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Research Article

# The Potential Elimination of Blood Transfusions in Lumbar Spine Fusion Surgery: Clinical Case Series of 620 Consecutive Minimally Invasive TLIF Surgeries and Review of the Literature

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## Background

Lumbar spine fusion is one of the most common surgical procedures performed in the operative management of adult degenerative spine disorders. The dual incision, mini-open TLIF surgery uses a minimally invasive surgical technique that decompresses neural elements through placement of an anterior interbody disc spacer and posterior stabilization with pedicle screws. It is well established that this approach results in significantly less muscle dissection than the open technique used in conventional TLIF, however a quantitative assessment of the need for blood transfusions during this procedure has been limited to relatively small case series. The aim of this study was to assess the incidence of blood transfusion amongst a large group of patients undergoing a mini-open dual incision TLIF procedure over an extended amount of time. A retrospective study was completed of 620 consecutive patients surgically treated with the Minimally Invasive Transforaminal Lumbar Interbody Fusion (MI-TLIF) procedure, the largest such study completed by a single surgeon at multiple institutions from 2004 to 2020.

## Methods

The study sample comprises 620 patients who underwent a mini-open TLIF procedure through a dual incision technique for treatment of lumbar degenerative diseases from January 2004 to October 2020. No patients who underwent the procedure were excluded from the series. Surgical and medical record review was conducted to determine whether patients required blood transfusions during their hospitalization. No patients were lost to three-month follow up.

## Results

The study group consisted of 620 patients, 332 women and 288 men. Ages ranged from 20 to 88 years old with a mean age of 54 years. No patients in the series required a blood transfusion during their surgery, hospitalization, or 3-month postoperative period.

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Conflicts of Interest Statement for Dr. Chanan Batra

b Sanjay Ghosh, MD is a San Diego, CA-based neurosurgeon with fellowship training in skull base surgery. As the Director of Neurosurgery for the world-renowned SENTA Clinic, he is committed to providing state of the art care to his patients with diseases of the brain, skull base, and spine.

Visit Dr. Sanjay Ghosh

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**Conclusions**

The dual incision MIS Mini-open transforaminal lumbar interbody fusion allows for decompression of neural elements, pedicle screw instrumentation, and placement of an anterior interbody cage while potentially eliminating the need for blood transfusions. While previous studies have shown the potential for reduced blood loss with the mini-open technique compared to the open technique, this study adds a significant volume of data-driven evidence to support this conclusion. As such, this study represents the largest single-surgeon case series to show consistent absence of blood transfusions with a mini-open TLIF technique over sixteen years.



## INTRODUCTION

The transforaminal lumbar interbody fusion (TLIF) is a surgical technique that provides decompression of the neural structures as well as circumferential stabilization and fusion of both the anterior and posterior spinal elements. In the traditional open technique of TLIF, the surgery is accomplished through a midline central incision in the patient's back. Following the skin incision, lumbar spinal musculature is dissected from the spine, and then decompression, placement of spinal instrumentation, and fusion is performed. The open muscle dissection results in significant blood loss. As a consequence, a significant percentage of patients who undergo an open TLIF procedure require some type of blood transfusion following surgery. In the United States, open spinal fusion surgery is one of the top ten reasons that patients receive a blood transfusion, with up to 17% of cases requiring a transfusion in recent years (Aoude, Nooh, Fortin, et al. 2016).

The last two decades have given rise to minimally invasive surgical (MIS) techniques for lumbar spinal decompression and fusion. The mini-open MIS-TLIF surgery is performed through two small paramedian incisions as opposed to a single midline incision. Following the skin incision, an expandable retractor system is deployed to provide a narrow aperture to the spine. Through this narrow window, the surgeon can perform surgical decompression of the nerves, restore disc height with an interbody spacer, and implant pedicle screws for immediate stabilization. In addition, both a posterior lumbar interbody fusion and posterolateral fusion can be achieved through the same exposure.

In contrast to open surgery, the MIS technique does not require dissection of the midline band of paraspinal muscles, thus allowing the band to remain attached to the posterior spinal elements. This decreased degree of muscle dissection results in a much lower rate of blood loss than the traditional open TLIF surgery.

