Spine Publish Ahead of Print
DOI:10.1097/BRS.0000000000005519

Does Velocity of Return-to-Work Differ between Circumferential Minimally-Invasive and Open Surgery to Treat Adult Spinal Deformity?

Mohamed Macki 1, Michael E. Tawil 2, Nima Alan 2, Nathan Han 2, Marc Prablek 2, Vivian P. Le 3, Alexander Aabedi 2, Paul Park 4, Juan S. Uribe 5, Jay D. Turner 5, Robert K. Eastlack 6, Richard G. Fessler 7, Kai-Ming Fu 8, Michael Y. Wang 9, Adam S. Kanter 10, David O. Okonkwo 11, Pierce D. Nunley 12, Neel Anand 13, Gregory M. Mundis, Jr. 14, Peter G. Passias 15, Shay Bess 16, Christopher I. Shaffrey 17, Dean Chou 3, Praveen V. Mummaneni 2, International Spine Study Group

Affiliations

1. Department of Neurological Surgery, Cleveland Clinic, Cleveland, OH.
2. Department of Neurological Surgery, University of California San Francisco, San Francisco, CA.
3. Department of Neurosurgery, Columbia University Irving Medical Center, New York, New York
4. Department of Neurosurgery, University of Tennessee, Memphis, TN.
5. Department of Neurosurgery, Barrow Neurological Institute, St. Joseph's Hospital and Medical Center, Phoenix, AZ.
6. Division of Orthopaedic Surgery, Scripps Clinic, La Jolla, California, USA.
7. Department of Neurosurgery, Rush University, Chicago, Illinois.

8. Department of Neurosurgery, Weill Cornell Medical College, New York, New York.
9. Department of Neurosurgery, University of Miami, Miami, Florida.
10. Department of Neurosurgery, Hoag Neurosciences Institute, Newport Beach, California.
11. Department of Neurosurgery, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania.
12. Spine Institute of Louisiana, Shreveport, Louisiana.
13. Department of Orthopedics, Cedars-Sinai Spine Center, Los Angeles, California.
14. Division of Orthopaedic Surgery, Scripps Clinic, La Jolla, California, USA.
15. Department of Orthopedic Surgery, Duke University Medical Center, Durham, NC, USA.
16. Department of Spine Surgery, Denver International Spine Center, Presbyterian St. Luke's/Rocky Mountain Hospital for Children, Denver, Colorado, USA.
17. Departments of Neurosurgery and Orthopaedic Surgery, Duke University Medical Center, Durham, North Carolina, USA.

Corresponding Author:
Nima Alan, MD
Department of Neurological Surgery
University of California, San Francisco
400 Parnassus Ave, A2300, San Francisco, CA 94143
nima.alan@ucsf.edu

Permission to reproduce copyrighted materials or signed patient consent forms

This study does not include any copyrighted materials or identifiable patient information, ensuring compliance with ethical and copyright standards.

Acknowledgments listed for grants, technical support, and corporate support

ISSG Foundation funds were received in support of this work.

IRB approval/Research Ethics Committee, or local equivalent

This study was approved by the Institutional Review Board of our institution.

IRB approval: 14-13558

Informed consent was obtained from all participants or waived due to the retrospective nature of the study, as approved by the ethics committee.

Running title: Return-to-Work After cMIS vs Open Spine Surgery

Key Points:

1. Circumferential Minimally Invasive Surgery (cMIS) is associated with a faster return-to-work compared to open surgery for adult spinal deformity, particularly at the first-year mark postoperatively (21.5% vs 10.5%).

2. Although both groups showed similar employment rates by 2 years, early postoperative recovery metrics (hospital stay, blood loss, surgery duration) favored cMIS, supporting its advantage in recovery velocity.

3. These findings support cMIS as a faster recovery approach in appropriately selected adult spinal deformity patients, with the potential for socioeconomic benefits from earlier workforce reintegration.

ABSTRACT

Study Design: Retrospective matched cohort study

Objective: We sought to compare circumferential minimally-invasive surgery (cMIS) to open deformity correction surgery on patients' timing of return to work.

Summary of Background Data: Adult spinal deformity (ASD) impacts functional ability and quality of life, often influencing patients' ability to work. Surgical correction can improve alignment and symptoms; however, recovery timelines may vary depending on surgical technique.

