



# Minimally-Invasive midline posterior interbody fusion with cortical bone trajectory screws compares favorably to traditional open transforaminal interbody fusion



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## ARTICLE INFO

### Keywords:

Medicine  
Surgery  
Neurology  
Transforaminal interbody fusion  
Lumbar degenerative disease  
Midline interbody fusion

## ABSTRACT

**Objective:** Posterior interbody fusion is commonly performed for degenerative lumbar conditions. A minimally invasive technique of midline exposure limited only to the facets and fixation with laterally directed cortical bone trajectory (CBT) screws was introduced with the intent of decreasing surgical morbidity. The purpose of this study was to determine if posterior interbody fusion with this limited midline exposure will have less blood loss and shorter operative times (i.e., can be considered minimally invasive) compared to traditional open transforaminal interbody fusion.

**Methods:** A consecutive single-surgeon series of patients who underwent posterior interbody fusion with either a navigated, midline only exposure (MidLIF) or full, traditional open, exposure of the transverse processes with a posterolateral fusion (open TLIF) were identified. Demographic, peri-operative data, patient reported outcomes (PROs), and reoperation/readmission rates were collected and compared.

**Results:** There were 29 cases in the MidLIF and 27 in the open TLIF group. Both groups were similar with respect to surgical indications, age, BMI, gender, ASA grade and operative level. The MidLIF group had significantly lower estimated blood loss (266 vs. 446 cc,  $p = 0.003$ ), shorter operative time (170 vs. 210 minutes,  $p = 0.003$ ), and shorter length of hospital stay (2.9 vs. 3.7 days,  $p = 0.016$ ) compared to the open TLIF group. A sub-analysis of single-level cases showed similar findings with significantly lower estimated blood loss (247 vs. 411 cc,  $p = 0.10$ ), shorter operative time (159 vs. 199 min,  $p = 0.003$ ), and shorter length of hospital stay (2.9 vs. 3.7 days,  $p = 0.023$ ) in the MidLIF group. Patient reported outcomes at 6 weeks, 3 months, 6 months, 12 months and 24 months post-operative favored MidLIF with significantly greater ODI improvements at both 6 weeks and 12 months; and lower ODI and back pain at both 12 months and 24 months.

**Conclusions:** MidLIF had lower blood loss and shorter operative time compared to the traditional open TLIF technique. These differences compare well to reported values in the literature for tubular minimally-invasive TLIF. Patient reported outcomes from 6 weeks to 24 months post-operative, hospital length of stay, and reoperation/readmission rates all favored MidLIF compared to traditional open TLIF.

## 1. Introduction

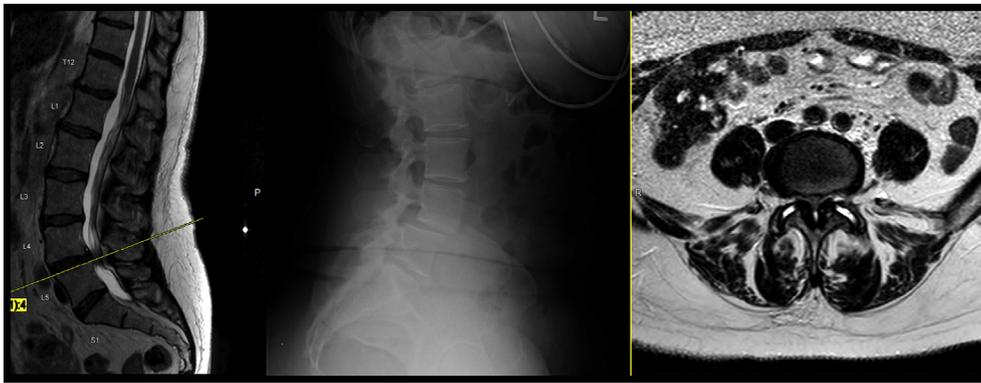
The concept of “minimally invasive surgery” (MIS) continues to attract the attention of patients and surgeons. The potential to obtain the full benefits of surgical treatment with less morbidity is a universal goal. While long-term patient reported outcomes and reoperation rates may be the ultimate measure of success, perioperative metrics such as length of surgery and blood loss can further our understanding of “invasiveness.”

Additionally, shorter operative times and less blood loss can translate into cost-savings, which are of utmost importance in the current social-medical climate (see Figs. 1 and 2).