**Table 1. Patient Characteristics**

| Parameter | Value |
|---|---|
| *Total MIS-TLIF Patients:* | *620* |
| **Age (Years)** | |
| Median | 54 |
| Minimum | 20 |
| Maximum | 88 |
| **Sex** | |
| Male | 288 |
| Female | 332 |
| *Total Open TLIF Patients:* | *33* |
| **Age (Years)** | |
| Median | 60 |
| Minimum | 34 |
| Maximum | 84 |
| **Sex** | |
| Male | 10 |
| Female | 23 |

The purpose of this study is to examine the incidence of blood transfusions following MIS-TLIF surgery utilizing the dual incision MIS technique as compared to the traditional open TLIF procedure.

## METHODS

We retrospectively reviewed a series of 620 consecutive patients who underwent single and multilevel mini-open TLIF surgeries. No patients who underwent the procedure were excluded from the series. The patients' ages ranged from 20 to 88 years with a median of 54 years. The patient population included 288 males and 332 females (Table 1).

**Table 2. Summary of Cohort's Most Common Preoperative Indications**

| Preoperative Indication | # of Patients with Indication |
|---|---|
| Spondylolisthesis | 234 |
| Lumbar Stenosis | 169 |
| Herniated Nucleus Pulposus | 130 |
| Recurrent Disc Herniation | 116 |
| Radiculopathy | 113 |
| Degenerative Disc Disease | 78 |
| Pars Defect | 61 |
| Disc Height Collapse | 49 |
| Disc Disruption | 40 |

Moreover, we conducted a retrospective review of a series of 33 patients who underwent open TLIF surgeries by the same surgeon from 2005-2013, which provided a foundation of observational data with which to compare operative outcomes. The age of patients in the Open TLIF series ranged from 34 to 84 years with a median of 60 years. The patient population included 10 males and 23 females (Table 1).

Indications for surgeries included but were not limited to: degenerative spondylolisthesis, recurrent disc herniation, isthmic spondylolysis, iatrogenic instability secondary to removal greater than 50% of the facets bilaterally, degenerative disc disease, and traumatic spondylolisthesis. The majority of the 620 patients included in the study presented with two or more indications upon initial consultation (Table 2).

Surgeries were performed in a consecutive manner over 16 years. Every patient had a hemoglobin and hematocrit level test on the first post operative day. After that test, they were followed for at least 90 days for clinical signs of significant anemia. The threshold to transfuse was based on a hemoglobin less than or equal to 7 g/dl in healthy individuals and 8 g/dl in individuals with coronary artery disease. Operative reports, hospital records, and at least three months of clinical follow-up were reviewed for evidence of a need for blood transfusion in the operative or post-operative period. An additional literature review was conducted to identify the incidence of blood transfusion in patients undergoing open Posterior Lumbar Fusion Surgery in other case series.

### SURGICAL TECHNIQUE

All 620 patients included in the study were treated with a mini-open TLIF technique. The procedure is performed with the patient placed prone on a Jackson table. All pressure points are padded while the patient is under general anesthesia. AP fluoroscopy is used to identify the mid-sagittal plane as well as pedicle screw entry sites of the impacted levels. Two separate paramedian incisions are made 3.5 cm lateral to the mid-sagittal plane that extend from pedicle screw entry site to pedicle screw site (Figure 1A). After the first incision is made in the skin and the lumbar dorsal fascia, blunt dissection is performed with the placement of sequential dilators and an expandable retractor under fluoroscopic visualization to expose the pedicle screw entry site (Figure 1B). Pedicle screws are then placed on the side contralateral to decompression under fluoroscopic visualization. Each pedicle is tapped under continuous electrophysiological stimulation and EMG monitoring. Further electrophysiologic stimulation of the screws is used to confirm appropriate placement of the instrumentation. Finally, appropriate screw placement is further confirmed by AP and lateral fluoroscopy.

A secondary incision is made 3.5 cm from the contralateral mid-sagittal plane and the lumbar dorsal fascia is divided. A secondary retractor is then placed on the contralateral lamina and facet under fluoroscopic visualization utilizing blunt dissection. With the use of the operative microscope and drill, surgical decompression is performed (Figure 1C). The nerve root is gently retracted to allow for discectomy. Then, sequential dilators are used to gradually restore disc height. The contralateral pedicle screws are tightened to maintain distraction and curets are employed to aggressively remove cartilage and disc from the endplate until there is healthy bleeding bone above and below the operative site.

