmission/reoperation
Bevevino et al[21]	408	MIS versus open TLIF		Fusion rate	
Lin et al[22]	994	MIS versus open TLIF	LOS, EBL, postoperative VAS	ODI, complications, fusions, OR time	Radiation exposure
Wu et al[23]	1028	MIS versus open TLIF		Fusion rate, complications	
Goldstein et al[24]	1662	MIS versus open TLIF	EBL, LOS, time to ambulation, medical complications, postoperative ODI	OR time, surgical complications, fusion, reoperations	
Li et al[25]	770	MIS versus open TLIF	Adjacent segment degeneration and disease		
Kim et al[6]	619	MIS versus open TLIF			Radiation 2.4 times less
Sun et al[26]	830	MIS versus open TLIF	EBL, postoperative drainage, LOS	ODI, VAS, complications	
Xie et al[27]	1967	MIS versus open TLIF	ODI, VAS, early ambulation, LOS, EBL	Fusion, reoperations, complications, OR time	
Phan et al[28]	384	Direct hospital costs, EBL, LOS, complications	Cost effectiveness	OR time	
Goldstein et al[29]	9397	Direct and indirect costs, OR time, EBL, LOS	Cost effectiveness	Complications	
Vertuani et al[30]	NA	Direct hospital costs	Cost effectiveness		
Keorochana et al[31]	9506	MIS TLIF versus MIS LLIF		Equal pain relief, fusion, can complications	

Abbreviations: EBL, estimated blood loss; LLIF, lateral lumbar interbody fusion; LOS, length of stay; MIS, minimally invasive surgery; NA, not available; ODI, Oswestry Disability Index; OR, operating room; PLIF, posterior lumbar interbody fusion; TLIF, transforaminal lumbar interbody fusion; VAS, visual analogue scale.

ing information was collected: patient population including sample size, outcome measures, and surgical technique used. When included in the article, the statistical significance of the findings was collected and included in the table.

RESULTS

The search guidelines outlined above yielded 34 studies that met the inclusion criteria, as shown in Figure 1. All of these studies compared open

Table 3. Navigation techniques.

Authors	n	Technique	Navigation Better, $P < .05$	Navigation = Free Hand	Free Hand Better, $P < .05$
Bourgeois et al[32]	599	3D CT Nav versus 2D Fluoro Nav	3D decreased breach rates		
Tjardes et al[33]	373 cervical, 450 thoracic, 413 lumbar	3D CT Nav versus FH	Lumbar/thoracolumbar screw placement, decrease radiation time and dose		Thoracic screw placement
Gelalis et al[34]	1105 patients	FH, 3D CT Nav, 2D Fluoro Nav	Screw placement, breach laterally/free hand breach medially		
Kosmopoulos et al[35]	37, 337 screws	3D CT Nav versus FH	Screw placement lumbar and cervical	Thoracic screw placement	
Moses et al[36]	N/A	3D CT Nav versus FH MIS	Screw placement, decrease neuromonitoring changes, decrease radiation exposure		
Mason et al[37]	1973 patients	3D Fluoro Nav versus 2D Fluoro Nav	Screw placement, decreased neurologic injury, decrease breach rate		
Liu et al[38]	257 patients	Robot assisted versus FH		Screw placement accuracy	
Srinivasan et al[39]	NA	Radiation safety all spine	MIS pedicle screw placement and MIS TLIF have highest dose		
Yu et al[40]	303	Radiation safety FH Fluoro versus 3D CT Nav MIS	Lower surgical team radiation dose		Lower patient dose

Abbreviations: 2D Fluoro Nav, 2-dimensional fluoroscopy-based navigation; 3D CT Nav, 3-dimensional computed tomography-based navigation system; FH, free hand; FH Fluoro, free hand with fluoroscopy; NA, not available; TLIF, transforaminal lumbar interbody fusion.