Methods: Prospectively collected data from the International Spine Study Group (ISSG) multicenter database was queried for ASD correction. Patients were evaluated in two cohorts: cMIS or open surgery. Propensity scoring matched age, body mass index, pelvic incidence–lumbar lordosis mismatch, and sagittal vertical axis. All patients had at least 2 year follow-up. The cohorts were compared at 6 weeks, 1 year, and 2 years.

Results: Of 173 matched patients (85 open, 88 cMIS), there were no significant differences in age, gender, or ASA classification. Average age was 68.2 years with ≥3 levels fused. The open group had significantly more direct posterior decompressions, higher median number of transforaminal lumbar interbody fusions, longer surgery time, greater blood loss, and longer hospital stay. The cMIS group had a higher median number of lateral lumbar interbody fusions.

Baseline **work** status did not differ significantly: disabled (4.7% vs 6.8%), **working**(20.0% vs 21.5%), retired (71.7% vs 67.0%), **not working** (3.5% vs 4.5%). At 6 weeks, **working** patients were similar (14.1% vs 15.9%, p=0.741); at 1 year, significantly more cMIS patients returned to work (10.5% vs 21.5%, p=0.049). At 2 years, more cMIS patients had returned to work (14.1% vs 19.3%), but this was not significant (p=0.277).

Conclusion: Patients undergoing cMIS surgery returned to work at a higher rate between 6 weeks and 1 year postoperatively. At 2 years, return-to-work remained higher for cMIS **but this difference was no longer statistically significant.**

INTRODUCTION

Circumferential minimally-invasive surgery (cMIS) procedures may reduce blood loss, speed postoperative recovery, and lower complication rates.[1–3]

Also, cMIS may have a positive impact on other outcomes compared to the equivalent open operation, such as reduced postoperative narcotic use, accelerated return to work, and accelerated Oswestry disability index improvement. Return-to-work after spinal surgery is influenced by multiple factors, with preoperative employment being the strongest predictor.[4]

We hypothesize that cMIS, as compared to an open approach, will have a positive impact on the velocity of return-to-work. We addressed this research question with a large, multi-institutional database that has the granularity to capture the velocity of return-to-work at three timepoints: 6 weeks, 1 year, and 2 years.

METHODS

Study Design

This cohort study consists of patients queried from a prospective collection of adult spinal deformity cases in the International Spine Study Group (ISSG) database.

Settings and Data Sources/ Measurement

ISSG represents a consortium of surgeons and researchers analyzing adult patients with spinal deformity. ISSG maintains a comprehensive, multicenter database of over 2000 patients from over 20 participating sites.

Clinical criteria for adult spinal deformity were uniformly standardized for all sites: age >18 years as well as degenerative or idiopathic deformity only. All patients must also meet at least one of the following radiographic criteria:

- Scoliotic curve >20°
- Pelvic incidence – lumbar lordosis (PI-LL) mismatch ≥ 20°
- Sagittal vertical angle (SVA) >10 cm
- Pelvic tilt (PT) >30°

Surgical strategies for correction of adult spinal deformity included both open and circumferential minimally-invasive surgery (cMIS). A cMIS was defined as at least one of the following procedural criteria

- ≥3 levels percutaneous posterior spinal instrumentation or 3 level stand-alone interbody
- Percutaneous placement **at all** posterior instrumented vertebra
- Single-position surgery ≥3 levels fused (S2 and/or pelvis/ ilium is not considered a level)
- Staged ≥3 levels fused with percutaneous pedicle screws
- 3 column osteotomy with percutaneous fixation
- Anterior column release incorporating open or percutaneous fixation as long as UIV and LIV are percutaneous screws

In the lumbar spine, fusion is achieved via interbody biomechanical device placement and arthrodesis via allograft and bone morphogenic protein, depending on surgeon's preference. This is further supplemented with intrafacet fusion where the surgeon exposes the facet via percutaneous tubular approach and then decorticates the facet and place autograft, allograft, and/or bone mophogentic protein (BMP) in the facet joint. In the

thoracic spine, the surgeons differ based on whether they choose paramedian incisions for posterior pedicle screw placement or midline. Interbody techniques in a cMIS cohort were not restrictive of transforaminal lumbar interbody fusion (TLIF), anterior lumbar interbody fusion (ALIF), antepsoas and/or transpsoas lateral lumbar interbody fusion (LLIF) [**Figure 1**]. **Further, to meet cMIS criteria , all pedicle screws were placed percutaneously with paramedian fascial incision (skin opening was midline or multiple paramedian incisions). We did not include in this cohort, patients with open midline exposure for screw placement. If decompression is necessary, it is executed via tubular approach, preserving the posterior tension band.**

Open surgery was defined as a midline posterior approach with retraction of the paraspinal muscles to expose the lamina, facets, and transverse processes for decompression and fusion [**Figure 2**].