Posterior Lumbar Interbody Fusion is performed by placing a mixture of bone fusion extender and harvested autologous bone from the facetectomy at the end of the disc space. An interbody device is then packed with bone graft extender and autologous bone from the facetectomy and placed into the disc space to fuse the anterior column and provide immediate support (Figure 1D). The retractor is then repositioned, allowing pedicle screws placed on the decompressed side to be interlinked with cross connector set screws (Figure 1E).

### ASSESSMENT OF RESULTS

The operative reports and hospital records of each patient in both the MIS-TLIF and Open-TLIF series were analyzed for evidence of intraoperative or post-operative blood transfusion. Review of the incidence of blood transfusion following Open Lumbar Spine Fusion surgery in the authors' series of 33 patients revealed an incidence of 15%, while additional literature review of the same procedure revealed a comparable incidence of approximately 17% in recent years (Aoude, Nooh, Fortin, et al. 2016).

## RESULTS

620 consecutive MIS-TLIF surgeries were performed by one surgeon over a span of sixteen years. Medical records revealed a numerical estimated blood loss in 511 cases out of 620 (Table 3). The range of estimated blood loss for these 511 cases was 10 cc to 750 cc, with a median blood loss of 100 cc and mean blood loss of 136 cc. In the remaining 109 cases, blood loss was deemed minimal, and a specific numerical value was not assigned. Hospital records for

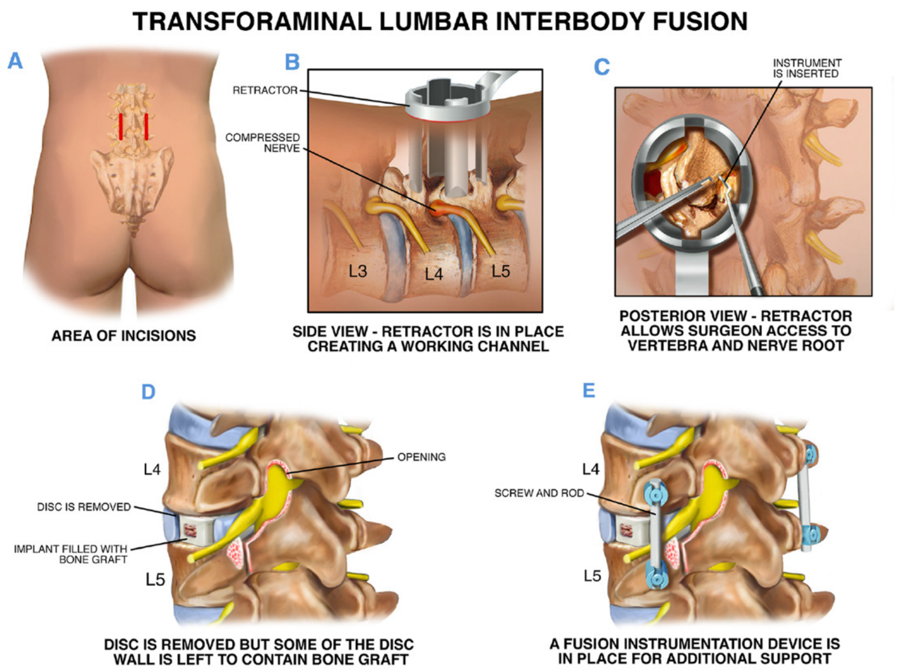


**Diagram 1. Step-by-Step TLIF Procedure**

**Table 3. EBL of Patients Treated with MIS-TLIF and Open TLIF from 2004-2020**

| Parameter | Value |
|---|---|
| *MIS Count:* | *511* |
| **EBL (mL)** | |
| Mean | 136 |
| Median | 100 |
| Minimum | 10 |
| Maximum | 750 |
| | |
| *Open Count:* | *33* |
| **EBL (mL)** | |
| Mean | 370 |
| Median | 300 |
| Minimum | 150 |
| Maximum | 1000 |

all 620 cases revealed that zero patients required a blood transfusion during surgery or during hospitalization following surgery. This includes cell saver, autologous blood, or any banked blood. Furthermore, at thirty-day post-operative follow-up, zero patients out of 620 required transfusion.