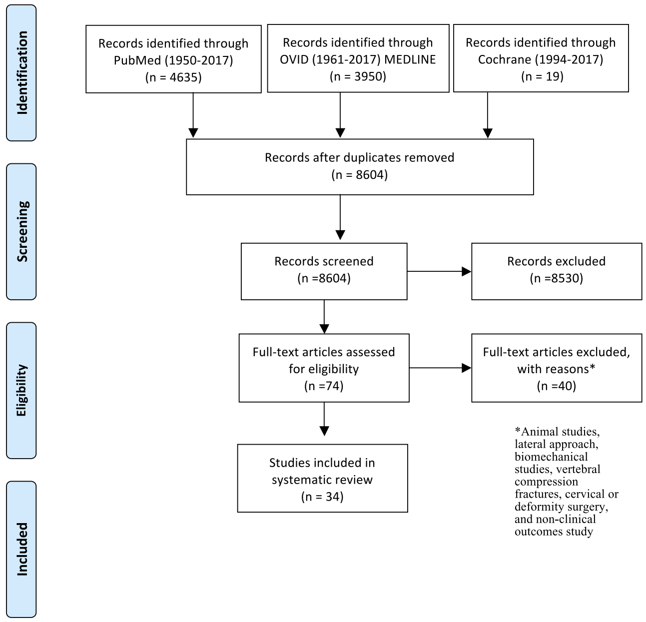

Figure 1. PRISMA flowchart for systematic review of meta-analysis studies on minimally invasive surgery techniques.

procedures to MIS procedures in some capacity, focusing primarily on operative efficiency and patient outcomes. There were 11 studies included which investigated MIS versus open posterior lumbar decompressions, shown in Table 1. There were 14 studies included which investigated MIS versus open posterior lumbar interbody fusions (PLIFs), shown in Table 2. Finally, there were 9 studies focused on navigation techniques and radiation safety within MIS procedures, shown in Table 3.

Posterior Lumbar Decompression

There were several studies in the literature evaluating the difference between open and minimally invasive lumbar decompression surgery, summarized in Table 1. Six studies pertained to MIS versus open microdiscectomy procedures. Four studies compared endoscopic versus open microdiscectomies. Finally, 1 study looked at MIS and open laminectomies. These studies reported procedural outcomes in terms of operative parameters and patient reported outcomes.

Of the 6 studies comparing MIS and open microdiscectomy procedures, 4 showed significantly shorter LOS associated with MIS procedures.[8–10,12] Three studies found significantly less estimated blood loss (EBL) associated with MIS,[9,10,12] including 2 that reported shorter incision length.[9,10] Rasouli et al[8] performed a Cochrane review in 2014 and found low quality evidence in favor of MIS for improved leg pain and in favor of open surgery for back pain, but these differences were likely not clinically significant.[8] In 1 study, using both a systematic review and meta-analysis approach, Kamper et al[13] separately compared conventional microdiscectomies with MIS interlaminar discectomies and MIS transforaminal discectomies. Their findings suggest that interlaminar discectomies decrease EBL and LOS, while MIS transforaminal discectomies were inconclusive due to a low number of studies. Additional MIS benefits were less nerve root damage,[11] fewer complications,[10] and lower rates of surgical site infection.[8] Minimally invasive surgery discectomy techniques were found to be equivalent to open procedures in several categories. Wang et al[12] examined 1012 decompressions, finding no statistical difference when comparing short- and long-term back pain, short- and long-term neck pain, Oswestry Disability Index (ODI) scores, and complications between surgical approaches. In a study including 2139 decompressions, Chang et al[9] exhibited comparable data for visual analogue scale (VAS) scores, hospital costs, surgical costs, as well as radiation exposure; however, this study also found an increased risk of recurrent herniated nucleus pulposus associated with MIS, providing the only support for open microdiscectomy surgery.

Four meta-analysis studies examined open, endoscopic, and microendoscopic discectomy approaches. Consistent with MIS approaches, both endoscopic and microendoscopic approaches yielded statistically better results than open procedures with regard to EBL[14–16] and LOS[15,17]; however, other patient outcome measures were inconclusive. Cong et al[15] performed a meta-analysis review of endoscopic and open microdiscectomies in 1092 patients. In addition to less EBL and shorter LOS, they concluded that endoscopic procedures had statistically better patient outcome scores (endoscopic: 93.21%, open: 80%, $P < .05$). On the other hand, Ruan et al[17] performed a meta-analysis including 7 studies with 1389 patients. While the endoscopic group had a shorter operating room (OR) time and LOS, VAS back pain, ODI, complication rate, and reoperation rate were statistically better in the open group.[16] Finally, beyond EBL and LOS, 2 studies found no statistical difference when comparing outcomes (VAS scores, ODI scores and complication rates, reoperation rates) between the 2 groups. In summary, although endoscopic and microendoscopic discectomy procedures improve operative time and EBL, additional research is necessary to resolve the advantages and disadvantages pertaining to patient outcomes and complications.