For this research protocol, enrollment into ISSG was defined as the date of surgery. Study enrollment spanned from 2008 to 2019, which ensured a minimum of two-year follow up.

Participants and Bias

Patients undergoing open correction of adult spinal deformity were compared to cMIS for adult spinal deformity. To eliminate a potential bias between the two cohorts, open surgery was matched to cMIS via a propensity score algorithm, based on age, body mass index, PI-LL mismatch, and SVA.

Variables

The primary outcome measure was return-to-work. Standardized preoperative questionnaires in the ISSG includes a self-reported **work** status: retired, disabled, **working**, or **not working**. All patients were surveyed at 6 weeks, 1 year, and 2 years. Patients with missing variables at 2 years were excluded. **Employment status and work status were not considered interchangeable because patients technically employed may qualify for the Family and Medical Leave Act (FMLA) of 1993. Thus, return-to-work categorization in this study only entails patients who attended to actual job responsibilities.**

Quantitative Variables and Statistical Methods

Baseline demographic variable, intraoperative parameters, and postoperative outcomes were described with summary statistics. The open and cMIS cohorts were compared with a student's t-test for continuous data, chi-squared test (χ^2) for categorical data, and Mann-Whitney U test for ordinal data.

Return-to-work was evaluated at discrete follow-up times, so the data obtained followed an interval-censored model. A discrete-time approach binned the return-to-work measure into one of the three follow up intervals: 6 weeks (time 1), 1 year (time 2), and 2 years (time 3). Patients who did not return-to-work were censored at the last follow-up. The hazards of return-to-work were calculated using a complementary log-log function in a discrete-time proportional hazards model.[5] As such, the hazards ratio of the open versus cMIS cohort estimated the velocity of return-to-work.

Statistical significance was set at $p < 0.05$. Statistical analysis was performed with STATA (version 17.0, College Station, TX, USA).

RESULTS

Participants

Of the 190 patients matched on age, body mass index, PI-LL, and SVA through propensity score matching, 173 patients (91%) had both baseline and 2-year follow up **work** status. Adult spinal deformity was corrected with an open technique in 85 patients (49.1%) and cMIS in 88 patients (50.8%).

Descriptive Data

The mean age of the study population was 68.2 years [**Table 1**]. The open and cMIS cohorts were equivalent with respect to gender and median American Society of Anesthesiologists (ASA) classification. In terms of intraoperative parameters, the open operation included statistically significantly more direct decompressions posteriorly (70.5% vs 23.8%, $p<0.001$), more median number of transforaminal lumbar interbody fusions (1 vs 0, $p<0.001$), longer length of surgery (6 hours 28 minutes vs 4 hours 59 minutes, $p<0.001$), higher estimated blood loss (1744.1 cc vs 260.2 cc, $p<0.001$), and longer length of hospital stay (8.2 days vs 5.3 days, $p<0.001$). On the other hand, cMIS cohort had a higher median number of lateral lumbar interbody fusions (0 vs 2, $p<0.001$).

Outcome Data and Main Results

The open versus cMIS cohort did not statistically significantly differ in baseline **work** status: disabled (4.7% vs 6.8%), **working** (20.0% [n=17] **open patients** vs 21.5% [n=19] **cMIS patients**), retired (71.7% **open patients** vs 67.0% **cMIS patients**), and **not working** (3.5% **open**

patients vs 4.5% **cMIS patients**) [**Table 2**]. The number of **working** patients between the open vs cMIS cohort did not significantly differ at 6 weeks (14.1% [n=12] vs 15.9% [n=14], p=0.741). However, by 1 year, there was a statistically significant difference both cohorts **in those who were working** (10.5% [n=9] **open patients** vs 21.5% [n=19] **cMIS patients**, p=0.049), with the cMIS group having significantly more patients return-to-work by 1 year. At 2 years, this difference **in percentage who were working** diminished, returning to no significant difference (14.1% [n=12] **open patients** vs 19.3% [n=17] **cMIS patients**, p=0.277).

