Published in final edited form as:

Spine J. 2022 April ; 22(4): 570–577. doi:10.1016/j.spinee.2021.10.013.

Do Pre-operative Clinical and Radiographic Characteristics Impact Patient Outcomes Following One-Level Minimally Invasive Transforaminal Lumbar Interbody Fusion Based Upon Presenting Symptoms?

Kyle W. Morse, MD[1], **Ram K. Alluri, MD**[1], **Avani S. Vaishnav, MBBS**[1], **Hikari Urakawa, MD**[1], **Jung Kee Mok, BS**[2], **Sohrab S. Virk, MD**[3], **Evan D. Sheha, MD**[1,2], **Sheeraz A. Qureshi, MD MBA**[1,2,*]

[1]Department of Orthopaedic Surgery, Hospital for Special Surgery, New York, NY.

[2]Weill Cornell Medical College, New York, NY.

[3]Department of Orthopaedic Surgery, North Shore Long Island Jewish Medical Center, New Hyde Park, NY.

Abstract

Background Context—Patients undergoing minimally invasive transforaminal lumbar interbody fusion (MI-TLIF) frequently present with lower extremity neurologic symptoms with or without associated lower back pain. While symptomatic improvement of leg and back pain has been reported, the resolution of back pain when it is a predominant presenting symptom remains underreported following MI-TLIF.

Purpose—The purpose of this study was to compare clinical outcomes at 1 year of patients undergoing MI-TLIF with lower extremity neurologic symptoms with and without a significant component of back pain.

Study Design—A retrospective review of prospectively collected data from a single surgeon surgical database from 2017 to 2019 was performed.

Patient Sample—Fifty one patients undergoing MI-TLIF.

Outcome Measures—Self-reported measures included the Oswestry Disability Index (ODI), Visual analog scale back pain (VAS-back), and VAS leg pain (VAS-leg).

[*]**Corresponding author:** Sheeraz A. Qureshi, MD MBA, Department of Orthopaedic Surgery, Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021, USA, Phone: 212-606-1585, Fax: 917-260-3185, sheerazqureshimd@gmail.com.

Level of Evidence: 3

Drug(s)/device(s) statement:
This manuscript submitted does not contain information about medical device(s)/drug(s).

Conflicts of Interest:
The authors report no conflicts of interest relevant to the topic of this study.

Methods—Patients were divided into two groups: Leg Pain Predominant (patients reported greater than 50% leg pain upon presentation) and Back Pain Predominant (patients reported 50% or greater back pain). Multivariate analysis was performed to determine differences between groups based upon any significantly baseline characteristics.

Results—Preoperative demographic and radiographic outcomes were similar between the two groups. Both groups demonstrated significant improvement in ODI, VAS-Back and VAS-leg at 1-year postoperatively. On multivariate analysis, there were differences in ODI at 1-year, 1-year back pain, and 1-year leg pain between groups with those who initially presented with leg pain having a lower ODI, VAS Back, and VAS leg. Patients who presented with predominantly leg pain were more likely to meet minimal clinically important difference (MCID) criteria for ODI and VAS-back compared to those with predominantly back pain.

Conclusion—Following MI-TLIF, patients with lower extremity neurologic symptoms with and without a significant component of back pain have improvements in back pain, leg pain, and ODI regardless of their primary presenting pain complaint; however, patients who presented with predominantly leg pain were more likely to meet MCID criteria for improvement in their back pain and ODI score.

Keywords

Minimally Invasive Surgery; TLIF; Back Pain; Leg Pain; Low Back Pain; MCID; Interbody Fusion; Radicular Pain; Post Operative Leg Pain; Post Operative Back Pain

Introduction:

Minimally invasive transforaminal lumbar interbody fusion (MI-TLIF) is a commonly used procedure to treat degenerative pathology in the lower lumbar spine that requires decompression and fusion.[1,2] Patients undergoing MI-TLIF frequently present with lower extremity neurologic symptoms with or without associated lower back pain. Previous studies have demonstrated good to excellent outcomes after MI-TLIF for resolution of neurologic symptoms as well as improvements in clinical outcome scores and radiographic parameters.[1,3–9]

The clinical and radiographic patient characteristics impacting the post-operative course following MI-TLIF have not fully been elucidated, especially when accounting for the patient's main pre-operative presenting symptom. While the symptomatic improvement of leg and back pain has been reported previously, the patient outcomes depending upon the predominant presenting symptoms remain underreported following MI-TLIF, as only one prior study has studied the subject previously.[3,10–14] Furthermore, prior studies have demonstrated that patients who undergo lumbar spine surgery for predominant leg pain symptoms have better satisfaction and functional outcomes compared to patients who present with predominantly back pain.[15–17] As MI-TLIF avoids extensive dissection of the posterior spinal musculature that is important for spine stabilization, there may be additional approach-related benefit associated with minimally invasive techniques which may result in reduced post-operative back pain.

The purpose of this study was to compare clinical and radiographic outcomes of patients undergoing MI-TLIF with lower extremity neurologic symptoms with and without a significant component of back pain.