One study in our review was unique in nature. Phan et al[41] performed a meta-analysis study evaluating open versus MIS laminectomies in 841 patients. Overall, MIS laminectomies had higher satisfaction rates (84% versus 75%) coinciding with lower VAS pain scores ($P < .001$). Additionally, MIS laminectomies displayed marked decrease in EBL ($P < .001$) and hospital stay (2.1 days; $P < .001$).[41] Longer operative time of 11 minutes was associated with the MIS procedures ($P = .001$), however, this appears to have little clinical significance.

Posterior Interbody Fusion

There were 14 meta-analysis studies comparing open versus MIS PLIFs and TLIFs, summarized in Table 2. Overall, MIS fusions positively affected the following outcome parameters: EBL, LOS, and cost effectiveness. While in 2 studies VAS and ODI scores were improved in the MIS fusion patients, these metrics were more commonly equal among the 2 approaches. Fusion and complications rates were also comparable between MIS and open techniques; however, 1 study of adjacent segment disease showed promising results for MIS TLIFs. Those studies including radiation exposure found significantly higher levels of exposure with the MIS technique.

Two studies summarize the overall findings comparing MIS and open fusion procedures. First, Khan et al performed a meta-analysis on 30 studies of TLIF surgeries using both MIS and open techniques. While no significant differences existed in ODI at 6 months and 1 year and VAS scores at 6 months, operative time, and fusion rates, there were significant advantages associated with MIS TLIFs. One-year postoperative VAS scores, lower EBL, and a lower rate of complications improved within MIS TLIF patients ($P < .001$). Radiation exposure was the only drawback of MIS TLIF procedures displaying approximately 38 extra seconds of fluoroscopy time.[19] Next, Sun et al conducted a meta-analysis comparing MIS to open TLIF in 12 studies with 830 patients. Consistent with the Khan et al study, Sun et al found minimally invasive patients had less EBL, shorter hospital stay, and less postoperative drainage. There was no difference in ODI, VAS, or complications.[26]

Among the present meta-analysis literature, both open and MIS techniques have high fusion rates. Bevevino et al performed a meta-analysis including 7 studies and 408 patients, assessing fusions using postoperative CT scans. For MIS and open TLIFs in which polyetheretherketone or allograft cages were used in conjunction with local autograft bone, equal fusion rates were reported (94.7% overall fusion).[20] Several other studies show equal fusion rates among MIS and open TLIF procedures, while supporting MIS procedures when considering LOS, EBL, ODI, and VAS scores.[22,23,27] In addition to equal fusion rates, these studies displayed comparable complication rates as well.

With regard to complications, Goldstein et al[29] reviewed 26 studies (856 MIS patients and 806 open patients), concluding equal results in patient outcomes and surgical complication rates, but reported a decrease in medical complication rates in the MIS group versus the open group. Furthermore, MIS TLIFs are believed to reduce adjacent segment disorders when compared to open surgery. Li et al[25] completed a meta-analysis examining adjacent segment pathology in 9 studies with 770 patients. They found significantly lower rates of adjacent segment pathology in patients who underwent MIS fusion surgery.[25] Furthermore, Jin-tao et al published a comparison of MIS versus open PLIF/TLIFs, noting the complication rates for both were similar. However, MIS procedures tended to have a higher revision/readmission rate, which they attributed to the deep learning curve associated with the procedure.[20]

Three studies featured cost analysis of open and MIS fusion procedures. Phan et al[42] studied cost effectiveness, reporting hospital costs were lower in MIS surgery, which may be attributable to the decrease in complications, EBL, and LOS. In a 45-study meta-analysis comparing 3472 MIS procedures and 5925 open procedures, Goldstein et al[24] determined that overall MIS procedures had decreased OR time, EBL, LOS, and equal patient-reported outcomes and complication rates. Additionally, MIS procedures resulted in approximately 2.5–49.3% cost savings. Finally, Vertuani et al[30] published a meta-analysis with an accompanying cost model, which revealed MIS total cost savings per procedure of €973 in Italy and €1666 in the

United Kingdom and an improvement of 0.004 quality-adjusted life-year over 2 years.