In the open cohort, 12 patients returned-to-work at 6-weeks, all of whom were **working** at baseline. At 1-year, 5 patients remained **working**, 1 patient became disabled, 4 patients retired. Two patients did not report **working** status at 1-year. Three patients who were **working** at baseline returned to work at 1-year, and 1 patient who was retired at baseline returned to work at 1-year. Hence, 9 patients were **working** at 1-year.

In the cMIS cohort, 14 patients returned-to-work at 6-weeks, all of whom were **working** at baseline. At 1-year, 13 patients remained **working**, and 1 patient retired. Four patients who were **working** at baseline returned-to-work at 1-year, and 1 patient who was retired at baseline returned-to-work at 1-year. One patient who was **not working** at baseline returned-to-work at 1-year. Hence, 19 patients were **working** at 1-year **after surgery [Figure 3].**

Other Analyses

In a sub-analysis of 36 patients who were **working** at baseline, the number of **working** patients between the open vs cMIS cohort did not significantly differ at 6 weeks (70.5% **open patients** vs 73.6% **cMIS patients**, p=0.636). By 1 year, there was a statistically significant difference **in the**

patients working (47.0% **open patients** vs 89.4% **cMIS patients**, p=0.006), however this was not sustained at 2 years (58.8% **open patients** vs 78.9% **cMIS patients**, p=0.191).

In a sub-analysis of 137 patients who were **not working** at baseline, none returned to work at 6 weeks. At one year, 1 **patient not working at baseline** returned to work in the open group and 2 patients returned to work in the cMIS group. The number of patients that returned to work between the open vs cMIS cohort did not significantly differ at 1 year (1.4% [n=1] vs 2.9% [n=2], p= 0.568) or 2 years (2.9% [n=2] vs 2.9% [n=2], p=0.191).

Complication rate differs between the MIS and open cohorts. Overall, MIS cohort had fewer medical and surgical complications. Specifically, cardiac complications were more common in the open cohort (4.7% vs 0%, p=0.04). Intraoperative complications (25.8% vs 5.7%, p<0.001) and postoperative infection (7.0% vs 0%, p=0.011) were also more frequent in the open cohort.

DISCUSSION

Key Results

Following propensity score matching on age, body mass index, PI-LL mismatch, and SVA, patients undergoing correction of adult spinal deformity with cMIS versus open surgery returned to work at the same rate as open patients at 6 weeks. But more cMIS patients were working at 1 year. However, the overall rate of return-to-work was **not statistically different** at two-year follow-up. Similar findings were reported in a sub-analysis of patients who were **working** at baseline.

Interpretation

In carefully selected patients, cMIS and open approaches have equivalent radiographic correction of adult spinal deformity; however, cMIS has the added benefits of increased disc height, correcting coronal imbalance, and reducing blood loss and morbidity.[6,7]

We explored the impact of cMIS clinically, more specifically, return-to-work. At 6-weeks we saw the largest percentage of return to work: 14.1% open vs. 15.9% cMIS (p=0.741). The nearly equal percentages between both groups likely reflects motivated patients who were keen on returning to work regardless of surgical approach. All the 6-week return-to-work patients were **working** at baseline. By 1 year, however, the cMIS group had a significantly higher return-to-work compared to the open group (10.5% [n=9] vs 21.5% [n=19], p=0.049). This likely reflects the quicker recovery from surgery in those having smaller incisions and less muscle dissection. Recent literature reveals a patient's pre-operative work state is the most important driver of return-to-work.[8,9] Anderson et al. also found that if patients were working at the time of the surgery, they had a 10.5 times greater chance of returning to work after undergoing a spinal fusion.[10]

In support of these findings, previous MIS vs open comparisons in the spine literature have shown that not all patient-reported outcome measures are significant in the short follow-up period after surgery; the benefits of MIS approaches may not be appreciated until 1-year **postoperative**. Lee et al. found the patient-reported outcome VAS-back did not unveil the advantage of MIS until the 6-month follow-up.[11] These findings continued until their final timepoint of 1-year. Commensurately, our study failed to elicit a statistically significant difference in the patient-reported outcome, return-to-work, at 6-weeks. The ISSG database has sufficient long-term follow-up to capture a statistically significant difference in return-to-work at 1-year.