In contrast, medical record review of the authors' 33 Open TLIF procedures within the same time period revealed a numerical estimated blood loss in 27 out of 33 cases (Table 3). The range of estimated blood loss for these 27 cases was 150 cc to 1000 cc, with a median blood loss of 300 cc and mean blood loss of 370 cc. The remaining 6 cases had minimal blood loss, and a specific numerical value was not assigned. 15% of these patients received some form of blood transfusion, equivalent to 93 cases out of 620. The difference of 93 expected transfusions in 620 open-TLIF surgeries to 0 observed transfusions in 620 MIS-TLIF surgeries is statistically significant using Fisher's Exact Test ($p<0.05$).

## DISCUSSION

Lumbar spine fusion is one of the most common surgical procedures performed in the operative management of adult degenerative spine disorders. The goals of these surgeries include decompression of the neural elements and stabilization of the vertebrae. Open-TLIF is one such lumbar spinal fusion surgery (Harms and Rolinger 1982; Rosenberg and Mummaneni 2001; Tormenti, Maserati, Bonfield, et al. 2012). This technique affords the surgeon the ability to decompress the neural elements, restore disc height with an interbody space, achieve interbody and posterolateral arthrodesis, and place pedicle screw instrumentation. All of this is done through a single midline incision with subsequent muscle dissection of the paraspinal muscles from the lamina and facets.

One significant disadvantage of the Open-TLIF technique is the large degree of muscle dissection required to achieve desired decompression (Aoude, Nooh, Fortin, et al. 2016). The surgical exposure in the Open-TLIF surgery requires the dissection and detachment of four key structures of the lumbar spinal region. First, the lumbodorsal fascia must be completely disconnected from the spinous processes of the target level as well as the levels above and below. Second, the Multifidus muscle must be detached and dissected from the mamillary processes of the lumbar spine over several segments. Third, the Spinalis component

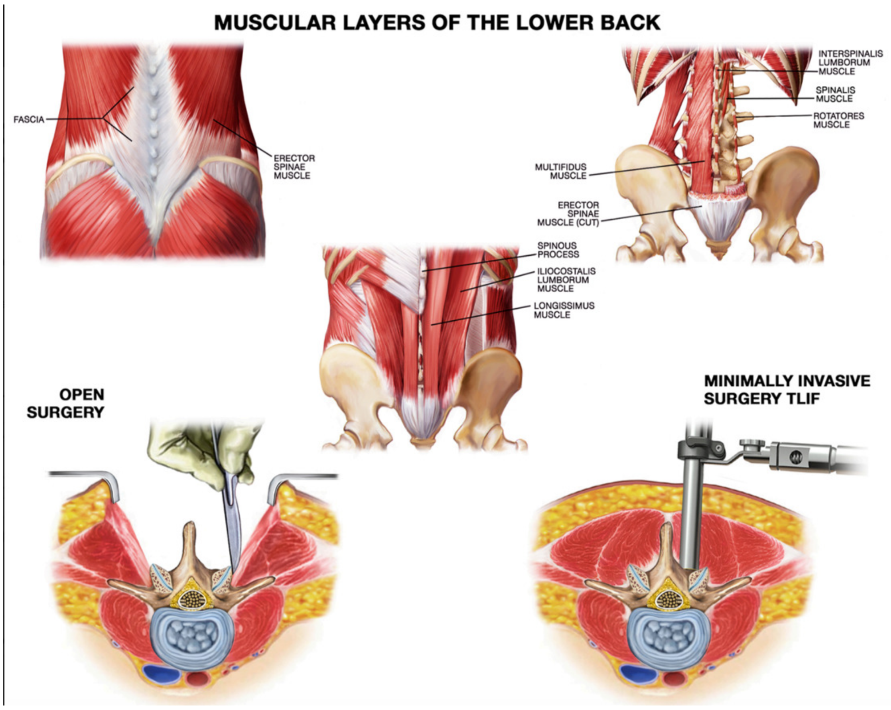


**Diagram 2. Muscle dissection in Open-TLIF vs. MIS-TLIF**

of the Erector Spinae muscle must be detached from multiple levels of spinous processes. Fourth, the Longissimus component of the Erector Spinae must be detached from the transverse process origins and insertions over multiple segments beyond the target level. This detachment of the paraspinal muscles from the posterior spinal elements during open surgical exposure often results in significant blood loss (Figure 2).

