JNS SPINE

CLINICAL ARTICLE

Does diabetes affect outcome or reoperation rate after lumbar decompression or arthrodesis? A matched analysis of the Quality Outcomes Database data set

Presented at the 2023 AANS/CNS Joint Section on Disorders of the Spine and Peripheral Nerves

James Mooney, MD,[1] Karim Rizwan Nathani, MBBS,[2,3] Daniel Zeitouni, MD,[4,5] Giorgos D. Michalopoulos, MD,[2,3] Michael Y. Wang, MD, MBA,[6] Domagoj Coric, MD,[7] Andrew K. Chan, MD,[8] Daniel C. Lu, MD, PhD,[9] Brandon A. Sherrod, MD,[10] Oren N. Gottfried, MD,[11] Christopher I. Shaffrey, MD,[11] Khoi D. Than, MD,[11] Jacob L. Goldberg, MD,[12] Ibrahim Hussain, MD,[12] Michael S. Virk, MD, PhD,[12] Nitin Agarwal, MD,[24] Steven D. Glassman, MD,[13] Mark E. Shaffrey, MD,[14] Paul Park, MD,[15] Kevin T. Foley, MD,[16] Dean Chou, MD,[8] Jonathan R. Slotkin, MD,[17] Luis M. Tumialán, MD,[18] Cheerag D. Upadhyaya, MD, MBA, MSc,[19] Eric A. Potts, MD,[20] Kai-Ming G. Fu, MD, PhD,[12] Regis W. Haid, MD,[22] John J. Knightly, MD,[23] Praveen V. Mummaneni, MD, MBA,[21] Erica F. Bisson, MD, MPH,[10] Anthony L. Asher, MD,[4] and Mohamad Bydon, MD[2]

[1]Department of Neurosurgery, University of Alabama at Birmingham, Alabama; [2]Department of Neurologic Surgery, Mayo Clinic Neuro-Informatics Laboratory, Mayo Clinic, Rochester, Minnesota; [3]Department of Neurologic Surgery, Mayo Clinic, Rochester, Minnesota; [4]Carolina Neurosurgery and Spine Associates, Charlotte, North Carolina; [5]Department of Neurosurgery, Atrium Health, Charlotte, North Carolina; [6]Department of Neurosurgery, University of Miami, Florida; [7]Neuroscience Institute, Carolina Neurosurgery & Spine Associates, Carolinas Healthcare System, Charlotte, North Carolina; [8]Department of Neurological Surgery, Columbia University, The Och Spine Hospital at NewYork-Presbyterian, New York, New York; [9]Department of Neurosurgery, University of California, Los Angeles, David Geffen School of Medicine, Los Angeles, California; [10]Department of Neurosurgery, Clinical Neurosciences Center, University of Utah, Salt Lake City, Utah; [11]Department of Neurological Surgery, Duke University Medical Center, Durham, North Carolina; [12]Department of Neurological Surgery, Weill Cornell Medical Center, New York, New York; [13]Norton Leatherman Spine Center, Louisville, Kentucky; [14]Department of Neurosurgery, University of Virginia, Charlottesville, Virginia; [15]Department of Neurosurgery, University of Michigan, Ann Arbor, Michigan; [16]Department of Neurosurgery, University of Tennessee, Memphis, Tennessee; [17]Department of Neurosurgery, Geisinger Health, Danville, Pennsylvania; [18]Department of Neurosurgery, Barrow Neurological Institute, St. Joseph's Hospital and Medical Center, Phoenix, Arizona; [19]Department of Neurosurgery, School of Medicine, University of North Carolina, Chapel Hill, North Carolina; [20]Department of Neurological Surgery, Goodman Campbell Brain and Spine, Indianapolis, Indiana; [21]Department of Neurological Surgery, University of California, San Francisco, California; [22]Atlanta Brain and Spine Care, Atlanta, Georgia; [23]Atlantic Neurosurgical Specialists, Morristown, New Jersey; and [24]Department of Neurological Surgery, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania

OBJECTIVE Diabetes mellitus (DM) is a known risk factor for postsurgical and systemic complications after lumbar spinal surgery. Smaller studies have also demonstrated diminished improvements in patient-reported outcomes (PROs), with increased reoperation and readmission rates after lumbar surgery in patients with DM. The authors aimed to examine longer-term PROs in patients with DM undergoing lumbar decompression and/or arthrodesis for degenerative pathology.

METHODS The Quality Outcomes Database was queried for patients undergoing elective lumbar decompression and/or arthrodesis for degenerative pathology. Patients were grouped into DM and non-DM groups and optimally matched in a 1:1 ratio on 31 baseline variables, including the number of operated levels. Outcomes of interest were readmissions and reoperations at 30 and 90 days after surgery in addition to improvements in Oswestry Disability Index, back pain, and leg pain scores and quality-adjusted life-years at 90 days after surgery.

ABBREVIATIONS DM = diabetes mellitus; LOS = length of stay; MCID = minimal clinically important difference; MIS = minimally invasive surgery; NRS = numeric rating scale; ODI = Oswestry Disability Index; PRO = patient-reported outcome; QALY = quality-adjusted life-year; QOD = Quality Outcomes Database.

SUBMITTED May 13, 2023. **ACCEPTED** September 25, 2023.
INCLUDE WHEN CITING Published online December 1, 2023; DOI: 10.3171/2023.9.SPINE23522.

RESULTS The matched decompression cohort comprised 7836 patients (3236 [41.3] females) with a mean age of 63.5 ± 12.6 years, and the matched arthrodesis cohort comprised 7336 patients (3907 [53.3%] females) with a mean age of 64.8 ± 10.3 years. In patients undergoing lumbar decompression, no significant differences in nonroutine discharge, length of stay (LOS), readmissions, reoperations, and PROs were observed. In patients undergoing lumbar arthrodesis, nonroutine discharge (15.7% vs 13.4%, $p < 0.01$), LOS (3.2 ± 2.0 vs 3.0 ± 3.5 days, $p < 0.01$), 30-day (6.5% vs 4.4%, $p < 0.01$) and 90-day (9.1% vs 7.0%, $p < 0.01$) readmission rates, and the 90-day reoperation rate (4.3% vs 3.2%, $p = 0.01$) were all significantly higher in the DM group. For DM patients undergoing lumbar arthrodesis, subgroup analyses demonstrated a significantly higher risk of poor surgical outcomes with the open approach.