Previous studies on tubular MIS transforaminal interbody fusion (TLIF) have used estimated blood loss (EBL) as a marker of invasiveness [1]. Surgical blood loss has been associated with increased surgical risks including infection and other complications [2]. Costs associated with surgical blood loss include cell saver costs and allogenic transfusion [3,

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**Fig. 1.** 65yo with a mobile Degenerative Spondylolisthesis with Lumbar Spinal Stenosis and Neurogenic Claudication. Pre-op ODI = 38, Back pain = 7, and Leg pain = 5.

4]. Recent meta-analyses have shown that tubular MIS TLIF is associated with lower blood loss compared to open TLIF [5, 6, 7, 8, 9].

Operative time is associated with direct costs including personnel and operating room costs. The charge for 1 h of operating room time (excluding physician time) has been reported to be \$3720 or more [10, 11]. Recent meta-analyses have shown that operative time for tubular MIS TLIF is not significantly different from open TLIF [5, 7, 8, 9], with one meta-analysis showing increased operative time for MIS TLIF [6].

The purpose of the current study is to quantify the “invasiveness” of a newer technique for posterior decompression and interbody fusion with limited midline exposure. The technique relies on the cortical bone trajectory for pedicle fixation, which does not require exposure lateral to the facet and avoids the additional dissection required to expose the transverse processes. The decompression and interbody fusion can be performed via the familiar midline exposure which greatly diminishes the learning curve. The study authors believe that this technique has been a substantial advancement in their clinical practice with significant improvements in EBL, operative time, length of stay, and patient reported outcomes (PROs) compared to their previous experience with traditional open TLIF. We hypothesized that a single-surgeon consecutive series would show these significant improvements and compare well with literature controls for tubular MIS TLIF.

## 2. Methods

A consecutive single-surgeon series of patients who underwent posterior interbody fusion from December 2014 to December 2016, during the transition from full, traditional open exposure of the transverse processes with freehand pedicle screws (open TLIF) to a navigated, limited midline exposure (MidLIF) with cortical bone trajectory screws, were identified. Demographic, peri-operative, and patient reported outcome data were collected and compared.

### 2.1. MidLIF surgical technique

A standard midline incision and subperiosteal dissection is made out to the lateral portion of the facet joint. A self-retaining retractor is placed and maintained until time of closure. A navigation frame is mounted to a spinous process clamp on the cranial end of the incision. Using intra-operative computed tomography based navigation instruments, screw paths are prepared using a cortical bone trajectory (inferior to superior, medial to lateral) through the pedicle. Care is taken to avoid impingement on the supra-adjacent facet. Decompression of the spinal stenosis and interbody fusion is then preformed using standard techniques. Remaining facets joints are decorticated and bone graft is placed. The



**Fig. 2.** Post-operative MidLIF with ODI = 9, Back pain = 0, and Leg pain = 0. Notice the medial to lateral Cortical Bone Screw (CBT) trajectory and the avoidance of the supra-adjacent facet.

self-retaining retractor is removed and the wound closed in standard fashion, typically without drains.

### 2.2. Traditional open TLIF surgical technique

A standard midline incision and subperiosteal dissection is made out to the tips of the transverse processes which elevates and detaches the longissimus and multifidus from the posterolateral gutter. Retractors typically are placed, but must be moved and adjusted to allow for the lateral to medial trajectory of traditional pedicle screws using a standard, “free-hand” technique. The decompression and interbody fusion then proceeds in standard fashion. Prior to closure, decortication and bone grafting of remaining facets and the transverse processes (lateral gutters) is performed.

This study was reviewed and approved by the University of Louisville Institutional Review Board.

### 3. Results

The two groups had similar demographics (Table 1) and number of surgical levels (Table 2). All surgeries were primary (non-revision) fusions of the index level. Surgical indications were similar between groups and included mobile spondylolisthesis and foraminal stenosis which required facet resection and/or elevation of foraminal height for adequate decompression.

Estimated blood loss was significantly less in the MidLIF group (266 vs. 446 mL,  $p = 0.003$ ). Consistent with lower EBL in the MidLIF group, cell saver volume infused was significantly less in the MidLIF group (42 vs. 133 mL,  $p = 0.007$ ). Surgical time (170 vs. 210 minutes,  $p = 0.003$ ) and length of hospital stay was significantly less in the MidLIF group (2.9 vs. 3.7 days,  $p = 0.016$ ).