Materials and Methods:

A full Institutional review board (IRB) approval (IRB #2018–1599) was obtained prior to prospective data collection and an expedited IRB approval was obtained for the retrospective review and analysis of this data.

Study Design and Data Collection

A retrospective review of prospectively collected data from a single surgeon surgical database from 2017 to 2019 was performed. All surgeries were performed by a fellowship trained spine surgeon at a high-volume academic medical center. The surgical database was queried for patients who underwent primary single-level MI-TLIF for degenerative conditions of the spine who had failed non-operative management. Patients with less than 1 year of follow-up, and those who underwent surgery for trauma, tumor or infection were excluded.

Data was collected and managed using REDCap (Research Electronic Data Capture) hosted at Weill Cornell Medicine Clinical and Translational Science Center supported by the National Center For Advancing Translational Science of the National Institute of Health under award number: UL1 TR002384. REDCap is a secure, HIPAA-compliant web-based software platform designed to support data capture for research studies.[18,19]

Patient demographics, Charlson Comorbidity Index (CCI)[20], pre-operative opioid usage, length of stay (LOS, hours), patient-reported outcome measures (PROMs), and radiographic parameters were collected. PROMs including Oswestry Disability Index (ODI), visual analog scale back pain (VAS-back) and VAS leg pain (VAS-leg) were collected prospectively at the pre-operative timepoint and at 2 weeks, 6 weeks, 12 weeks, 6 months and 1 year after surgery as standard of care.[21]

Radiographic measurements including pelvic tilt, sacral slope, pelvic incidence (PI), lumbar lordosis (LL), and PI-LL mismatch were measured on pre-operative standing lateral radiographs. These measurements were performed manually by two independent observers not involved in patient care and an average of the two measurements was used for this study. In addition, the presence of adjacent segment disease, defined as moderate central stenosis, foraminal stenosis, or facet osteoarthritis or Grade II spondylolisthesis was assessed at one level above and one level below the operative level on pre-operatively on, x-rays, magnetic resonance imaging (MRI), and computed tomography (CT). The presence of coronal plane deformity was also documented from these imaging modalities. Fusion at one year post-operatively was assessed with CT imaging by assessing bridging trabecular bone with regards to the cage according to the message described by Virk et al.[22].

The surgical technique was performed as previously described in the literature.[7,23–26] Patients were indicated for MI-TLIF for symptomatic lumbar stenosis with degenerative spondylolisthesis, lumbar spinal stenosis with isthmic spondylolisthesis, or a recurrent disc herniation. In brief, general anesthesia is administered and the patients are positioned prone. A skin-anchored intraoperative 3D navigation (ION) with SpineMask (Stryker Corporation, Kalamazoo, MI) is placed cranially to the surgical site. Following registration, navigation guidance is utilized to place guidewires into the pedicles, which are followed by screw shanks bilaterally. The posterior superior iliac spine is found under navigated guidance and iliac crest bone graft (ICBG) is harvested percutaneously. The MI-TLIF is then performed. An 18mm incision is made followed by sequential tubular dilation with the final 18mm tube placed over the operative facet joint. The facetectomy and laminotomy is then performed under microscopic visualization with use of both the high-speed burr and Kerrison rongeurs. Kambin's triangle is identified and an annulotomy is performed. The disc space is then prepared. Interbody cage size and orientation is determined with navigation. The appropriate cage is then packed with ICBG, tamped into place, expanded, and then locked. The traversing nerve root is then identified and visualized caudal to the pedicle to ensure that it is not compressed. Fluoroscopy confirms accurate position of the cage. Lastly, appropriately sized rods are placed percutaneously under the fascia and locked. Hemostasis is achieved and a layered closure is performed.

Statistics

SPSS Version 27 was used for the entirety of the analysis (International Business Machines, Armonk, NY). Patients were divided into 2 groups based on self-reported pain predominance to their back or leg: Leg Pain Predominant (greater than 50% leg pain) and Back Pain Predominant (50% or greater back pain). Baseline characteristics were summarized using descriptive statistics and the two groups were compared using Chi-Squared, Fisher's exact test, or two-sample t-test as appropriate. Multivariate analysis with Bonferroni correction was performed to determine differences in post-operative PROMs between groups based upon any significant difference in baseline characteristics. Achievement of minimal clinically importance difference (MCID) at 1-year was also compared between groups. MCID for ODI was 14.0, VAS-leg 2.1, and VAS-back 2.1 according to Parker et al.[27] Patients whose preoperative scores were lower than the MCID threshold were excluded from these analyses. In order to assess differences between those who achieved MCID and those who did not, a subgroup analysis was performed within each group to compare baseline demographic and radiographic data, as well as pre- and post-operative patient-reported outcomes. Logistic regressions were performed to determine factors associated with failure to achieve MCID criteria, while controlling for any pre-operative differences. Statistical significance was defined as $p<0.05$.