The 6-week follow-up timepoint is notable for several reasons. Patients typically schedule surgeon clinic visits at 6-weeks. Following liberalization of activities by their surgeons at 6-weeks, patients will begin to gain more autonomy in activities of daily living. More aggressive rehabilitation may be prescribed to enhance functional status. With this regained mobility, patient progression is now primarily limited by perceived pain and individual tolerance.[12,13]

Moreover, cMIS leads to less overall tissue damage, which results in a reduced time to ambulation, reduced hospital length-of-stay, and less narcotic use (an indicator of patient pain severity) compared to open surgeries.[14–17] **Less tissue damage arises from percutaneous placement of posterior instrumentation.**

These benefits of cMIS harmonize together to jump-start an early postoperative recovery, which was captured between 6-weeks and 1-year in the ISSG dataset. Of the 14 patients that were keen to return-to-work at 6-weeks in the cMIS cohort, 13 (93%) patients remained **working** at 1-year. However, compared to the open cohort, only 5 (42%) patients of the 12 who returned to work at 6-weeks remained **working** at 1-year. Evidently, the sooner restoration of functional status in the cMIS cohort **seems to** translate to one-year favorable **return to work** that has not been thoroughly described in the literature. At 2-year follow-up, the significant difference in return-to-work status dissipates (14.1% vs 19.3%, p=0.277). Patients 2 years after their operation, regardless of the type of surgery, may have completed a physical therapy program and had adequate time to recover from sustained tissue **disruption**.

The comparable return-to-work rates at two years is commensurate with other long-term outcomes measures after cMIS verus open deformity corrections. Our previous publication on an equivalent cohort of patients from the ISSG database found that, with a

mean follow up of 32.8 months, reoperation rates for proximal junctional kyphosis did not differ between the two groups of operations. Fusion of the cMIS construct still primarily occurs across the interbody levels. Above those levels, however, our surgeons often utilize a tubular system to decorticate and graft the facet joints between the pedicle screws where interbody cages are not placed.

Limitations and Generalizability

Patients undergoing a cMIS or open surgery were not randomized in reference to the type of surgery they received. The decision to proceed with a cMIS or open approach was solely based on surgeon preference leading to the possible introduction of a selection bias in this study. However, we do not have granularity on the number of revision fixation procedures influencing the surgeons' preference on surgical approach. **The differences in return-to-work between the cMIS and open cohorts was statistically significant at one year (favoring c-MIS) but did not reach statistical significance at 2 years. To capture both short-term and long-term differences in return-to-work, a large cohort size would be required to appropriately power the study. A larger cohort for patients would be necessary to detect these differences.** Additionally, since the inception of cMIS surgery, changes and improvements to the surgical protocols have resulted in improved radiographic and patient-reported outcomes.[18] Given the heterogeneity of the ISSG database encompassing numerous surgeons, institutions, and various practice settings, a specific standardized protocol could not be implemented in this study**. Not all patients are a candidate for** cMIS particularly in the presence of severe deformities **which is commonly not amenable to correction techniques via minimally invasive approach.** This **heterogeneity** was mitigated by propensity score matching on age, body mass index, PI-LL mismatch, and SVA.

CONCLUSION

In the context of patient expectations following correction of adult spinal deformity, employment status at 6 weeks was similar between cMIS and open surgery. At 1 year, a greater proportion of cMIS patients were working. By 2 years, the percentage of those who were working was higher in the cMIS group but this was not statistically significant. These findings suggest a potential short-term advantage for cMIS patients to return to work sooner than patients treated with open.