CONCLUSIONS Patients with and without DM undergoing lumbar spinal decompression alone have comparable readmission and reoperation rates, while those undergoing arthrodesis procedures have a higher risk of poor surgical outcomes up to 90 days after surgery. Surgeons should target optimal DM control preoperatively, particularly for patients undergoing elective lumbar arthrodesis.

https://thejns.org/doi/abs/10.3171/2023.9.SPINE23522

KEYWORDS lumbar spinal arthrodesis; lumbar spinal decompression; Quality Outcomes Database; patient-reported outcomes; readmission rates; reoperation rates; diabetes mellitus

Diabetes mellitus (DM) is a group of diseases characterized by the inability to regulate blood glucose levels properly. Patients with DM have chronic wound-healing problems due to vascular, neuropathic, and immune abnormalities.[1] Studies that measure the prevalence of diabetes in the United States have found it to be around 9.5%.[2] Because of the prevalence and complications associated with DM, understanding the difficulties it may present in spine surgery is important.

Studies have shown that patients with DM undergoing lumbar spine surgery for degenerative conditions have increased odds of cardiac complications, deep venous thrombosis, reoperation, inpatient mortality, and increased length of stay (LOS).[3,4] While prior studies have reported intra- and postoperative complication and reoperation rates, large studies have not compared patient-reported outcomes (PROs) in patients with and without DM undergoing lumbar decompression or arthrodesis. The aim of this study was to examine for differences in reoperation, readmission rates, and PROs in patients with and without DM undergoing lumbar decompression or arthrodesis.

Methods

Patient Cohort

The lumbar spine module of the Quality Outcomes Database (QOD) was queried for patients undergoing decompression with or without arthrodesis for the degenerative lumbar spine. The QOD is a nationwide quality registry introduced by the NeuroPoint Alliance in 2012.[5] Patients were categorized into DM and non-DM groups based on their preoperative DM type 1 or 2 diagnosis. All patients without at least 90 days of follow-up were excluded from the study.

Outcomes of Interest

The primary outcomes of this study were readmissions and reoperations at 30 and 90 days after surgery. We also examined LOS; nonroutine discharge; improvements in Oswestry Disability Index (ODI), back pain, and leg pain scores; and improvement in quality-adjusted life-years (QALY) at 90 days after surgery. Nonroutine discharge was defined as discharge to a destination other than home. The minimal clinically important difference (MCID) was defined as a 30% improvement of the corresponding score from baseline to follow-up. The 90-day follow-up was chosen as it is considered a "global period" by Medicare health coverage.

Statistical Analysis

Categorical data are presented as frequencies and percentages, and continuous data are presented as means with standard deviations. Multiple model-based imputations were performed to generate replacement values for missing baseline patient-reported data, and the final imputed data were used for our analysis.[6] Each variable had its own imputation model; we used predictive mean matching for continuous data, logistic regression for binary data, and polytomous logistic regression for unordered categorical data. The R package used for the imputation was mice (The R Project for Statistical Computing).[7] The independent Student t-test and Pearson's chi-square test were performed for univariate analyses of continuous and categorical variables, respectively. All statistical analysis was performed in R (version 4.1.1).[8] The results were considered statistically significant at $p < 0.05$.

Optimal Matching

The DM and non-DM groups were matched to create highly homogeneous groups via 1:1 optimal matching. Optimal matching involves matching the patients with respect to their characteristics and is preferable to nearest neighbor matching because it generates greater homogeneity of the overall cohort instead of ideal matching for individual patients.[9]

We performed individual matching of the groups with the optimal algorithm on 31 baseline variables to produce the main cohort of this study. The matched baseline variables included age, sex, BMI, smoking status, comorbidities, number of levels treated, and baseline PRO scores. The standardized mean difference < 0.1 was considered sufficient matching between the study groups.[10] The R package used for matching was MatchIt.[11] The groups were matched and analyzed separately for cases undergoing decompression only and decompression with arthrodesis.

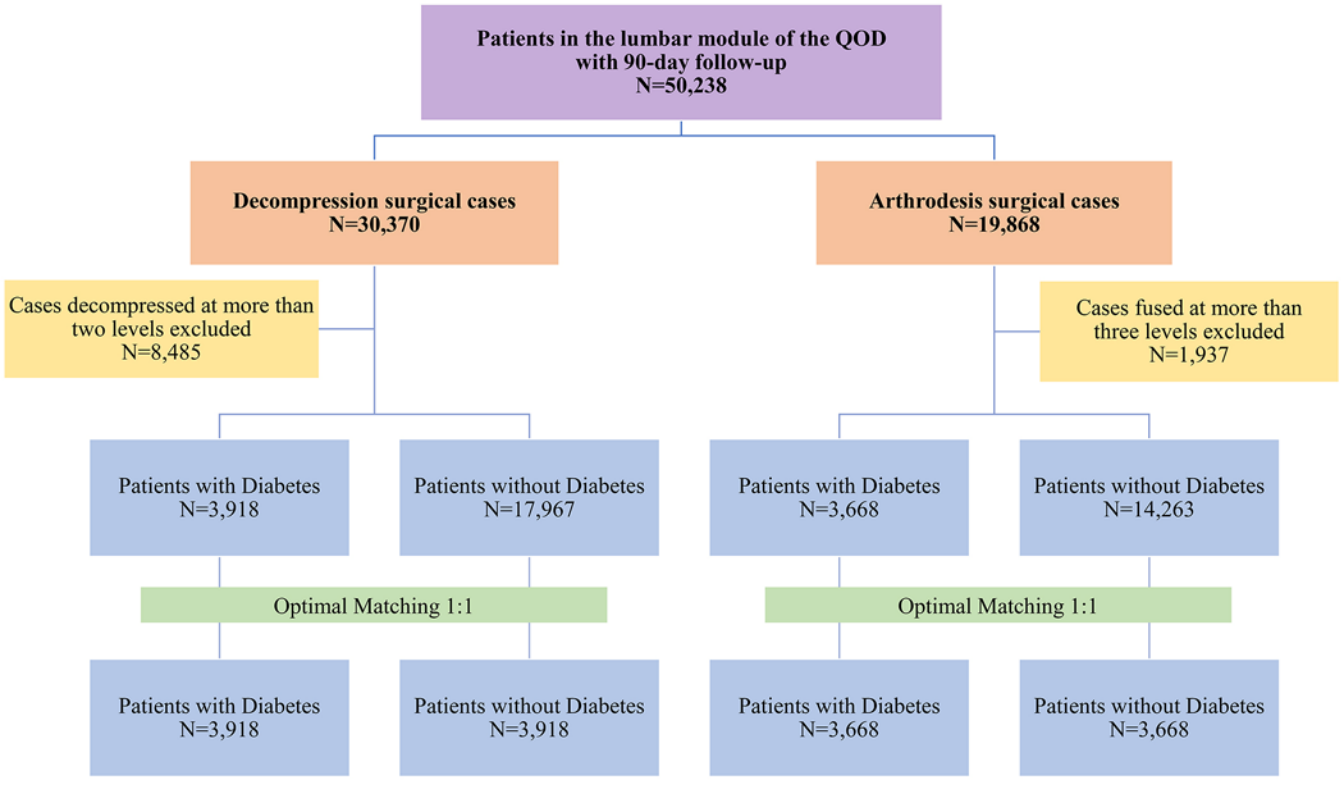

FIG. 1. Flowchart of the filtering process of the total cohort to generate the study cohort. Figure is available in color online only.