A sub-group analysis of single level cases (Table 3) showed similar results with less EBL (247 vs. 411 mL,  $p = 0.010$ ), surgical time (159 vs. 199 minutes,  $p = 0.003$ ), and hospital stay (2.9 vs. 3.6 days,  $p = 0.023$ ) in

**Table 1**  
Summary of demographic parameters.

	MidLIF	Open TLIF	p-value
N	29	27	
Males, N	7	9	0.647
Age, years, mean (SD)	61.66 (7.81)	58.26 (9.94)	0.164
BMI, kg/m [2], mean (SD)	34.79 (5.94)	34.66 (7.67)	0.943
ASA Grade, N			
2	3	5	0.375
3	26	21	
4	0	1	

**Table 2**  
Summary of surgical parameters.

	MidLIF	Open TLIF	p-value
N	29	27	
Estimated Blood Loss, cc, mean (SD)	266.38 (129.09)	446.11 (261.88)	0.003
Cell Saver			
Patients infused	9	16	0.060
Volume infused	42.41 (64.40)	133.15 (152.67)	0.007
Operative Time, min, mean (SD)	170.10 (36.51)	209.92 (53.65)	0.003
No of Surgical Levels, N			0.978
1	23	22	
2	5	5	
No of Interbody Fusions, N			0.760
1	26	25	
2	3	2	
Length of Hospital Stay	2.90 (1.24)	3.70 (1.20)	0.016

**Table 3**  
Sub-analysis of single level cases.

	MidLIF	Open TLIF	p-value
N	23	22	
Age, years, mean	60.04 (7.59)	58.45 (9.10)	0.529
BMI, kg/m [2], mean	34.76 (6.11)	35.67 (7.09)	0.647
Males	5	8	0.279
ASAGrade			0.382
2	3	5	
3	20	16	
4	0	1	
Estimated Blood Loss, cc, mean (SD)	247 (127.10)	411 (252.40)	0.010
Operative Time, min, mean (SD)	159 (28.32)	199 (50.74)	0.003
Length of Hospital Stay	2.91 (1.16)	3.64 (1.29)	0.023

the minimally invasive, MidLIF group.

Patient reported outcomes (PROs) at baseline, 6 weeks, 3 months, 6 months, 12 months and 24 months are shown in Table 4. Pre-operative PROs showed a slightly lower baseline Back Pain in the MidLIF group (6.3 vs. 7.7,  $p = 0.003$ ). Six week PROs showed greater ODI improvement in the MidLIF group (23 vs. 7,  $p = 0.008$ ). Twelve-month PROs favored MidLIF with lower ODI (less lumbar disability) (26.7 vs. 43.1,  $p = 0.009$ ), more improvement in ODI (23.1 vs. 7.3,  $p = 0.018$ ) and less Back Pain (2.45 vs. 5.14,  $p = 0.002$ ). Twenty-four month PROs also favored MidLIF with lower ODI (less lumbar disability) (26.9 vs. 47.1,  $p = 0.015$ ) and less Back Pain (2.79 vs. 5.54,  $p = 0.019$ ) compared to the open TLIF group.

Readmissions and reoperations are reported in Table 5. Readmission rates (<90 days) were not significantly different between groups. Late reoperations for symptomatic adjacent segment pathology (Adjacent Segment Disease) were significantly greater in the traditional open TLIF group (4/27 vs. 0/29,  $p = 0.048$ ). Late reoperations for pseudoarthrosis were not significantly different between groups.

### 4. Discussion

The “MidLIF” using a cortical bone trajectory for pedicle screw fixation is a modification of the traditional midline exposure used in the open TLIF technique. The difference with this “minimally invasive” modification is limiting the exposure just lateral edge of the facet. Avoiding exposure lateral to the facet avoids elevating the multifidus, avoids detaching the longissimus from the transverse process, and potentially spares the neurovascular bundle to the erector spinae muscles. The concept of the cortical bone trajectory has made pedicle screw fixation possible through this limited midline exposure. Because the technique is relatively new, significant questions still remain. One of these questions is the “invasiveness” of the surgery. “Invasiveness” can be measured in various ways. The purpose of the current study was to look at three commonly measured perioperative parameters (i.e. surgical time, blood loss, and length of hospital stay) and to compare the new technique to the traditional technique. Secondly, by looking at the existing literature, we are able to establish reference standards for open TLIF and minimally invasive TLIF.

The current study was designed as a single-surgeon series to minimize the inherent variability from surgeon to surgeon in experience and surgical technique. The study was designed as a consecutive series to minimize selection bias, as well as, present a “worse case scenario” for the learning curve of the new technique. Additionally, the transition period between the old technique and the new technique minimizes any confounding changes that may evolve over time in a surgeon's practice.