Results:

Baseline Characteristics

Sixty patients underwent MIS-TLIF, of whom 51 (85%) had information available regarding their pre-operative back/leg pain rating and clinical outcome measures. All patients had follow up at one year post-operatively. There were 28 women (55%). Twenty-nine patients (57%) had back pain predominant symptoms and 22 (43%) had predominantly leg pain. CCI was significantly greater for back pain predominant patients, but otherwise there were no significant differences in pre-operative demographics, radiographic parameters, diagnosis (Table 1). 40 patients underwent surgery at L4-L5 while 11 underwent surgery at L5-S1 and there were no differences in the fusion level between groups. Primary indications for surgery included 41 patients with degenerative spondylolisthesis, 8 patients with isthmic spondylolisthesis, 1 patient with herniated nucleus pulposus and foraminal stenosis, and lastly 1 patient with degenerative disc disease and facet arthropathy. Additional pathology included 6 patients with herniated nucleus pulposus, 41 with central stenosis, 46 with neuroforaminal stenosis, and 44 with lateral recess stenosis, and 4 patients with a facet cyst. There was no correlation between diagnosis and pre-operative back pain. Patients who had a diagnosis of degenerative spondylolisthesis had greater pre-operative VAS-leg pain (5.8 ± 3.4 vs. 3.0 ± 3.6, p=0.023) and those with a diagnosis of isthmic spondylolisthesis had less (5.7 ± 3.4 vs. 2.8 ± 3.5, p=0.028). One patient in the leg pain predominant group presented with L4 weakness not requiring the use of an ankle foot orthosis.

One Year Results

Both groups demonstrated significant improvement in ODI, VAS-Back and VAS-leg at 1-year postoperatively (Table 2). Patients with a diagnosis of herniated nucleus pulposus had less back pain at 1-year (1.1 ± 1.5 vs. 2.8 ± 2.8, p=0.027). Patients with neuroforaminal stenosis had lower VAS-leg compared to those who did not (1.0 ± 2.2 vs. 4.3 ± 3.60, p=0.004). On multivariate analysis controlling for CCI (Table 2) back pain predominant patients presented with worse back pain pre-operatively (p=0.015) and worse ODI (p<0.001) and back pain at 1-year (p<0.001). There was no difference between groups for 1-year leg pain (p=0.076). There was no significant difference in the fusion rate at 1-year (86.4% vs. 88.2%, p>0.05 respectively).

Achievement of MCID

Table 3 displays the percentage of patients in each group meeting MCID criteria. Patients who presented with leg pain predominant symptoms were more likely to meet MCID criteria for all PROMs compared to those with back pain predominant symptoms.

Sub-Group Analysis for Back Pain Predominant Patients

Table 4 shows the difference in demographic, surgical, and radiographic parameters between patients who met MCID criteria and those who do not. Within the back pain predominant group, there were no significant differences except patients who did not meet MCID for ODI had a higher CCI (p=0.047) and patients who did not achieve MCID for VAS Back had a higher pre-operative lumbar lordosis (p=0.020). Additionally, there was a positive correlation between pre-operative VAS-back and PI-LL (r=0.388, p=0.018). Despite differences in VAS-back at 1-year, there was no correlation with a diagnosis of herniated nucleus pulposus and achievement of MCID (p=0.647).

88.6% of patients who did not meet MCID criteria for VAS-back had adjacent segment disease compared to 66.7% of those who met criteria (p=0.193). The mean lumbar scoliosis was 11.81 +/− 5.87 degrees) and while there were trends for increased Cobb angle for those who did not meet MCID criteria for VAS-leg and VAS-back, they were not significant. Similar trends were observed for patients who did not meet MCID for VAS-Leg.

There were no significant differences between those who achieved MCID for VAS leg and those who did not (Table 5). There were no differences in fusion rates at 1 year between patients who met MCID criteria and those who did not.

Factors Associated with Failure to Achieve MCID in Back Pain Predominant Patients

The logistic regression for achievement of MCID on VAS-back was significant (χ^2=23.9, p=0.027, Nagelkerke, R^2 =0.426) and demonstrated that when controlling for age and ODI, pre-operative lumbar lordosis is associated with achievement of MCID (p=0.030), with increasing pre-operative lumbar lordosis associated with lower likelihood of meeting MCID.

Similarly, the logistic regression for achievement of MCID on ODI was significant (χ^2=26.1, p=0.006, Nagelkerke, R^2 =0.405) and demonstrated that when controlling for age and CCI, pre-operative ODI was associated with achievement of MCID (p=0.040), with higher pre-operative ODI associated with a lower likelihood of meeting MCID.

Complications

There were no operative complications and there was a total of 7 post-operative complications (wound drainage, n=3, nausea/emesis, n=1, urinary retention, n=3). There were no differences in achievement of MCID for ODI, VAS-Back, and VAS-Leg based upon a hospital complications. Two patients required revisions. One patient returned to the operating room for wound infection and subsequent cultures grew Propionibacterium Acnes. The patient was treated with a prolonged course of antibiotics and revision fusion. Another patient had extension of fusion for continued back pain and spondylolysis below the level of the fusion. The fusion was extended to included the L5/S1 level. Both of these patients failed to achieve MCID for VAS-back after their initial procedure.