References

1. Mobbs RJ, Sivabalan P, Li J. Minimally invasive surgery compared to open spinal fusion for the treatment of degenerative lumbar spine pathologies. *Journal of Clinical Neuroscience*. 2012;19(6):829-835. doi:10.1016/J.JOCN.2011.10.004
2. 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 (Phila Pa 1976)*. 2013;38(23):2049-2055. doi:10.1097/BRS.0B013E3182A8212D
3. Passias PG, Tretiakov PS, Nunley PD, et al. Incremental benefits of circumferential minimally invasive surgery for increasingly frail patients with adult spinal deformity. *J Neurosurg Spine*. 2023;39(2):168-174. doi:10.3171/2023.2.SPINE221278
4. Lee YP, Farhan SD, Kiester D, Rosen C, Pendi A, Bhatia N. Variables affecting return to work after spinal surgery in a nonworkers' compensation population: A retrospective cohort study. *Journal of the American Academy of Orthopaedic Surgeons*. 2017;25(12):e282-e288. doi:10.5435/JAAOS-D-17-00098
5. Singer JD, Willett JB. Applied Longitudinal Data Analysis: Modeling Change and Event Occurrence. *Applied Longitudinal Data Analysis: Modeling Change and Event Occurrence*. Published online September 1, 2003:1-644. doi:10.1093/ACPROF:OSO/9780195152968.001.0001
6. Manwaring JC, Bach K, Ahmadian AA, Deukmedjdjian AR, Smith DA, Uribe JS. Management of sagittal balance in adult spinal deformity with minimally invasive anterolateral lumbar interbody fusion: a preliminary radiographic study: Clinical article. *J Neurosurg Spine*. 2014;20(5):515-522. doi:10.3171/2014.2.SPINE1347

7. Anand N, Rosemann R, Khalsa B, Baron E. Mid-term to long-term clinical and functional outcomes of minimally invasive correction and fusion for adults with scoliosis. *Neurosurg Focus*. 2010;28(3):E6. doi:10.3171/2010.1.FOCUS09272

8. Asher AL, Devin CJ, Archer KR, et al. An analysis from the Quality Outcomes Database, Part 2. Predictive model for return to work after elective surgery for lumbar degenerative disease. *J Neurosurg Spine*. 2017;27(4):370-381. doi:10.3171/2016.8.SPINE16527

9. Macki M, Anand SK, Hamilton T, et al. Analysis of Factors Associated with Return-to-Work after Lumbar Surgery up to 2-Years Follow-up: A Michigan Spine Surgery Improvement Collaborative (MSSIC) Study. *Spine (Phila Pa 1976)*. 2022;47(1):49-58. doi:10.1097/BRS.0000000000004163

10. Anderson PA, Schwaegler PE, Cizek D, Leverson G. Work status as a predictor of surgical outcome of discogenic low back pain. *Spine (Phila Pa 1976)*. 2006;31(21):2510-2515. doi:10.1097/01.BRS.0000239180.14933.B7

11. Lee L, Idris Z, Beng T, et al. Outcomes of minimally invasive surgery compared to open posterior lumbar instrumentation and fusion. *Asian J Neurosurg*. 2017;12(04):620-637. doi:10.4103/AJNS.AJNS_331_16

12. Archer KR, Devin CJ, Vanston SW, et al. Cognitive-Behavioral-Based Physical Therapy for Patients with Chronic Pain Undergoing Lumbar Spine Surgery: A Randomized Controlled Trial. *Journal of Pain*. 2016;17(1):76-89. doi:10.1016/j.jpain.2015.09.013

13. den Boer JJ, Oostendorp RAB, Beems T, Munneke M, Evers AWM. Continued disability and pain after lumbar disc surgery: The role of cognitive-behavioral factors. *Pain*. 2006;123(1-2):45-52. doi:10.1016/J.PAIN.2006.02.008

14. 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 (Phila Pa 1976)*. 2013;38(23):2049-2055. doi:10.1097/BRS.0B013E3182A8212D

15. Park Y, Ha JW. Comparison of one-level posterior lumbar interbody fusion performed with a minimally invasive approach or a traditional open approach. *Spine (Phila Pa 1976)*. 2007;32(5):537-543. doi:10.1097/01.BRS.0000256473.49791.F4

16. Chou D, Mummaneni P, Anand N, et al. Treatment of the Fractional Curve of Adult Scoliosis With Circumferential Minimally Invasive Surgery Versus Traditional, Open Surgery: An Analysis of Surgical Outcomes. doi:10.1177/2192568218775069

17. Cheng JS, Park P, Le H, Reisner L, Chou D, Mummaneni P V. Short-term and long-term outcomes of minimally invasive and open transforaminal lumbar interbody fusions: is there a difference? *Neurosurg Focus*. 2013;35(2):E6. doi:10.3171/2013.5.FOCUS1377