The current literature contains extensive comparisons between traditional open TLIF and minimally invasive TLIF [5, 6, 7, 8, 9, 12, 13, 14]. The term “minimally invasive TLIF” is most commonly used to refer to a paramedian approach where a tubular retractor and “percutaneous” screws are used to accomplish the surgical goals of decompression and stabilization. The tubular MIS TLIF literature has matured to the point where systematic reviews and meta-analyses are possible [5, 6, 7, 8, 9].

**Table 4**  
Patient Reported Outcomes for patients with 12 month and 24 month follow-up.

	MidLIF		Open TLIF		p-value
N	29		27		
N Baseline PROs	28		24		
	Mean	SD	Mean	SD	p-value
Baseline ODI	48.11	16.28	54.03	18.86	0.239
Baseline BP	6.30	1.51	7.67	1.63	0.003
Baseline LP	6.14	2.45	7.21	2.23	0.106
Baseline EQ5D	0.56	0.21	0.46	0.25	0.247
N 6 week PROs	28		18		
	Mean	SD	Mean	SD	p-value
6 week ODI	26.82	18.45	42.45	18.32	
6 week BP	2.45	2.23	3.80	2.38	0.052
6 week LP	1.55	2.01	2.65	2.25	0.088
6 week EQ5D	0.76	0.17	0.66	0.16	0.132
Change_6w_ODI	22.85	18.20	6.66	18.98	0.008
Change_6w_BP	3.78	2.33	3.33	2.91	0.591
Change_6w_LP	4.71	2.61	3.94	3.67	0.446
Change_6w_EQ5D	0.24	0.25	0.28	0.16	0.612
N 3 month PROs	24		21		
	Mean	SD	Mean	SD	p-value
3 month ODI	26.23	17.94	40.68	21.31	
3 month BP	2.85	2.51	3.87	2.74	0.180
3 month LP	2.33	2.59	3.17	3.08	0.307
3 month EQ5D	0.71	0.22	0.60	0.25	0.178
Change_3m_ODI	24.63	22.86	13.23	20.23	0.083
Change_3m_BP	3.40	2.90	3.43	3.06	0.974
Change_3m_LP	3.69	3.75	3.62	3.44	0.945
Change_3m_EQ5D	0.16	0.28	0.24	0.23	0.509
N 6 month PROs	19		16		
	Mean	SD	Mean	SD	p-value
6 month ODI	27.15	17.26	43.18	22.60	
6 month BP	3.15	2.11	3.89	2.52	0.337
6 month LP	2.45	3.27	3.17	2.64	0.460
6 month EQ5D	0.72	0.23	0.57	0.23	0.143
Change_6m_ODI	22.32	21.00	9.00	23.46	0.096
Change_6m_BP	3.05	2.50	3.00	3.06	0.956
Change_6m_LP	4.11	3.89	3.25	2.84	0.458
Change_6m_EQ5D	0.13	0.21	0.15	0.16	0.898
N 12 month PROs	20		22		
	Mean	SD	Mean	SD	p-value
12 month ODI	26.65	21.59	43.14	16.42	0.009
12 month BP	2.45	2.50	5.14	2.61	0.002
12 month LP	2.75	2.85	4.23	2.86	0.102
12 month EQ5D	0.72	0.22	0.56	0.24	0.158
Change_12m_ODI	23.11	22.51	7.29	16.54	0.018
Change_12m_BP	3.61	2.81	2.35	2.54	0.157
Change_12m_LP	3.74	3.96	2.55	3.25	0.314
Change_12m_EQ5D	0.20	0.20	0.17	0.22	0.764
N 24 month PROs	14		13		
	Mean	SD	Mean	SD	p-value
24 month ODI	26.86	21.21	47.08	19.06	0.015
24 month BP	2.79	2.86	5.54	2.82	0.019
24 month LP	3.23	3.42	4.62	2.66	0.261
24 month EQ5D	0.73	0.24	0.61	0.24	0.198
Change_24m_EQ5D	0.12	0.24	0.17	0.24	0.622
Change_24m_ODI	16.50	21.98	4.82	12.19	0.107
Change_24m_BP	3.29	3.02	1.36	2.54	0.098
Change_24m_LP	2.85	4.10	1.73	2.05	0.399

ODI = Oswestry Disability Index (0–100), BP = Back pain (0–10), LP = Leg pain (0–10), EQ5D = EuroQol-5D (0–1).