Results

Study Cohort

The lumbar module of the QOD database consisted of 50,238 patients with at least 90 days of follow-up; 30,370 patients underwent decompression procedures and 19,868 underwent arthrodesis procedures. Figure 1 demonstrates the filtering process to generate the final study cohort. Among the patients undergoing lumbar decompression at one or two spinal levels, 3918 patients with DM were matched against 3918 patients without DM. Of the patients undergoing lumbar arthrodesis at two or three spinal levels, 3668 DM patients were matched against 3668 non-DM patients. Tables 1 and 2 show the baseline characteristics and postoperative outcomes of the matched cohort for lumbar decompression included in the study. A Cohen's d value < 0.1 for all baseline variables indicated sufficient matching between the two groups. Tables 3 and 4 show the baseline characteristics and postoperative outcomes of the matched cohort for lumbar arthrodesis included in the study.

Lumbar Decompression

As shown in Table 2, no significant differences were observed in the mean LOS between the DM (1.0 ± 6.0 days) and non-DM (0.9 ± 1.4 days) groups undergoing lumbar decompression ($p = 0.26$). Similarly, the two groups were also comparable in nonroutine discharge rates (both 3.0%, $p = 0.95$). At the 30-day follow-up, the readmission and reoperation rates in the DM (6.0% and 1.9%, respectively) and non-DM (5.6% and 2.4%, respectively) groups were not significantly different ($p = 0.36$ and $p = 0.16$, respectively). At the 90-day follow-up, the readmission and reoperation rates in the DM (8.5% and 3.4%, respectively) and non-DM (8.1% and 3.5%, respectively) groups were also not significantly different ($p = 0.54$ and $p = 0.81$, respectively).

At the 90-day follow-up, overall satisfaction was slightly higher in the DM group (86.9% vs 85.7%) but the difference was not significant ($p = 0.11$). The proportions of patients achieving MCID in back and leg pain numeric rating scale (NRS) scores at 90 days were 71.7% and 76.1%, respectively, in the DM group and 71.8% and 75.4%, respectively, in the non-DM group, with no statistical significance ($p = 0.96$ and $p = 0.45$, respectively) in either case. The mean improvement in ODI score was also similar in the DM and non-DM groups (23.2 ± 21.2 vs 23.0 ± 21.2, $p = 0.74$). The proportions of patients achieving MCID in ODI score at 90 days were 67.3% in the DM group and 67.1% in the non-DM group ($p = 0.83$). Similarly, the proportions of patients achieving MCID in QALY scores were comparable in the DM and non-DM groups (53.4% vs 51.2%, $p = 0.05$).

Lumbar Arthrodesis

Although the increase was small, the DM group had a statistically significantly longer mean LOS than the non-DM group (3.2 ± 2.0 vs 3.0 ± 3.5 days, $p < 0.01$), as shown in Table 4. The DM group also had significantly

TABLE 1. Baseline characteristics of the DM and non-DM groups undergoing lumbar decompression following matching

	DM Group (n = 3918)	Non-DM Group (n = 3918)	p Value	Cohen's d
Mean age, yrs (SD)	63.26 (11.80)	63.68 (13.35)	0.138	0.034
Mean BMI (SD)	32.64 (6.39)	32.53 (7.09)	0.466	0.016
Female sex, n (%)	1615 (41.2)	1621 (41.4)	0.909	0.003
Smoking, n (%)	618 (15.8)	626 (16.0)	0.829	0.006
Osteoporosis, n (%)	153 (3.9)	157 (4.0)	0.862	0.005
COPD, n (%)	330 (8.4)	325 (8.3)	0.870	0.005
Depression, n (%)	964 (24.6)	931 (23.8)	0.399	0.02
Anxiety, n (%)	767 (19.6)	726 (18.5)	0.250	0.027
Race, n (%)			0.089	0.05
Black	357 (9.1)	303 (7.7)		
White	3426 (87.4)	3480 (88.8)		
Other	135 (3.4)	135 (3.4)		
Insurance payer, n (%)			0.390	0.046
Medicare	1881 (48.0)	1941 (49.5)		
Medicaid	188 (4.8)	208 (5.3)		
Private	1716 (43.8)	1645 (42.0)		
Uninsured	26 (0.7)	28 (0.7)		
VA/government	107 (2.7)	96 (2.5)		
Workers' compensation, n (%)	101 (2.6)	96 (2.5)	0.773	0.008
Liability claim, n (%)	133 (3.4)	125 (3.2)	0.658	0.011
Unemployed, n (%)	2480 (63.3)	2515 (64.2)	0.424	0.019
ASA class, n (%)			0.756	0.008
I–II	1329 (33.9)	1315 (33.6)		
III–IV	2589 (66.1)	2603 (66.4)		
Dependent ambulation, n (%)	831 (21.2)	765 (19.5)	0.068	0.042
Predominant symptom, n (%)			0.844	0.013
Numbness/tingling	320 (8.2)	310 (7.9)		
Pain	3417 (87.2)	3434 (87.6)		
Weakness	181 (4.6)	174 (4.4)		
Symptom duration <3 mos, n (%)	568 (14.5)	554 (14.1)	0.675	0.01
Disc herniation, n (%)	2011 (51.3)	1927 (49.2)	0.061	0.043
Grade 1 spondylolisthesis, n (%)	291 (7.4)	301 (7.7)	0.700	0.01
Spinal stenosis, n (%)	2344 (59.8)	2488 (63.5)	0.001	0.076
Adjacent-segment disease, n (%)	101 (2.6)	107 (2.7)	0.725	0.01
Mechanical disc collapse, n (%)	8 (0.2)	9 (0.2)	>0.999	0.005
Minimally invasive approach, n (%)	1213 (31.0)	1256 (32.1)	0.307	0.024
Incidental durotomy during op, n (%)	56 (1.4)	57 (1.5)	>0.999	0.002
Levels treated, n (%)			>0.999	<0.001
1	1107 (28.3)	1107 (28.3)		
2	2811 (71.7)	2811 (71.7)		
Mean length of op, mins (SD)	82.35 (40.88)	84.40 (40.54)	0.026	0.05
Mean ODI score at baseline (SD)	48.45 (17.08)	47.65 (17.32)	0.041	0.046
Mean back pain NRS score at baseline (SD)	6.73 (2.72)	6.63 (2.74)	0.111	0.036
Mean leg pain NRS score at baseline (SD)	7.09 (2.64)	7.04 (2.59)	0.342	0.021
Mean QALY score at baseline (SD)	0.52 (0.22)	0.53 (0.22)	0.084	0.039

ASA = American Society of Anesthesiologists; COPD = chronic obstructive pulmonary disease; VA = Veterans Affairs.
Sufficient matching is documented by Cohen's d values < 0.1.