There was 1 meta-analysis study performed by Keorochana et al[31] that compared outcomes for lateral lumbar interbody fusion (LLIF) to MIS TLIF. The study included 9506 patients, of which 3778 underwent LLIFs, while 5728 patients underwent MIS TLIFs. Overall, MIS TLIF techniques exhibited better leg pain improvement, postoperative back pain, ODI scores, equivalent fusion rates, and decreased complication rates.[31] This is similar to results on lateral approach surgeries found by other studies, but these studies are not systematic reviews.[43,44]

Within our systematic review, radiation exposure was the most common issue related to MIS lumbar fusions. Three studies reported greater radiation exposure when directly comparing MIS and open lumbar fusions.[6,19,22] In a meta-analysis of 8 cohort studies with a total of 619 patients, Kim et al[6] recorded fluoroscopy time and radiation exposure. Mean fluoroscopy time was 39.42 to 94.21 seconds, while radiation exposure was 0.66 to 1.58 mSv for open and MIS procedures, respectively. These findings represent a 2.4-fold increase in radiation when comparing MIS to open TLIF procedures and suggest that clinicians should strive to use the lowest amount of radiation possible.[6]

Navigation Techniques and Radiation Safety

Nine studies reviewed the use of navigation techniques as well as radiation safety, summarized in Table 3. Seven of the studies focused on the accuracy of pedicle screw placement between the following techniques: 3D CT-based navigation systems (3D CT Nav), 2-dimensional fluoroscopy-based navigation (2D Fluoro Nav), free hand with fluoroscopy (FH Fluoro), and free hand (FH). Metrics included pedicle screw accuracy (screw fully enclosed in bone), rates of pedicle breaches, neurologic incidents, as well as dose rate and radiation time. Two studies specifically addressed radiation safety and described the necessary steps to minimize exposure.

Seven meta-analysis studies evaluated the outcomes of various pedicle screw insertion techniques. Pedicle screw placement was consistently more accurate when 3D CT Nav techniques were used in cervical and lumbar screw placement, but inconclusive for thoracic screw placement. Gelalis et al compared screw placement accuracy for FH, FH Fluoro, 2D Fluoro Nav, and 3D CT Nav. Screw insertion accuracies were as follows: FH 69–94%, FH Fluoro 28–85%, 2D Fluoro Nav 81–92%, and 3D CT Nav 89–100%. Interestingly, inaccurate FH screws tended to breach medially, while inaccurate 3D CT Nav screws breached laterally.[34] In a similar literature review, Tjardes et al reviewed 23 cervical, 24 thoracic, and 24 lumbar spine studies concerning image guided screw placement. Three-dimensional CT Nav significantly improved screw placement in the cervical and lumbar regions; however, thoracic pedicle screw placement was more accurate using FH technique.[33] Kosmopoulos et al confirmed 3D CT Nav improves accuracy in the cervical and lumbar regions, yet found no added advantage in the thoracic levels.[35] Finally, Mason et al abstracted and analyzed datasets from 30 studies including 12 FH Fluoro, 8 2D Fluoro Nav, and 20 3D CT Nav. Using 3D CT Nav consistently resulted in higher screw placement accuracy (95.5%) when compared to FH Fluoro and 2D Fluoro Nav (68.1 and 84.3%, respectively). In conjunction with accurate screw placement, breach rates and neurologic injuries decreased with 3D CT Nav.[32,37]

Moses et al applied the same review process for advanced image guidance in 52 studies pertaining to MIS screw placement. As in open procedures, 3D CT Nav outperformed FH Fluoro techniques by a wide margin (98.8 to 79.0%). Additionally, 3D CT Nav decreased neuromonitoring changes, radiation exposure, and screw placement time (54 to 89 minutes).[40] In an effort to further optimize pedicle screw accuracy while reducing radiation exposure, physicians have begun to incorporate robot-assisted technology. To evaluate the efficacy, Liu et al[38] published a meta-analysis on pedicle screw accuracy between robot-assisted and FH techniques. Three of the 5 studies showed greater accuracy using the robot-assisted approach; however, they were not statistically different results. Also, the other 2 studies provided evidence for more accurate FH approaches. Therefore, the meta-analysis was unable to determine which technique was more accurate.