Discussion:

The purpose of this study was to compare clinical and radiographic outcomes for patients undergoing MI-TLIF with and without a significant component of back pain. Following surgery, there were improvements in VAS-Back, VAS-Leg, and ODI at 1 year regardless of the predominant presenting symptom. However, patients who presented with leg pain predominant symptoms were more likely to achieve MCID for these outcomes compared to patients who presented with back predominant symptoms. Back pain predominant patients who did not meet MCID criteria for VAS back had significantly larger lumbar lordosis pre-operatively and increasing PI-LL was associated with increased back pain pre-operatively. Additionally, these patients had larger percentage of adjacent segment disease, but this finding was not statistically significant.

Both leg pain predominant patients and back pain predominant patients in our patient cohort presented with similar demographics and radiographic parameters, however patients with back pain predominant symptoms had a greater CCI. The etiology of back pain is multifactorial and this raises the possibility that their back pain may not be spine related. CCI may be a predictor for poorer quality of life following lumbar spine surgery and importantly, patients with more comorbidities may not be as likely to reach MCID for back pain following TLIF.[28,29] Regardless, both groups of patients showed significant improvement in their ODI, VAS-Back, and VAS-Leg scores post-operatively demonstrating a potential benefit of surgery. The improvement of these clinical outcomes following MI-TLIF is similar to prior studies.[1,3]

Despite improvements at 1 year post-operatively and after controlling for CCI, patients with legpain predominant symptoms had lower post-operative ODI and VAS-Back scores compared to patients with back pain predominant symptoms. In a recent MI-TLIF series, Massel et al.[3] reported greater post-operative improvements in VAS Leg pain for patients with leg pain predominant symptoms versus those with predominant back pain. Similar to the current study, they found that patients with predominant leg pain symptoms were more likely to achieve MCID versus the back pain predominant cohort for their respective predominant symptoms, though this was not statistically significant. The authors however did not analyze pre-operative radiographic parameters. Khan et al.[30] compared a cohort with equal and leg pain predominant symptoms to back pain predominant symptoms following open posterior lumbar fusion for patients with low-grade lumbar spondylolisthesis. They reported significant improvements in VAS-Back and VAS-Leg with each group meeting MCID criteria for their leg and back pain respectively. Additionally, the authors found no differences in ODI post-operatively between groups.[30]

In an analysis of patients with degenerative spondylolisthesis, Pearson et al.[15] reported greater improvement in ODI, and physical function scores for patients with leg pain-predominant symptoms; however, the authors note that patients with back pain predominant symptoms had improvement in these clinical outcomes following fusion compared to non-operative treatment. Our findings following MI-TLIF may be similar in that both groups demonstrated improvement in leg pain in our cohort. Additionally, Lim et al.[31] reported that improvement in leg pain following open TLIF was the only predictor for patient satisfaction at 2 years, which further supports that patients with leg pain predominant symptoms may have greater clinical benefit post-operatively.

Furthermore, within our cohort only leg pain predominant patients met MCID criteria for improvement in their back pain. We found that 100% of this cohort met MCID for back and leg pain improvement and 90% met MCID for ODI. In contrast, just over 50% of patients with back pain predominant symptoms met MCID criteria for ODI, VAS-Leg, and VAS-Back. These findings are contrary to those reported in a prior MI-TLIF series. Massel et al.[3] reported no difference in the percentage of patients who met MCID based upon their major presenting symptom with approximately 80% of patients who presented with predominant back pain achieving MCID for VAS-Back and Vas-Leg. While the authors utilized different MCID threshold values, our findings are not likely explained by this variability.

There are several factors which may play a role in persistent back pain following MI-TLIF. In a subgroup analysis of the patients who did not meet MCID for improvement of back pain, CCI was not a significant predictor in a regression model for ODI. The model, while only predicting 75% of cases correctly, did find higher ODI as a significant predictor, as patients with a higher score have a greater chance to achieve clinical improvement. Additionally, patients who did not meet MCID for VAS-back had greater lumbar lordosis pre-operatively and increasing PI-LL mismatch was correlated with increasing pre-operative back pain, and the importance of sagittal balance correction remains an active area of future research. The overall fusion rate in this series was 88% and patients who achieved solid fusion did not have greater improvement of their back pain as has been suggested by previous studies.[32] Lastly, back pain predominant patients who did not reach MCID were more likely to have degenerative scoliosis and adjacent segment disease, and while not reaching statistical significance, these may play a role in pain persistence.