TABLE 2. Comparison of postoperative outcomes after lumbar decompression between the DM and non-DM cohorts following matching on baseline characteristics

	DM Group (n = 3918)	Non-DM Group (n = 3918)	p Value
Mean LOS, days (SD)	1.0 (6.0)	0.9 (1.4)	0.262
Nonroutine discharge, n (%)	118 (3.0)	119 (3.0)	0.947
30-day readmission, n (%)	237 (6.0)	218 (5.6)	0.359
30-day reop, n (%)	74 (1.9)	92 (2.3)	0.163
90-day readmission, n (%)	332 (8.5)	317 (8.1)	0.539
90-day reop, n (%)	134 (3.4)	138 (3.5)	0.805
Satisfaction (NASS score 1 or 2) at 90 days, n (%)	3406 (86.9)	3357 (85.7)	0.107
Mean improvement in ODI score at 90 days (SD)	23.2 (21.2)	23.0 (21.2)	0.743
MCID in ODI score at 90 days, n (%)	2637 (67.3)	2628 (67.1)	0.829
Mean improvement in leg pain NRS score at 90 days (SD)	4.4 (3.7)	4.4 (3.6)	0.270
MCID in leg pain NRS score at 90 days, n (%)	2982 (76.1)	2953 (75.4)	0.445
Mean improvement in back pain NRS score at 90 days (SD)	3.7 (3.4)	3.6 (3.3)	0.247
MCID in back pain NRS score at 90 days, n (%)	2810 (71.7)	2812 (71.8)	0.960
Mean improvement in QALY score at 90 days (SD)	0.2 (0.3)	0.2 (0.3)	0.210
MCID in QALY score at 90 days, n (%)	2091 (53.4)	2005 (51.2)	0.052

NASS = North American Spine Society.

higher nonroutine discharge rates than the non-DM group (15.7% and 13.4%, $p < 0.01$). At the 30-day follow-up, the readmission rate was significantly higher in the DM group than in the non-DM group (6.5% vs 4.4%, $p < 0.01$). The 30-day reoperation rate was higher in the DM group than in the non-DM group (3.2% vs 2.5%, $p = 0.07$), with the difference being insignificant, though trending toward significance. Additionally, at the 90-day follow-up, the DM group had significantly higher readmission (9.1% vs 7.0%, $p < 0.01$) and reoperation (4.3% vs 3.2%, $p = 0.01$) rates than the non-DM group.

At the 90-day follow-up, overall satisfaction was significantly lower in the DM versus the non-DM group (87.2% vs 88.8%, $p = 0.04$). The proportions of patients achieving MCID in back and leg pain NRS scores at 90 days were 71.8% and 74.5%, respectively, in the DM group and 72.7% and 76.3%, respectively, in non-DM group with no statistical significance ($p = 0.39$ and $p = 0.06$, respectively) in either case. However, the DM group had significantly lower improvement in leg pain NRS score (4.1 ± 3.7 vs 4.4 ± 3.6, $p < 0.01$) than the non-DM group. The mean improvement in ODI score was also significantly lower in the DM versus the non-DM group (19.4 ± 19.1 vs 20.8 ± 18.6, $p < 0.01$). The proportions of patients achieving MCID in ODI score at 90 days were 60.2% in the DM group and 62.9% in the non-DM group ($p = 0.02$). Additionally, the MCID in QALY scores was achieved by 52.8% of patients in the DM group compared with 53.3% in the non-DM group, with the difference being insignificant ($p = 0.62$).

Minimally Invasive Surgery and Open Approaches

Surgical outcomes were examined based on minimally invasive surgery (MIS) or open surgical approach, as shown in Table 5. The surgical approach did not demonstrate any significant effect on the outcomes of DM patients for lumbar decompression. For lumbar arthrodesis, DM patients undergoing an open approach had a significantly higher odds of poor surgical outcomes, including nonroutine discharge (OR 1.19 [95% CI 1.03–1.36], $p = 0.02$), 30-day readmission (OR 1.50 [95% CI 1.20–1.87], $p < 0.01$), 30-day reoperation (OR 1.40 [95% CI 1.03–1.89], $p = 0.03$), 90-day readmission (OR 1.33 [95% CI 1.11–1.59], $p < 0.01$), and 90-day reoperation (OR 1.44 [95% CI 1.10–1.88], $p < 0.01$) compared with non-DM patients.

Single- and Multilevel Surgeries

Surgical outcomes were examined in subgroups determined based on one- or two-level surgery, as shown in Table 6. For lumbar decompression, DM patients undergoing one-level decompression were at a significantly higher risk for 30-day readmission (6.3% vs 4.4%, OR 1.46 [95% CI 1.00–2.12], $p = 0.048$) compared with non-DM patients. For lumbar arthrodesis, DM patients undergoing two-level arthrodesis were at a significantly higher risk for 30-day readmission (5.8% vs 3.8%, OR 1.54 [95% CI 1.18–2.00], $p < 0.01$]) and 90-day readmission (8.4% vs 6.3%, OR 1.37 [95% CI 1.11–1.70], $p < 0.01$) than non-DM patients. DM patients undergoing three-level arthrodesis had a significantly higher rate of nonroutine discharge (22.0% vs 16.6%, OR 1.41 [95% CI 1.14–1.74], $p < 0.01$), 30-day readmission (8.3% vs 5.8%, OR 1.48 [95% CI 1.07–2.05], $p = 0.02$), and 90-day reoperation (5.0% vs 3.3%, OR 1.56 [95% CI 1.02–2.38], $p = 0.04$) than non-DM patients.