18. Anand N, Cohen JE, Cohen RB, Khandehroo B, Kahwaty S, Baron E. Comparison of a Newer Versus Older Protocol for Circumferential Minimally Invasive Surgical (CMIS) Correction of Adult Spinal Deformity (ASD)—Evolution Over a 10-Year Experience. *Spine Deform*. 2017;5(3):213-223. doi:10.1016/J.JSPD.2016.12.005

Figure 1. X-rays from circumferential minimally-invasive surgery: (A) anteroposterior and (B) lateral preoperative 36-inch radiographs. Patient underwent a lateral L2-L5 interbody fusion, anterior L5-S1 interbody fusion, and minimally-invasive approach to L2-pelvis screw: (C) anteroposterior and (D) lateral postoperative 36-inch radiographs.

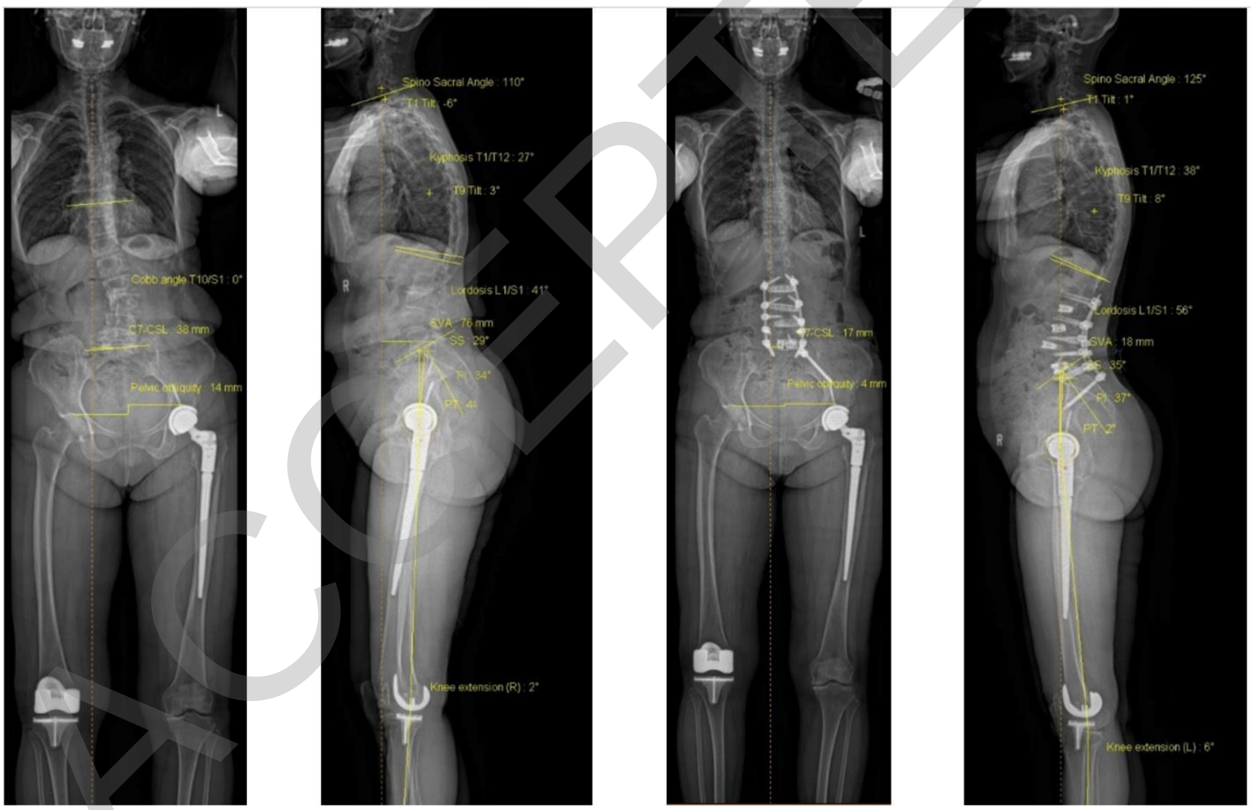

Figure 2. Open surgery preoperative and postoperative X-rays (A) anteroposterior and (B) lateral preoperative 36-inch radiographs. Patient underwent a T10-pelvis, L4 pedicle subtraction osteotomy, transforaminal L1-L2 & L3-L4 interbody fusion. (C) Anteroposterior and (D) lateral postoperative 36-inch radiographs.