Consequently, many patients who undergo open posterior lumbar fusion surgery require post-operative blood transfusions. In fact, open spinal fusion surgery is one of the top ten surgeries associated with blood transfusions in the United States (Segal, Guallar, and Powe 2001). Basques et al. observed a 16.7 percent transfusion rate amongst 4223 patients who underwent open posterior lumbar interbody fusion procedures (Basques, Anandasivam, et al. 2015). In a study published three years later, Morcos et al. observed a transfusion rate of 18 percent amongst 722 patients who underwent open posterior spinal fusion (Morcos, Jiang, et al. 2018).

The last 25 years have afforded substantial advancement in spinal fusion surgery with the rise of minimally invasive surgery (MIS). MIS techniques incorporate a fixed or expandable tubular retractor system that achieves surgical exposure of the spine without stripping the paraspinous muscles directly from the spine. The use of the expandable retractor system in lumbar MIS surgery provides four key advantages over open lumbar spine surgery. First, it allows for preservation of the interspinous ligament and its associated lumbodorsal fascia, which is a key origin and insertion point for all three muscle layers of the back. Second, the expandable retractor helps avoid complete dissection of the spinalis muscle from the spinous processes. Third, the expandable retractor allows for preservation of the Longissimus and Multifidus muscles. Finally, the MIS technique allows the surgeon to minimize the area of muscle dissection to just the target levels of the spine, rather than having to extend the muscle dissection beyond the scope of treatment as is traditionally required in the open procedure.

Dr. Richard Fessler was an early pioneer in the development of the MIS-TLIF procedure (P. Lee and Fessler 2012; Wong, Smith, Nixon, et al. 2015). His technique included surgical decompression of the neural elements through a tubular retractor followed by percutaneous placement of pedicle screws. Further modification of this minimally invasive technique by Drs. Sanjay Dhall, Michael Wang, and Praveen Mummaneni resulted in the mini-open TLIF technique, which utilizes two separate incisions approximately 3 to 4 cm from the midline to access both sides of the spine (Dhall, Wang, and Mummaneni 2008). An expandable tubular retractor is used to maintain a pathway to the spine. This dual incision mini-open TLIF approach provides the surgeon with a direct visual corridor to the lamina, facet, and transverse process, all while preserving the attachment of the Longissimus paraspinal musculature.

While literature published by these pioneers and others support the observation of a significant reduction in blood loss with the MIS technique compared to the Open procedure, the utility and complication rates of MIS-TLIF procedures has been analyzed in variable patient sample sizes (Table 4). Dr. Mummaneni's team series observed a mean estimated blood loss (EBL) of 194 cc in 21 MIS-TLIF patients, compared to 505 cc in 21 Open TLIF patients. Dr. Fessler's team presented the intraoperative and perioperative complications of 513 MIS-TLIF surgeries. In his team's series, 2 of the 513 patients required post-operative blood transfusion following surgery, equivalent to a 0.4 percent