Discussion

DM presents a significant public health challenge, accounting for more than $150 billion in direct medical costs.[12,13] DM has been associated with an increased incidence of infectious and noninfectious complications, nonroutine discharge, and greater LOS across multiple surgical subspecialties including orthopedic, general, gy-

TABLE 3. Baseline characteristics of DM and non-DM groups undergoing lumbar arthrodesis following matching

	DM Group (n = 3668)	Non-DM Group (n = 3668)	p Value	Cohen's d
Mean age, yrs (SD)	64.71 (9.76)	64.88 (10.81)	0.474	0.017
Mean BMI (SD)	33.24 (6.40)	33.11 (6.72)	0.403	0.020
Female sex, n (%)	1959 (53.4)	1948 (53.1)	0.815	0.006
Smoking, n (%)	393 (10.7)	411 (11.2)	0.525	0.016
Osteoporosis, n (%)	202 (5.5)	211 (5.8)	0.685	0.011
COPD, n (%)	358 (9.8)	360 (9.8)	0.969	0.002
Depression, n (%)	1030 (28.1)	1049 (28.6)	0.641	0.011
Anxiety, n (%)	723 (19.7)	668 (18.2)	0.108	0.038
Race, n (%)			0.289	0.037
Black	361 (9.8)	322 (8.8)		
White	3183 (86.8)	3223 (87.9)		
Other	124 (3.4)	123 (3.4)		
Insurance payer, n (%)			0.98	0.015
Medicare	2023 (55.2)	2027 (55.3)		
Medicaid	167 (4.6)	171 (4.7)		
Private	1339 (36.5)	1341 (36.6)		
Uninsured	16 (0.4)	15 (0.4)		
VA/government	123 (3.4)	114 (3.1)		
Workers' compensation, n (%)	79 (2.2)	77 (2.1)	0.935	0.004
Liability claim, n (%)	174 (4.7)	171 (4.7)	0.912	0.004
Unemployed, n (%)	2670 (72.8)	2649 (72.2)	0.601	0.013
ASA class, n (%)			0.957	0.002
I or II	934 (25.5)	931 (25.4)		
III or IV	2734 (74.5)	2737 (74.6)		
Dependent ambulation, n (%)	820 (22.4)	754 (20.6)	0.065	0.044
Predominant symptom, n (%)			0.834	0.014
Numbness/tingling	216 (5.9)	212 (5.8)		
Pain	3343 (91.1)	3355 (91.5)		
Weakness	109 (3.0)	101 (2.8)		
Symptom duration <3 mos, n (%)	133 (3.6)	151 (4.1)	0.304	0.025
Disc herniation, n (%)	734 (20.0)	762 (20.8)	0.434	0.019
Grade 1 spondylolisthesis, n (%)	1978 (53.9)	1907 (52.0)	0.102	0.039
Spinal stenosis, n (%)	2323 (63.3)	2307 (62.9)	0.717	0.009
Adjacent-segment disease, n (%)	478 (13.0)	482 (13.1)	0.917	0.003
Mechanical disc collapse, n (%)	65 (1.8)	53 (1.4)	0.307	0.026
Minimally invasive approach, n (%)	540 (14.7)	614 (16.7)	0.019	0.055
Incidental durotomy during surgery, n (%)	50 (1.4)	46 (1.3)	0.758	0.010
Levels treated, n (%)			0.062	0.044
2	2534 (69.1)	2538 (69.2)		
3	1134 (30.9)	1130 (30.8)		
Mean length of op, mins (SD)	177.21 (76.26)	175.68 (77.05)	0.393	0.020
Mean ODI score at baseline (SD)	48.95 (15.75)	49.22 (15.36)	0.464	0.017
Mean back pain NRS score at baseline (SD)	7.22 (2.37)	7.24 (2.39)	0.772	0.007
Mean leg pain NRS score at baseline (SD)	6.86 (2.69)	6.92 (2.68)	0.346	0.022
Mean QALY score at baseline (SD)	0.51 (0.21)	0.51 (0.21)	0.919	0.002

Sufficient matching is documented by Cohen's d values < 0.1.

TABLE 4. Comparison of postoperative outcomes after lumbar arthrodesis between the DM and non-DM groups following matching on baseline characteristics

	DM Group (n = 3668)	Non-DM Group (n = 3668)	p Value
Mean LOS, days (SD)	3.2 (2.0)	3.0 (3.5)	**0.008**
Nonroutine discharge, n (%)	577 (15.7)	492 (13.4)	**0.005**
30-day readmissions, n (%)	240 (6.5)	162 (4.4)	**<0.001**
30-day reoperations, n (%)	117 (3.2)	91 (2.5)	0.068
90-day readmissions, n (%)	332 (9.1)	257 (7.0)	**0.001**
90-day reoperations, n (%)	156 (4.3)	116 (3.2)	**0.013**
Satisfaction (NASS score 1 or 2) at 90 days, n (%)	3200 (87.2)	3257 (88.8)	**0.040**
Mean improvement in ODI score at 90 days (SD)	19.4 (19.1)	20.8 (18.6)	**<0.001**
MCID in ODI score at 90 days, n (%)	2207 (60.2)	2307 (62.9)	**0.016**
Mean improvement in leg pain NRS score at 90 days (SD)	4.1 (3.7)	4.4 (3.6)	**0.006**
MCID in leg pain NRS score at 90 days, n (%)	2731 (74.5)	2800 (76.3)	0.061
Mean improvement in back pain NRS score at 90 days (SD)	3.8 (3.1)	3.9 (3.1)	0.429
MCID in back pain NRS score at 90 days, n (%)	2635 (71.8)	2668 (72.7)	0.389
Mean improvement in QALY score at 90 days (SD)	0.2 (0.2)	0.2 (0.2)	0.454
MCID in QALY score at 90 days, n (%)	1935 (52.8)	1956 (53.3)	0.623

Boldface type indicates statistical significance.

necological, cardiothoracic, and neurological surgery.[14–18] Prior studies have also examined the effects of DM on postoperative complications after spinal procedures, while fewer have specifically investigated surgical and patient-specific outcomes after lumbar spinal procedures in diabetic patients. Although studies have examined lumbar decompression and arthrodesis categories separately, the present study is the largest to compare outcomes directly in these separate cohorts of DM patients. Additionally, this is the largest matched study examining PROs in DM and non-DM patients undergoing lumbar decompression or decompression with arthrodesis.