This study has several limitations some of which are inherent to its retrospective design. These include selection bias as patients were sampled from a single institution and those lost to follow up were not included. Despite being retrospective in nature, all data was collected prospectively, which limits any potential recall bias. While the series is small, it is similar in size to others previously reported in the literature.[1,27] We do not routinely collect radiographs at one year as CT is chosen to assess fusion, limiting the ability to correlate longer term radiographic and alignment outcomes – which may be better assessed with upright radiographs – to pain outcomes at one year. Back pain predominant patients also reported a considerable amount of leg pain. This finding is explained in our study design as patients who reported equal leg and back pain were included in the back pain predominant group and therefore could report a large amount of leg pain that is equal to their back pain. Given the difficulty of patients to truly rate their pain, patients in our cohort were asked to rate their leg and back pain as a percentage of their total pain, similar to other studies.[12,33] The ability for patients to identify their primary pain complaints remains an active area of research.[33] Lastly, we used MCID values reflecting a cost value analysis of MI-TLIF as other cited MCID values have combined MI with open TLIF cases.[34] Minimally invasive techniques are designed to provide a targeted approach to correct a focal problem and these techniques may not be as effective if the etiology of pain is multi-factorial or widespread. Surgeons should carefully review upright plain radiographs for the presence of preoperative sagittal imbalance and adjacent segment disease as these factors may be related to poor patient outcomes. Patients should be counseled that the targeted approached offered by a MI-TLIF may not result in the full resolution of back pain.

Following MI-TLIF, patients with lower extremity neurologic symptoms with and without a significant component of back pain have improvements in back pain, leg pain, and ODI regardless of their primary presenting pain complaint; however, patients who presented with predominantly leg pain were more likely to meet MCID criteria for improvement in their back pain, leg pain, and ODI score.

Source of Funding:

No direct funding was received for this study. However, the study used REDCap (Research Electronic Data Capture) hosted at Weill Cornell Medicine Clinical and Translational Science Center supported by the National Center For Advancing Translational Science of the National Institute of Health (NIH) under award number: UL1 TR002384.

References

1. Kim J-S, Jung B, Lee S-H. Instrumented Minimally Invasive Spinal-Transforaminal Lumbar Interbody Fusion (MIS-TLIF): Minimum 5-Year Follow-Up With Clinical and Radiologic

Outcomes. Clin Spine Surg. 2018;31(6):E302–E309. doi:10.1097/BSD.0b013e31827415cd [PubMed: 23027364]

2. Overley SC, McAnany SJ, Anwar MA, et al. Predictive Factors and Rates of Fusion in Minimally Invasive Transforaminal Lumbar Interbody Fusion Utilizing rhBMP-2 or Mesenchymal Stem Cells. Int J Spine Surg. 2019;13(1):46–52. doi:10.14444/6007 [PubMed: 30805286]
3. Massel DH, Mayo BC, Narain AS, et al. Improvements in Back and Leg Pain Following a Minimally Invasive Transforaminal Lumbar Interbody Fusion. Int J Spine Surg. 2020;14(5):745–755. doi:10.14444/7107 [PubMed: 33184122]
4. Goldstein CL, Macwan K, Sundararajan K, Rampersaud YR. Comparative outcomes of minimally invasive surgery for posterior lumbar fusion: a systematic review. Clin Orthop. 2014;472(6):1727–1737. doi:10.1007/s11999-014-3465-5 [PubMed: 24464507]
5. Khajavi K, Shen A, Hutchison A. Substantial clinical benefit of minimally invasive lateral interbody fusion for degenerative spondylolisthesis. Eur Spine J Off Publ Eur Spine Soc Eur Spinal Deform Soc Eur Sect Cerv Spine Res Soc. 2015;24 Suppl 3:314–321. doi:10.1007/s00586-015-3841-1
6. Seng C, Siddiqui MA, Wong KPL, et al. Five-year outcomes of minimally invasive versus open transforaminal lumbar interbody fusion: a matched-pair comparison study. Spine. 2013;38(23):2049–2055. doi:10.1097/BRS.0b013e3182a8212d [PubMed: 23963015]
7. Vaishnav AS, Saville P, McAnany S, et al. Retrospective Review of Immediate Restoration of Lordosis in Single-Level Minimally Invasive Transforaminal Lumbar Interbody Fusion: A Comparison of Static and Expandable Interbody Cages. Oper Neurosurg Hagerstown Md. 2020;18(5):518–523. doi:10.1093/ons/opz240
8. Carlson BB, Saville P, Dowdell J, et al. Restoration of lumbar lordosis after minimally invasive transforaminal lumbar interbody fusion: a systematic review. Spine J Off J North Am Spine Soc. 2019;19(5):951–958. doi:10.1016/j.spinee.2018.10.017
9. Louie PK, Vaishnav AS, Gang CH, et al. Development and Initial Internal Validation of a Novel Classification System for Perioperative Expectations Following Minimally Invasive Degenerative Lumbar Spine Surgery. Clin Spine Surg. Published online August 30, 2021. doi:10.1097/BSD.0000000000001246
10. Tian Y, Liu X. Clinical outcomes of two minimally invasive transforaminal lumbar interbody fusion (TLIF) for lumbar degenerative diseases. Eur J Orthop Surg Traumatol Orthop Traumatol. 2016;26(7):745–751. doi:10.1007/s00590-016-1755-1
11. Kim CH, Easley K, Lee J-S, et al. Comparison of Minimally Invasive Versus Open Transforaminal Interbody Lumbar Fusion. Glob Spine J. 2020;10(2 Suppl):143S–150S. doi:10.1177/2192568219882344
12. Sigmundsson FG, Jönsson B, Strömqvist B. Outcome of decompression with and without fusion in spinal stenosis with degenerative spondylolisthesis in relation to preoperative pain pattern: a register study of 1,624 patients. Spine J Off J North Am Spine Soc. 2015;15(4):638–646. doi:10.1016/j.spinee.2014.11.020
13. Kleinstueck FS, Fekete TF, Mannion AF, et al. To fuse or not to fuse in lumbar degenerative spondylolisthesis: do baseline symptoms help provide the answer? Eur Spine J Off Publ Eur Spine Soc Eur Spinal Deform Soc Eur Sect Cerv Spine Res Soc. 2012;21(2):268–275. doi:10.1007/s00586-011-1896-1
14. Pearson A, Blood E, Lurie J, et al. Predominant leg pain is associated with better surgical outcomes in degenerative spondylolisthesis and spinal stenosis: results from the Spine Patient Outcomes Research Trial (SPORT). Spine. 2011;36(3):219–229. doi:10.1097/BRS.0b013e3181d77c21 [PubMed: 21124260]
15. Pearson A, Blood E, Lurie J, et al. Predominant leg pain is associated with better surgical outcomes in degenerative spondylolisthesis and spinal stenosis: results from the Spine Patient Outcomes Research Trial (SPORT). Spine. 2011;36(3):219–229. doi:10.1097/BRS.0b013e3181d77c21 [PubMed: 21124260]
16. Kleinstück FS, Grob D, Lattig F, et al. The influence of preoperative back pain on the outcome of lumbar decompression surgery. Spine. 2009;34(11):1198–1203. doi:10.1097/BRS.0b013e31819fcf35 [PubMed: 19407677]