**Table 4. Quantity of MI-TLIF Patients and Blood Transfusion Rate in Relevant Contemporary Literature**

| Literature Source | # of MIS-TLIF Patients in Study | Blood Transfusion Incidence Rate |
|---|---|---|
| Dhall SS, Wang MY, Mummaneni PV. Clinical and radiographic comparison of mini-open transforaminal lumbar interbody fusion with open transforaminal lumbar interbody fusion in 42 patients with long-term follow-up (Dhall, Wang, and Mummaneni 2008). | 21 | NR |
| Rosenberg WS, Mummaneni PV. Transforaminal lumbar interbody fusion: technique, complications, and early results (Rosenberg and Mummaneni 2001). | 22 | NR |
| Tsahtsarlis A, Wood M. Minimally invasive transforaminal lumber interbody fusion and degenerative lumbar spine disease (Tsahtsarlis and Wood 2012). | 34 | NR |
| Parker SL, Mendenhall SK, Shau DN, Zuckerman SL, Godil SS, Cheng JS, McGirt MJ. Minimally invasive versus open transforaminal lumbar interbody fusion for degenerative spondylolisthesis: comparative effectiveness and cost-utility analysis (Parker, Mendenhall, Shau, et al. 2014). | 50 | NR |
| Park Y, Ha JW, Lee YT, Oh HC, Yoo JH, Kim HB. Surgical outcomes of minimally invasive transforaminal lumbar interbody fusion for the treatment of spondylolisthesis and degenerative segmental instability (Park et al. 2011). | 66 | NR |
| Lee KH, Yue WM, Yeo W, Soeharno H, Tan SB. Clinical and radiological outcomes of open versus minimally invasive transforaminal lumbar interbody fusion (K. H. Lee et al. 2012). | 72 | 0.00% |
| Villavicencio AT, Burneikiene S, Bulsara KR, Thramann JJ. Perioperative complications in transforaminal lumbar interbody fusion versus anterior-posterior reconstruction for lumbar disc degeneration and instability (Villavicencio et al. 2006). | 73 | 0.00% |
| Villavicencio AT, Burneikiene S, Roeca CM, Nelson EL, Mason A. Minimally invasive versus open transforaminal lumbar interbody fusion (Villavicencio et al. 2010). | 76 | 1.32% |
| Lee P, Fessler RG. Perioperative and postoperative complications of single-level minimally invasive transforaminal lumbar interbody fusion in elderly adults (P. Lee and Fessler 2012). | 84 | 0.00% |
| Rosen DS, Ferguson SD, Ogden AT, Huo D, Fessler RG. Obesity and self-reported outcome after minimally invasive lumbar spinal fusion surgery (Rosen et al. 2008). | 110 | NR |
| Morcos, Mina, MD, MSc, Jiang, Fan, et al. Predictors of Blood Transfusion in Posterior Lumbar Spinal Fusion: A Canadian Spine Outcome and Research Network Study (Morcos, Jiang, et al. 2018). | 115 | 1.70% |
| Wu WJ, Liang Y, Zhang XK, Cao P, Zheng T. Complications and clinical outcomes of minimally invasive transforaminal lumbar interbody fusion for the treatment of one- or two-level degenerative disc diseases of the lumbar spine in patients older than 65 years (Wu et al. 2012). | 151 | NR |
| Wang J, Zhou Y. Perioperative complications related to minimally invasive transforaminal lumbar fusion: evaluation of 204 operations on lumbar instability at single center (Wang and Zhou 2014). | 204 | NR |
| Wong AP, Smith ZA, Nixon AT, Lawton CD, Dahdaleh NS, Wong RH, Auffinger B, Lam S, Song JK, Liu JC, Koski TR, Fessler RG. Intraoperative and perioperative complications in minimally invasive transforaminal lumbar interbody fusion: a review of 513 patients (Wong, Smith, Nixon, et al. 2015). | 513 | 0.39% |
| Tormenti MJ, Maserati MB, Bonfield CM, Gerszten PC, Moossy JJ, Kanter AS, Spiro RM, Okonkwo DO. Perioperative surgical complications of transforaminal lumbar interbody fusion: a single-center experience (Tormenti, Maserati, Bonfield, et al. 2012). | 531* | NR |
| *(The Potential Elimination of Blood Transfusions in Lumbar Spine Fusion Surgery: Clinical Case Series of 620 Consecutive Minimally Invasive TLIF Surgeries and Review of the Literature.)* | 620 | 0.00% |

*Open and MIS Procedures not counted separately

incidence of blood transfusion (Wong, Smith, Nixon, et al. 2015).

Villavencio et al. observed a statistically significant reduction in blood loss when comparing minimally invasive to open TLIF surgeries in a series of 139 patients (Villavicencio et al. 2010). 76 patients underwent spinal fusion surgery with the MIS technique and 63 patients underwent spinal fusion surgery with the Open technique. The mean estimated blood loss for MIS-TLIF patients was 162 cc compared to 366 cc for their Open-TLIF patients. Of their 76 patients that underwent a MIS-TLIF procedure, one required a post-operative blood transfusion, equivalent to a blood transfusion incidence rate of 1.3 percent in their series.