In general, prior literature has reported a higher rate of complications including cardiac complications, venous thrombosis, pulmonary thromboembolism, surgical site infection, need for transfusion, pneumonia, in-hospital mortality, nonroutine discharge, and greater LOS in diabetic patients undergoing lumbar spinal surgery.[3,19–24] Examining lumbar arthrodesis procedures specifically, Arrighi-Allisan et al. reported that DM was a predictor of longer overall LOS, ICU stay, and higher nonroutine discharge and 30-day and 90-day readmission rates.[19] Zhuang et al., using a national claims database with more than 46,000 patients, reported that uncontrolled DM was associated with a higher odds of deep surgical site infection, cerebrovascular accident, acute kidney injury, pulmonary thromboembolism, pneumonia, urinary tract infection, and transfusion.[24] Taree et al. examined factors predictive for readmission at 30 and 90 days after posterior lumbar arthrodesis and found that DM was a strong predictor in addition to liver disease, obesity, and Medicaid status.[25]

Our study observed differences in the influence of DM on outcomes between lumbar arthrodesis and decompression surgeries. While patients with DM undergoing decompression surgery exhibited comparable readmission and reoperation rates when compared with the control group, significant differences were reported in the context of arthrodesis procedures. Our findings demonstrated that patients with DM undergoing lumbar arthrodesis faced a higher risk of poor surgical outcomes. These results indicate that the impact of DM on surgical outcomes may be more pronounced in the case of arthrodesis procedures compared with decompression surgeries. This differential effect could be attributed to the more complex nature of arthrodesis surgeries, which involve a greater degree of tissue manipulation and instrumentation.[20,21,26] Moreover, the inherent challenges of diabetes-related wound healing and susceptibility to infections may be exacerbated in the context of arthrodesis procedures.[20,21,26]

In patients undergoing lumbar arthrodesis procedures, the present study found that patients with DM have a significantly longer LOS with higher 30-day and 90-day reoperation rates than non-DM patients. In contrast, Kim et al. did not report any increase in risk of reoperation in diabetic patients after lumbar arthrodesis for either short- or long-term follow-up up to 5 years.[27] However, Wang et al. found diabetic patients to have a significantly higher risk of reoperation after lumbar arthrodesis at the 90-day follow-up but not at long-term follow-up.[28] It is possible that the larger incisions and tissue manipulation required for lumbar arthrodesis amplify postsurgical complications, including infection and wound healing in DM patients, resulting in a higher short-term reoperation rate. Additionally, hardware complications may be greater in diabetic patients due to poor blood supply and a higher rate of pseudarthrosis.[29] Impaired wound healing has been widely reported with DM and can lead to poor surgical outcomes. However, it is important to note that the indications for readmission and reoperation cannot be sufficiently analyzed for the impact of preoperative DM between the two groups due to the low granularity of the data set and the relatively small number of cases available for analysis.

TABLE 5. Comparison of ORs of surgical outcomes between the DM and non-DM groups according to MIS and open approaches for lumbar decompression and arthrodesis

	Lumbar Decompression			
	DM Group	Non-DM Group	OR (95% CI)	p Value
Nonroutine discharge				
Overall	118 (3.0)	119 (3.0)	0.99 (0.77–1.28)	0.947
MIS	34 (2.8)	21 (1.7)	1.70 (0.98–2.94)	0.057
Open	84 (3.1)	98 (3.7)	0.84 (0.62–1.13)	0.244
30-day readmission				
Overall	237 (6.0)	218 (5.6)	1.09 (0.90–1.32)	0.359
MIS	61 (5.0)	70 (5.6)	0.90 (0.63–1.28)	0.546
Open	176 (6.5)	148 (5.6)	1.18 (0.94–1.48)	0.145
30-day reop				
Overall	74 (1.9)	92 (2.4)	0.80 (0.59–1.09)	0.163
MIS	25 (2.1)	26 (2.1)	1.00 (0.57–1.74)	0.992
Open	49 (1.8)	66 (2.5)	0.73 (0.50–1.06)	0.094
90-day readmission				
Overall	332 (8.5)	317 (8.1)	1.05 (0.90–1.24)	0.539
MIS	94 (7.7)	100 (8.0)	0.97 (0.72–1.30)	0.845
Open	238 (8.8)	217 (8.2)	1.09 (0.90–1.32)	0.395
90-day reop				
Overall	134 (3.4)	138 (3.5)	0.97 (0.76–1.24)	0.805
MIS	43 (3.5)	43 (3.4)	1.04 (0.67–1.59)	0.869
Open	91 (3.4)	95 (3.6)	0.94 (0.70–1.26)	0.682
	Lumbar Arthrodesis			
	DM Group	Non-DM Group	OR (95% CI)	p Value
Nonroutine discharge				
Overall	577 (15.7)	492 (13.4)	1.21 (1.06–1.37)	**0.005**
MIS	64 (11.9)	59 (9.6)	1.26 (0.87–1.84)	0.218
Open	513 (16.4)	433 (14.2)	1.19 (1.03–1.36)	**0.015**
30-day readmission				
Overall	240 (6.5)	162 (4.4)	1.52 (1.23–1.86)	**<0.001**
MIS	34 (6.3)	25 (4.1)	1.58 (0.93–2.69)	0.087
Open	206 (6.6)	137 (4.5)	1.50 (1.20–1.87)	**<0.001**
30-day reop				
Overall	117 (3.2)	91 (2.5)	1.29 (0.98–1.71)	0.078
MIS	12 (2.2)	17 (2.8)	0.80 (0.38–1.69)	0.578
Open	105 (3.4)	74 (2.4)	1.40 (1.03–1.89)	**0.029**
90-day readmission				
Overall	332 (9.1)	257 (7.0)	1.32 (1.11–1.57)	**0.001**
MIS	40 (7.4)	37 (6.0)	1.25 (0.79–1.98)	0.348
Open	292 (9.3)	220 (7.2)	1.33 (1.11–1.59)	**0.002**
90-day reop				
Overall	156 (4.3)	116 (3.2)	1.36 (1.06–1.74)	**0.013**
MIS	19 (3.5)	22 (3.6)	0.98 (0.53–1.83)	0.953
Open	137 (4.4)	94 (3.1)	1.44 (1.10–1.88)	**0.007**

Values are presented as the number of patients (%) unless stated otherwise. Boldface type indicates statistical significance.

When examining patients undergoing decompression-only procedures, the present study found no significant differences in LOS, reoperation, or readmission rates between DM and non-DM patients. These findings suggest that DM may influence surgical outcomes more greatly after lumbar spinal arthrodesis compared with decompression-only procedures. Prior studies examining lumbar decompression-only procedures in DM patients have re-

TABLE 6. Comparison of ORs of surgical outcomes between the DM and non-DM groups according to the spinal levels treated for lumbar decompression and arthrodesis