17. Katz JN, Stucki G, Lipson SJ, Fossel AH, Grobler LJ, Weinstein JN. Predictors of surgical outcome in degenerative lumbar spinal stenosis. Spine. 1999;24(21):2229–2233. doi:10.1097/00007632-199911010-00010 [PubMed: 10562989]
18. Harris PA, Taylor R, Minor BL, et al. The REDCap consortium: Building an international community of software platform partners. J Biomed Inform. 2019;95:103208. doi:10.1016/j.jbi.2019.103208
19. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. J Biomed Inform. 2009;42(2):377–381. doi:10.1016/j.jbi.2008.08.010 [PubMed: 18929686]
20. Parrish JM, Jenkins NW, Hrynewycz NM, Brundage TS, Yoo JS, Singh K. The Impact of Comorbidity Burden on Postoperative PROMIS Physical Function Following Minimally Invasive Transforaminal Lumbar Interbody Fusion. Clin Spine Surg. 2020;33(6):E294–E298. doi:10.1097/BSD.0000000000000934 [PubMed: 31913181]
21. Vaishnav AS, McAnany SJ, Iyer S, Albert TJ, Gang CH, Qureshi SA. Psychometric Evaluation of Patient-reported Outcomes Measurement Information System Physical Function Computer Adaptive Testing in Minimally Invasive Lumbar Spine Surgery: An Analysis of Responsiveness, Coverage, Discriminant Validity, and Concurrent Validity. J Am Acad Orthop Surg. 2020;28(17):717–729. doi:10.5435/JAAOS-D-19-00306 [PubMed: 32833390]
22. Virk S, Vaishnav AS, Sheha E, et al. Combining Expandable Interbody Cage Technology With a Minimally Invasive Technique to Harvest Iliac Crest Autograft Bone to Optimize Fusion Outcomes in Minimally Invasive Transforaminal Lumbar Interbody Fusion Surgery. Clin Spine Surg. Published online July 1, 2021. doi:10.1097/BSD.0000000000001228
23. Vaishnav AS, Merrill RK, Sandhu H, et al. A Review of Techniques, Time Demand, Radiation Exposure, and Outcomes of Skin-anchored Intraoperative 3D Navigation in Minimally Invasive Lumbar Spinal Surgery. Spine. 2020;45(8):E465–E476. doi:10.1097/BRS.0000000000003310 [PubMed: 32224807]
24. Kumar A, Merrill RK, Overley SC, et al. Radiation Exposure in Minimally Invasive Transforaminal Lumbar Interbody Fusion: The Effect of the Learning Curve. Int J Spine Surg. 2019;13(1):39–45. doi:10.14444/6006 [PubMed: 30805285]
25. Qureshi S Pearls: Improving Upon Minimally Invasive Transforaminal Lumbar Interbody Fusion. Clin Orthop. 2019;477(3):501–505. doi:10.1097/CORR.0000000000000596 [PubMed: 30624316]
26. Virk S, Qureshi S. Navigation in minimally invasive spine surgery. J Spine Surg Hong Kong. 2019;5(Suppl 1):S25–S30. doi:10.21037/jss.2019.04.23
27. Parker SL, McGirt MJ. Determination of the minimum improvement in pain, disability, and health state associated with cost-effectiveness: introduction of the concept of minimum costeffective difference. Neurosurgery. 2015;76 Suppl 1:S64–70. doi:10.1227/01.neu.0000462079.96571.dc [PubMed: 25692370]
28. Lubelski D, Feghali J, Nowacki AS, et al. Patient-specific prediction model for clinical and quality-of-life outcomes after lumbar spine surgery. J Neurosurg Spine. Published online January 29, 2021:1–9. doi:10.3171/2020.8.SPINE20577
29. Jenkins NW, Parrish JM, Nolte MT, et al. Charlson Comorbidity Index: An Inaccurate Predictor of Minimally Invasive Lumbar Spinal Fusion Outcomes. Int J Spine Surg. 2021;15(4):770–779. doi:10.14444/8099 [PubMed: 34266930]
30. Khan JM, Harada GK, Basques BA, et al. Patients with predominantly back pain at the time of lumbar fusion for low-grade spondylolisthesis experience similar clinical improvement to patients with predominantly leg pain: mid-term results. Spine J Off J North Am Spine Soc. 2020;20(2):276–282. doi:10.1016/j.spinee.2019.09.021
31. Lim JBT, Yeo W, Chen JLT. Preoperative Leg Pain Score Predicts Patient Satisfaction After Transforaminal Lumbar Interbody Fusion Surgery. Glob Spine J. 2018;8(4):354–358. doi:10.1177/2192568217723888
32. Park Y, Ha JW, Lee YT, Sung NY. The effect of a radiographic solid fusion on clinical outcomes after minimally invasive transforaminal lumbar interbody fusion. Spine J Off J North Am Spine Soc. 2011;11(3):205–212. doi:10.1016/j.spinee.2011.01.023