Our study is unique in that it represents the efforts of a single surgeon over a period of 16 years with 620 consecutive MIS-TLIF surgeries, the largest study population of its kind. No patients who underwent the procedure were excluded from the series. In this contiguous series, no patients required a post-operative blood transfusion. Our zero percent incidence is lower than in currently available MIS-TLIF literature and is in stark contrast to the 16 to 20 percent incidence of transfusion witnessed in Open-TLIF surgeries.

We identify two likely reasons for the reduction in transfusion incidence: incision size and the degree of required muscle dissection. First, in MIS surgery, the size of the surgical incision is smaller and more targeted than that of Open-TLIF surgery. In the case of an L4-5 fusion with the MIS technique, each incision extends from the transverse process of L4 to the transverse process of L5. On the other hand, L4-5 exposure utilizing an Open-TLIF method requires a midline incision that typically extends from the top of the L3 spinous process to the midsacrum. This larger incision results in greater tissue dissection and potential blood loss.

Second, the degree of muscle dissection in the MIS-TLIF technique is significantly less than what is required with the open technique. In the open TLIF surgery, the Longissimus, Spinalis, and Multifidus musculature are all dissected from the spinous process, lamina, and transverse processes of the spine (Figure 2). Furthermore, the key lumbodorsal muscle groups are completely detached from their primary point of insertion, the Supraspinal Ligament. In contrast, the dual incision MIS technique requires a blunt channel through the left and right erector spinae groups, with each incision 3.5 centimeters from midline (Hoh, Wang, and Ritland 2010). As a consequence, the central 7 centimeters of the left and right erector spinae musculature of the longissimus and spinalis groups are left undissected in the MIS exposure (Figure 2). Furthermore, the key attachment of the posterior lumbar musculature into the spinous process and Supraspinous Ligament are unaffected in the MIS-TLIF technique. This reduction in the degree of muscle dissection is the most likely reason for the dramatic difference in the incidence of blood transfusion between open and MIS-TLIF techniques.

The benefit of reduced blood loss is particularly important in obese patients (BMI, >30), who often have a much deeper surgical field in open lumbar spinal surgeries as compared to patients with a normal BMI (18.5-24.9). As a result, a larger incision must be made to expose deep surgical fields in obese patients compared to fields in patients with a normal BMI. This is a likely reason that obese patients who undergo open lumbar spine surgery typically experience greater blood loss compared to their peers with a normal BMI (Rosen et al. 2008).

In contrast, the size of the incision in MIS-TLIF procedures is not affected by the depth of the surgical field. The expandable retractor system affords a sustained corridor to the spinal anatomy regardless of depth of field; therefore, the same sized incision can be used on an obese patient as a thin patient in MIS-TLIF surgery. Consequently, Rosen et al. observed no statistically significant difference in the blood loss of obese patients who underwent MIS-TLIF surgery compared to patients with a normal BMI who underwent MIS-TLIF surgery (Rosen et al. 2008).

The primary limitations of this study are that it is a retrospective study without any randomization of the patients between open and minimally invasive surgery. As the primary surgeon gained experience and comfort with the minimally invasive approach, the open technique was gradually phased out of the practice, as represented by the significant difference in the number of patients who underwent lumbar spinal fusion with the minimally invasive approach as compared to the open approach. Due to the marked decrease in morbidity with the minimally invasive approach compared to the open, it is unlikely that any surgeon would agree to a randomized trial to further the validity of the MIS technique.

In summary, the MIS-TLIF surgical technique results in significantly less blood loss compared to the open technique. Current literature supports this fact; however, this study adds a significant volume of data-driven evidence to support this conclusion. This is the largest single-surgeon case series to show consistent absence of blood transfusions over sixteen years and 620 consecutive cases of MIS-TLIF surgery. Further study is required to determine whether there are additional benefits of MIS techniques in spinal surgery, particularly as it relates to the duration and extent of functional recovery following surgery.

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