	Lumbar Decompression			
	DM Group	Non-DM Group	OR (95% CI)	p Value
Nonroutine discharge				
Overall	118 (3.0)	119 (3.0)	0.99 (0.77–1.28)	0.947
1-level	26 (2.3)	21 (1.9)	1.24 (0.70–2.22)	0.461
2-level	92 (3.3)	98 (3.5)	0.94 (0.70–1.25)	0.658
30-day readmission				
Overall	237 (6.0)	218 (5.6)	1.09 (0.90–1.32)	0.359
1-level	70 (6.3)	49 (4.4)	1.46 (1.00–2.12)	**0.048**
2-level	167 (5.9)	169 (6.0)	0.99 (0.79–1.23)	0.910
30-day reop				
Overall	74 (1.9)	92 (2.3)	0.80 (0.59–1.09)	0.163
1-level	23 (2.1)	26 (2.3)	0.88 (0.50–1.56)	0.665
2-level	51 (1.8)	66 (2.3)	0.77 (0.53–1.12)	0.167
90-day readmission				
Overall	332 (8.5)	317 (8.1)	1.05 (0.90–1.24)	0.539
1-level	99 (8.9)	85 (7.7)	1.18 (0.87–1.60)	0.281
2-level	233 (8.3)	232 (8.3)	1.00 (0.83–1.21)	0.961
90-day reop				
Overall	134 (3.4)	138 (3.5)	0.97 (0.76–1.24)	0.805
1-level	40 (3.6)	43 (3.9)	0.93 (0.60–1.44)	0.737
2-level	94 (3.3)	95 (3.4)	0.99 (0.74–1.32)	0.941
	Lumbar Arthrodesis			
	DM Group	Non-DM Group	OR (95% CI)	p Value
Nonroutine discharge				
Overall	577 (15.7)	492 (13.4)	1.21 (1.06–1.37)	**0.005**
2-level	328 (12.9)	304 (12.0)	1.09 (0.92–1.29)	0.298
3-level	249 (22.0)	188 (16.6)	1.41 (1.14–1.74)	**0.001**
30-day readmission				
Overall	240 (6.5)	162 (4.4)	1.52 (1.23–1.86)	**<0.001**
2-level	146 (5.8)	97 (3.8)	1.54 (1.18–2.00)	**0.001**
3-level	94 (8.3)	65 (5.8)	1.48 (1.07–2.05)	**0.018**
30-day reop				
Overall	117 (3.2)	91 (2.5)	1.29 (0.98–1.71)	0.078
2-level	75 (3.0)	65 (2.6)	1.16 (0.83–1.62)	0.441
3-level	42 (3.7)	26 (2.3)	1.63 (1.00–2.68)	0.050
90-day readmission				
Overall	332 (9.1)	257 (7.0)	1.32 (1.11–1.57)	**0.001**
2-level	213 (8.4)	159 (6.3)	1.37 (1.11–1.70)	**0.003**
3-level	119 (10.5)	98 (8.7)	1.23 (0.93–1.64)	0.141
90-day reop				
Overall	156 (4.3)	116 (3.2)	1.36 (1.06–1.74)	**0.013**
2-level	99 (3.9)	79 (3.1)	1.27 (0.94–1.71)	0.124
3-level	57 (5.0)	37 (3.3)	1.56 (1.02–2.38)	**0.037**

Values are presented as the number of patients (%) unless stated otherwise. Boldface type indicates statistical significance.

ported mixed findings. Contrary to the present study, Kim et al. reported that DM did not affect reoperation rates after lumbar arthrodesis procedures but did affect these rates after lumbar decompression procedures at 3 months to 5 years postoperatively.[27] In contrast, Cinotti et al. reported similarly favorable surgical outcomes in DM and non-DM patients undergoing lumbar decompression.[30] However, several other studies have reported a higher risk of deep

surgical site infection requiring surgery, a higher risk of postoperative persistent numbness, and increased revision and complication rates in DM patients undergoing lumbar decompression only.[31–33]

Examining PROs in the present study, DM patients undergoing decompression-only procedures were noted to have similar ODI and VAS back and leg pain improvements to non-DM patients. Several prior smaller studies have examined PROs in DM and non-DM patients. Silverstein et al. found that DM independently predicted diminished quality of life improvement on the EQ-5D and Pain Disability Questionnaire scales after lumbar decompression.[34] Contrary to the findings in our study, examining DM and non-DM patients undergoing lumbar arthrodesis, Khan et al. found no differences in clinical outcomes or reoperation or complication rates.[35] However, others have noted higher ODI scores in DM patients undergoing arthrodesis with lower arthrodesis rates[36] as well as higher final visual analog scale scores.[37]

The current study suggested limited impact of one- or two-level lumbar decompression on outcomes of DM patients. However, the effect of the number of levels was more pronounced in the DM patients undergoing lumbar arthrodesis. The current evidence is scarce for studies reporting on the association between levels operated and surgical outcomes in DM patients. Examining patients undergoing single-level lumbar discectomy, Smith et al. reported a significantly higher risk of reoperation in DM patients, which was in contrast to the observation in this study.[38] The low number of cases available for subgroup analyses for single- and multilevel procedures limits the statistical power and ability to detect significant differences.

Interestingly, prior literature has suggested a specific benefit of MIS for DM patients undergoing lumbar surgery. Regev et al. found an equivalent LOS as well as complication and revision rates in DM and non-DM patients undergoing MIS lumbar decompression,[39] while Senker et al. noted a similar complication rate in DM and non-DM patients undergoing MIS lumbar arthrodesis.[40] Hathi et al. reported that MIS approaches were associated with more favorable outcomes for DM patients undergoing lumbar decompression with arthrodesis.[41] Narain et al. also suggested that reduced operative exposure and tissue trauma after MIS lumbar arthrodesis may mitigate the risk of DM-related complications, reducing LOS and hospital costs.[42] The results of the current study support these prior findings, as DM patients were found to have a greater odds of nonroutine discharge, readmission, and reoperation following open lumbar arthrodesis. However, the effect of DM on surgical outcomes was not observed for lumbar arthrodesis with the MIS approach. The DM patients undergoing MIS decompression-only procedures were noted to have similar surgical outcomes to those of non-DM patients. Thus, further prospective study examining the topic of MIS in diabetic patients is necessary.

Overall, the present study confirms that DM influences outcomes after lumbar surgery and may more greatly affect patients specifically undergoing lumbar arthrodesis procedures. DM often presents with a spectrum of cardiovascular comorbidities, including hypertension, dyslipidemia, and ischemic heart disease, which collectively influence surgical outcomes. Interventions, such as prehabilitation and enhanced recovery after surgery programs, may provide a more holistic approach to reducing risks of complications and optimizing surgical outcomes. Further research is necessary to determine additional factors, such as DM control, associated complications, and target A1c or blood glucose level, in patients undergoing lumbar decompression or arthrodesis procedures. Additionally, a prior study demonstrated that some patients with high preoperative A1c levels may achieve greater reductions in these levels after surgical intervention through restoration to a more functional activity level when compared with medical management alone.[43] Thus, surgical decisions must be made on a case-by-case basis examining individual patient goals. However, surgeons should use the present data to counsel patients preoperatively on the potential effects of DM and inadequate blood glucose control on postoperative complications and need for surgical revision after lumbar decompression and arthrodesis procedures.