33. Wai EK, Howse K, Pollock JW, Dornan H, Vexler L, Dagenais S. The reliability of determining "leg dominant pain." Spine J Off J North Am Spine Soc. 2009;9(6):447–453. doi:10.1016/j.spinee.2008.11.009
34. Parker SL, Adogwa O, Paul AR, et al. Utility of minimum clinically important difference in assessing pain, disability, and health state after transforaminal lumbar interbody fusion for degenerative lumbar spondylolisthesis. J Neurosurg Spine. 2011;14(5):598–604. doi:10.3171/2010.12.SPINE10472 [PubMed: 21332281]

Table 1:

Baseline characteristics

	Leg Pain Predominant	Back Pain Predominant
Age (in years)	61.4 ± 11.6	58.3 ± 15.5
Body Mass Index (BMI; kg/m^2)	27.0 ± 5.8	26.9 ± 5.4
Pre-Operative Narcotic Use – Yes(%)	4 (14%)	6 (27%)
Charlson Comorbidity Index (CCI) w/o Age component	0.3 ± 0.6	0.8 ± 1.1$^{p=0.025}$
Duration of Sensory Symptoms (in months)	5.3 ± 7.6	5.7 ± 4.0
Estimated Blood Loss (in ml)	45.5 ± 26.3	39.0 ± 21.6
Operative Time (in minutes)	94.0 ± 25.1	91.9 ± 17.9
Post-Operative Length of Stay (hours)	35.0 ± 22.0	28.4 ± 11.7
Pre-Operative Pelvic Tilt (degrees)	19.0 ± 8.5	23.7 ± 9.3
Pre-Operative Sacral Slope (degrees)	35.8 ± 8.1	37.2 ± 9.1
Pre-Operative Pelvic Incidence (degrees)	54.9 ± 9.7	61.5 ± 14.2
Pre-Operative Lumbar Lordosis (degrees)	−46.8 ± 12.4	−52.2 ± 12.9
Pre-Operative LL-PI Mismatch (degrees)	8.1 ± 16.1	8.3 ± 11.4
Gender (Male/Female)	7(68%)/15(32%)	16 (55%)/13(45%)

Table 2:

Multivariate analysis for leg pain and back pain predominant cohorts controlling for Charlson Comorbidity Index (CCI).

	Leg Pain Predominant	Back Pain Predominant	p-value[#]
Pre-Operative ODI	34.1 ± 19.2	33.3 ± 17.6	0.661
1-Year ODI	5.9 ± 7.6	22.2 ± 17.2	0.000
Change in ODI	−28.1 ± 17.4	−11.1 ± 19.4	0.014
p-value[*]	0.005	0.000	
Pre-Operative VAS Back Pain	4.3 ± 3.4	6.1 ± 2.4	0.015
1-Year VAS Back Pain	1.0 ± 1.5	3.8 ± 2.8	0.000
Change in VAS Back Pain	−3.3 ± 3.3	−2.3±3.5	0.519
p-value[*]	0.001	0.000	
Pre-Operative VAS Leg Pain	5.8 ± 3.5	4.9 ± 3.6	0.479
1-Year VAS Leg Pain	0.5 ± 1.1	1.9 ± 3.1	0.076
Change in VAS Leg Pain	−5.3 ± 3.5	−2.9 ± 4.1	0.075
p-value[*]	0.001	0.000	

[#] p-value for comparison between groups;

[*] p-value for change within each group

Table 3:

Percentage of patients reaching MCID based upon presenting pain predominance.