Figure 3. Flowchart of return-to-work outcomes in the open versus cMIS cohorts

Working status over time for patients undergoing open versus circumferential minimally-invasive surgery.

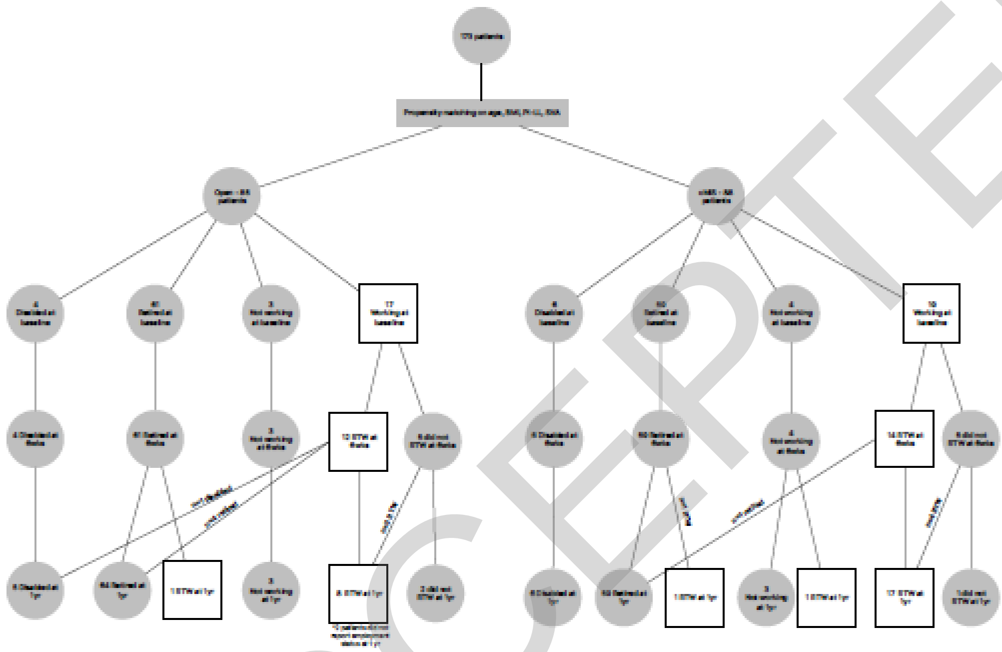

Table 1. Comparisons of the open versus cMIS cohorts

	Open Technique N=85	Circumferential Minimally-Invasive Surgery N=88	P
Age	67.9 ± 1.1	68.5 ± 1.1	MATCHED
Male Gender	29 (34.1%)	26 (29.5%)	0.519
Median American Society of Anesthesiologists (ASA) Classification	3	2	0.171
Decompression	60 (70.5%)	21 (23.8%)	**<0.001**
Median Number of Interbody Fusions			
Anterior	0	1	0.064
Transforaminal	1	0	**<0.001**
Lateral	0	2	**<0.001**
Length of Surgery (minutes)	388.8 ± 14.5	299.2 ± 13.2	**<0.001**
Estimated Blood Loss (mL)	1744.1 ± 212.1	260.2 ± 29.0	**<0.001**
Length of Hospital Stay (days)	8.2 ± 0.5	5.3 ± 0.3	**<0.001**
Return to work			
6 weeks	14.1%	15.9%	0.741
1 year	10.5%	21.5%	**0.049**
2 years	14.1%	19.3%	0.277

Table 2. The (+) denotes the number of patients who returned to work within each category.

Open Cohort (n=85)				
Baseline	Disabled (n=4)	**Working** (n=17)	Retired (n=61)	**Not Working** (n=3)
6 weeks		+12		
1 year		+3	+1	
2 years		+1	+2	
cMIS Cohort (n=88)				
Baseline	Disabled (n=6)	**Working** (n=19)	Retired (n=59)	**Not Working** (n=4)
6 weeks		+14		
1 year		+4	+1	+1
2 years	+1	+1		+1