Two meta-analyses looked specifically at the radiation exposure of navigation techniques. First, Srinivasan et al presented a literature review based on 11 studies examining the increased radiation exposure due to fluoroscopy. Minimally invasive surgery pedicle screw placement and TLIF procedures had the highest radiation doses. Given the efficiency of these innovations and therefore likelihood of widespread implementation, Srinivasan et al suggested that surgeons begin to take the following precautions in minimizing radiation exposure: time, distance, and shielding. Furthermore, they recommended minimizing the use of single-shot fluoroscopy, increasing the use of pulsed fluoroscopy and the appropriate manipulation of the fluoroscopic equipment.[39] On the same note, Yu et al[40] reviewed 22 studies pertaining to increased radiation exposure associated with MIS techniques. Free hand Fluoro resulted in higher radiation effecting the surgical team; however, 3D CT Nav increased radiation affecting the patient, although it was lower than the amount in a normal CT scan. As a result, they suggested intraoperative 3D CT Nav should be a low dose protocol in order to reduce the amount of radiation exposure to the patient.[40]

DISCUSSION

After conducting a thorough literature review, the results of 11 meta-analyses evaluating the outcomes of traditional open to minimally invasive microdiscectomy or laminectomy, 14 studies evaluating traditional open lumbar fusion to minimally invasive lumbar fusion, and 9 studies evaluating navigation and radiation safety were included in this study. There is evidence that MIS techniques lead to a shorter LOS, decreased complication rates, and improved accuracy for all of these minimally invasive procedures. Furthermore, important outcome metrics such as fusion rates, VAS scores, and ODI scores are equivalent. Increased radiation exposure is higher during these procedures; however, implementing 3D CT Nav can significantly reduce exposure.

Substantial literature exists associating MIS and endoscopic discectomies with shorter LOS and lesser EBL when compared to open procedures.[8–10,12–14,16,17] While the literature is less conclusive with regard to patient outcomes between endoscopic and open procedures, several studies highlight MIS discectomies as being superior within this arena.[8,10,12] Some early studies showed that MIS may be inferior in terms of relief of leg pain, low back pain, and rehospitalization. As techniques improved, these differences in clinical outcome became equivalent. With the evidence showing some improved hospital metrics such as LOS and EBL, and equivalent clinical outcome metrics, MIS microdiscectomies may have benefits over open microdiscectomies.

In addition to microdiscectomies, current literature supports MIS lumbar fusions over their open counterparts in a number of variables. The largest procedural benefits associated with MIS fusions are decreased EBL and LOS.[16,19,22,26,27,29] Considering these benefits are consistently associated with equivalent or better patient-reported outcomes, fusion rates, and complications, physicians can confidently implement MIS lumbar fusions into their practice without fear of reprisal.[19,20,22,23,25–27,29] Finally, multiple studies provide evidence that the shorter LOS results in cost savings which more than compensate for the additional instrumentation costs.[30,45,46] With the rising costs of health care, a safe, reliable, and cost-effective solution such as the MIS TLIF could be extremely beneficial.

Those supporting open surgery claim the learning curve and additional radiation exposure outweigh the benefits to MIS surgery.[47,48] Therefore, navigation and radiation safety is considered an important part of evaluating the current state of minimally invasive lumbar surgery. As MIS developed, the techniques initially employed a higher use of fluoroscopy compared to traditional open procedures.[33,36,40] With the high risk of radiation exposure to the surgeon, the surgical team, and the patient, ways to decrease this are of high value in spine surgery. As navigation techniques become more sophisticated, the radiation exposure is much less, while allowing for improved pedicle screw placement accuracy.[33,36,40] Given these findings, navigation appears to be the solution to high radiation exposure associated with MIS lumbar fusion.

CONCLUSIONS

Trends in MIS posterior decompressions versus open posterior decompressions show that there is decreased EBL, decreased LOS, decreased complication rates, and equivalent overall postoperative patient outcomes. Concerning MIS posterior interbody fusions, MIS procedures have decreased EBL, decreased LOS, decreased complication rates, overall better postoperative patient outcomes and better cost effectiveness. When examining the different types of screw placement techniques, there is an overall reported increase in accuracy with 3D CT Nav versus all other options. Regarding radiation safety, the general consensus within the reviewed literature was that there was a decrease in patient radiation when using CT navigation, but the higher radiation amount for the surgical team should be decreased by implementing the low dose CT protocol.

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Disclosures and COI: The authors received no funding for this study and report no conflicts of interest.

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Published 21 December 2018