	Leg Pain Predominant	Back Pain Predominant
1-Year ODI	90.0%$^{p=0.011}$	53.6%
1-Year VAS Back Pain	100.0%$^{p=0.002}$	53.6%
1 Year VAS Leg Pain	100.0%$^{p=0.022}$	68.4%

Table 4:

Characteristics for patients who achieved MCID compared to those who did not for each outcome variable for patients presenting with back pain predominant symptoms.

	ODI		VAS Back		Vas Leg	
	Yes	No	Yes	No	Yes	No
Age	53.6±14.6	64.0±15.7	53.2±14.8	62.5±14.3	55.2±10.8	68.2±15.6 $^{p=0.050}$
BMI	27.6±6.9	26.8±3.0	28.1±6.9	25.9±3.2	27.0±7.6	27.4±2.4
Duration of Sensory Symptoms	6.0±4.6	5.1±3.4	6.0±4.3	5.3±4.0	6.7±5.2	4.3±3.2
CCI w/o age	0.5±0.7	1.3±1.3 $^{p=0.047}$	0.8±1.0	0.9±1.2	0.7±0.9	1.2±1.3
EBL	42.0±22.3	34.6±21.7	35.3±12.5	44.2±29.1	42.3±23.7	33.3±12.9
OR Time	97.0±19.3	85.7±15.4	92.5±16.8	92.1±20.2	92.3±14.7	87.7±21.1
LOS	31.3±13.7	25.6±8.6	28.8±14.7	28.6±7.8	27.0±5.8	29.7±9.4
POD0 MME	126.6±123.3	120.8±81.6	138.8±127.4	103.6±69.8	141.5±135.0	118.7±101.7
Pre-Operative Pelvic Tilt	24.0±9.7	23.5±9.3	24.9±9.5	23.1±9.6	28.2±8.4	23.5±13.1
Pre-Operative Sacral Slope	35.5±8.5	40.5±8.4	34.5±9.3	40.3±8.6	34.0±7.0	42.6±13.9
Pre-Operative Pelvic Incidence	59.3±12.2	64.0±16.5	60.3±12.4	63.4±16.8	63.1±11.5	66.0±25.5
Pre-Operative Lumbar Lordosis	−49.4±12.9	−57.5±10.1	−46.6±12.9	−58.7±10.5 $^{p=0.020}$	−47.4±12.1	−59.2±12.2
Pre-Op PI-LL	9.9±13.5	6.5±8.5	12.3±11.9	4.7±10.2 $^{p=0.113}$	14.1±11.7	6.8±12.8
Adjacent Segment Disease % (Yes)	80.0%	76.9%	66.7%	88.6%	69.2%	83.5%
Scoliosis % (Yes)	57.1%	58.3%	46.2%	69.2%	50.0%	83.3%
Cobb Angle (degrees)	11.8±6.4	11.9±5.6	14.0±6.3	9.4±4.6	13.2±7.1	9.4±5.6
Fusion % at 1 year	91.7%	80.0%	90.0%	90.9%	87.5%	75.0%

Table 5:

Characteristics for patients who achieved MCID compared to those who did not for each outcome variable for patients presenting with leg pain predominant symptoms.

	VAS Back		Vas Leg		ODI	
	Yes	No	Yes	No	Yes	No
Age	62.8±12.1	−	61.8±13.4	−	59.6±12.2	76.0
BMI	27.7±6.1	−	26.1±3.9	−	27.5±4.6	20.5
Pre-Operative Narcotic Usage	4.9±11.3	−	8.4±13.9	−	8.0±12.9	0.0
Duration of Sensory Symptoms	6.0±9.5	−	2.8±2.6	−	5.2±8.7	1.0
CCI w/o age	0.2±0.6	−	0.3±0.6	−	0.3±0.7	0.0
EBL	40.3±24.0	−	37.5±16.9	−	38.3±16.0	25.0
OR Time	89.2±27.1	−	94.1±30.7	−	93.3±27.9	75.0
LOS	34.9±22.8	−	29.6±14.7	−	38.1±23.6	20.6
POD0 MME	92.7±49.5	−	100.6±53.7	−	104.9±46.3	50.0
Pre-Operative Pelvic Tilt	21.7±8.7	−	19.5±7.3	−	19.0±8.3	28.4
Pre-Operative Sacral Slope	36.7±9.1	−	37.5±8.9	−	37.0±8.2	31.0
Pre-Operative Pelvic Incidence	58.4±8.7	−	57.0±8.2	−	56.1±8.7	59.4
Pre-Operative Lumbar Lordosis	−45.1±13.0	−	−47.2±12.9	−	−48.2±12.8	−44.7
Pre-Op PI-LL	13.4±16.6	−	9.8±15.8	−	8.0±17.5	14.7
Fusion % at 1 Year	90.0%	−	91.7%	−	92.9%	7.1%