The majority of these recent meta-analyses have shown that there is no significant difference in surgical time between tubular MIS TLIF and Open TLIF [5, 7, 8, 9, 12, 13], with the exception of Hu [6] et al that showed increased operative time for the MIS group. All of the meta-analyses have consistently shown that EBL is lower in MIS TLIF when compared to Open TLIF. The results of the current study compare

**Table 5**  
Re-admissions and Re-operations.

	MIDLIF N = 29	Open TLIF N = 27	p-value
Readmission (<90 days) Total	2	5	0.244
Readmission (<90 days) for medical complication (chest pain)	0	1	0.999
Readmission (<90 days) with reoperation for wound complication	1	2	0.605
Readmission (<90 days) with reoperation for persistent radiculopathy	1	1	1.000
Late reoperation for Adjacent Segment Disease	0	4	0.048
Late reoperation for Pseudoarthrosis	1	0	1.000

**Table 6**  
Current study data for single level MidLIF cases compares favorably to literature controls for tubular “minimally invasive surgery” (MIS) TLIF.

Comparative study or meta-analysis	EBL (cc), mean		Difference favoring MIS (cc)	Surgical time (min), mean		Difference favoring MIS (min)
	MIS	Open		MIS	Open	
Current (MidLIF)	247	411	164	159	199	40
Djurasovic (Comparative MIS)	262	614	352	264	279	NS
Xie (Meta-analysis MIS)	224	506	266	195	198	NS
Hu (Meta-analysis MIS)	267	535	268	212	190	*
Goldstein (Meta-analysis MIS)	NR	NR	260	NR	NR	NS
Phan (Meta-analysis MIS)	177	461	256	185	186	NS
Tian (Meta-analysis MIS)	NR	NR	219	NR	NR	NS

NS = No Significant difference, NR = Not Reported, \* = Favors open.

favorably to this best-available evidence regarding MIS TLIF (Table 6). Also, the results compare favorably to a recent comparative study from the same institution as the current study [15]. (Table 6).

Limitations of the current study include the relatively small sample size and single surgeon series. Future studies with more patients and more surgeons are needed to determine if the same technique advantages are generalizable. Additionally, it is important to note that lack of formal posterolateral fusion (which is similar to the tubular TLIF techniques) likely requires successful interbody fusion for long-term success. Formal assessment of fusion was not possible in this series, as the majority of patients did not have postoperative computed tomography and plain radiographs are generally considered inadequate for fusion assessment. Although we did not see a significant difference in reoperation rates for pseudoarthrosis in this series, fusion success will depend on various patient specific and surgeon controlled variables that may become more apparent with additional experience and study.

The results of the study suggest that “minimally invasive” MidLIF compares favorably to open TLIF and MIS tubular TLIF with regards to EBL and surgical time. Importantly, patient reported outcomes and reoperation rates also favored MidLIF when compared to a traditional open TLIF technique. Future experience and study will ultimately determine if the procedure advantages are generalizable to a broader patient and surgeon population.

**Declarations**

*Author contribution statement*

Charles H. Crawford III: Conceived and designed the experiments;

Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Roger K. Owens II, Mladen Djurasovic, Jeffrey L. Gum: Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

John R. Dimar II: Performed the experiments; Contributed reagents, materials, analysis tools or data.

Leah Y. Carreon: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

#### *Funding statement*

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

#### *Competing interest statement*

The authors declare the following conflict of interests: Charles H. Crawford III: is an employee of Norton Healthcare; received consulting fees from Alphatec, Medtronic and Nuvasive; received payments for speaking from Medtronic and Titan; received funds for trips and travel from SRS and NASS and is on the scientific board of Medtronic. Roger K. Owens II: is an employee of Norton Healthcare; receives consulting fees from Medtronic, Alphatec and Nuvasive; funds for trips and travel from DePuy, Sunthes. Mladen Djurasovic: is an employee of Norton Healthcare; receives consulting fees from Medtronic and Nuvasive, Jeffrey L. Gum: receives royalties from Acuity; receives consulting fees from Medtronic, DePuy, Alphatec, Stryker, Acuity, K2M, Nuvasu, PacMed; receives honoraria from Pacira; John R. Dimar II: is an employee of Norton Healthcare; receives royalties, consulting and speaker fees from Medtronic, Member of Board of Directors of the Scoliosis Research Society Leah Y. Carreon: is an employee of Norton Healthcare; Member, Editorial Advisory Board, Spine Deformity, Spine and Spine Journal; Institutional Review Board Member, University of Louisville.

#### *Additional information*

No additional information is available for this paper.

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