Limitations

The limitations and weaknesses inherent in the current study have implications for its interpretation. First, this was an observational study, and patients were not randomized. Although we used optimal matching to reduce potential selection bias and the effect of confounders, it is possible that variables not collected and adjusted for could have affected the results. This is an inherent limitation of observational studies. Second, our length of follow-up was 90 days, which limits our ability to comment on the long-term comparative outcomes in DM and non-DM patients undergoing lumbar decompression with or without arthrodesis. Additionally, the study aggregated patients with DM types 1 and 2 together. The two subtypes exhibit distinct pathophysiologies, and separately analyzing them could have offered valuable insights.

Additionally, the determination of patient DM status was performed by retrospectively examining the prerecorded comorbidity QOD variables. Further details regarding DM control, medications, and other comorbidities, such as hypertension, were not available in the study data set. These unmeasured confounders may have introduced biases that could affect the interpretation as they were not matched between the groups. Additionally, the subgroup analyses of the current study are limited by the few numbers of cases in each subgroup, particularly in the lumbar decompression-only group. Thus, only trends toward poor surgical outcomes associated with open versus MIS approaches and multilevel surgery could be reported. Lastly, the low number of cases reporting indications for readmission and reoperation limits detailed and granular evaluation of these complications. Future systematic research with more granular data should seek to focus on specific complications in patient subgroups undergoing lumbar decompression or arthrodesis procedures.

Conclusions

Patients with DM undergoing lumbar spinal arthrodesis demonstrated longer LOS and higher nonroutine dis-

charge and reoperation rates at 30 and 90 days. Patients with DM undergoing lumbar decompression alone had readmission and reoperation rates up to 90 days after surgery that were comparable to those of patients without DM but demonstrated diminished ODI score improvements. Further systematic research is necessary to determine the optimal glucose control prior to lumbar surgery; however, surgeons should counsel patients on the potential influence of DM on postsurgical outcomes, specifically after lumbar spinal arthrodesis.

Acknowledgments

This research was supported by the NeuroPoint Alliance (NPA), the Neurosurgery Research & Education Foundation (NREF), and the American Association of Neurological Surgeons (AANS)/Congress of Neurological Surgeons (CNS) Joint Section on Disorders of the Spine and Peripheral Nerves (Spine Section). The NPA is a 501(c)(6) affiliate nonprofit organization of the AANS dedicated to the improvement of the quality of care in neurosurgical practice via the institution of national quality registries, such as the one utilized for this study. The NREF is the philanthropic arm of the AANS and has financially supported the creation and maintenance of the QOD. The Spine Section is a neurosurgical community aiming at advancing spine and peripheral nerve patient care through education, research, and advocacy.

References

1. Greenhalgh DG. Wound healing and diabetes mellitus. *Clin Plast Surg*. 2003;30(1):37-45.
2. Bullard KM, Cowie CC, Lessem SE, et al. Prevalence of diagnosed diabetes in adults by diabetes type—United States, 2016. *MMWR Morb Mortal Wkly Rep*. 2018;67(12):359-361.
3. Guzman JZ, Iatridis JC, Skovrlj B, et al. Outcomes and complications of diabetes mellitus on patients undergoing degenerative lumbar spine surgery. *Spine (Phila Pa 1976)*. 2014; 39(19):1596-1604.
4. Luo M, Cao Q, Wang D, et al. The impact of diabetes on postoperative outcomes following spine surgery: a meta-analysis of 40 cohort studies with 2.9 million participants. *Int J Surg*. 2022;104:106789.
5. Asher AL, Knightly J, Mummaneni PV, et al. Quality Outcomes Database Spine Care Project 2012-2020: milestones achieved in a collaborative North American outcomes registry to advance value-based spine care and evolution to the American Spine Registry. *Neurosurg Focus*. 2020;48(5):E2.
6. Li P, Stuart EA, Allison DB. Multiple imputation: a flexible tool for handling missing data. *JAMA*. 2015;314(18):1966-1967.
7. van Buuren S, Groothuis-Oudshoorn K. mice: Multivariate Imputation by Chained Equations in R. *J Stat Softw*. 2011; 45(3):1-67.
8. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing; 2013. Accessed October 11, 2023. http://www.R-project.org/
9. Stuart EA. Matching methods for causal inference: a review and a look forward. *Stat Sci*. 2010;25(1):1-21.
10. Fortin SP, Johnston SS, Schuemie MJ. Applied comparison of large-scale propensity score matching and cardinality matching for causal inference in observational research. *BMC Med Res Methodol*. 2021;21(1):109.
11. Ho D, Imai K, King G, Stuart EA. MatchIt: nonparametric preprocessing for parametric causal inference. *J Stat Softw*. 2011;42(8):1-28.
12. National Diabetes Statistics Report. Centers for Disease Control and Prevention. Accessed October 3, 2022. https://www.cdc.gov/diabetes/data/statistics-report/index.html
13. Dall TM, Zhang Y, Chen YJ, Quick WW, Yang WG, Fogli J. The economic burden of diabetes. *Health Aff (Millwood)*. 2010;29(2):297-303.
14. Hogan C, Bucknell AL, King KB. The effect of diabetes mellitus on total joint arthroplasty outcomes. *JBJS Rev*. 2016; 4(2):e3.
15. Wukich DK, Lowery NJ, McMillen RL, Frykberg RG. Postoperative infection rates in foot and ankle surgery: a comparison of patients with and without diabetes mellitus. *J Bone Joint Surg Am*. 2010;92(2):287-295.
16. Latham R, Lancaster AD, Covington JF, Pirolo JS, Thomas CS Jr. The association of diabetes and glucose control with surgical-site infections among cardiothoracic surgery patients. *Infect Control Hosp Epidemiol*. 2001;22(10):607-612.
17. Malone DL, Genuit T, Tracy JK, Gannon C, Napolitano LM. Surgical site infections: reanalysis of risk factors. *J Surg Res*. 2002;103(1):89-95.
18. Martin ET, Kaye KS, Knott C, et al. Diabetes and risk of surgical site infection: a systematic review and meta-analysis. *Infect Control Hosp Epidemiol*. 2016;37(1):88-99.
19. Arrighi-Allisan AE, Neifert SN, Gal JS, et al. Diabetes is predictive of postoperative outcomes and readmission following posterior lumbar fusion. *Global Spine J*. 2022;12(2):229-236.
20. Browne JA, Cook C, Pietrobon R, Bethel MA, Richardson WJ. Diabetes and early postoperative outcomes following lumbar fusion. *Spine (Phila Pa 1976)*. 2007;32(20):2214-2219.
21. Glassman SD, Alegre G, Carreon L, Dimar JR, Johnson JR. Perioperative complications of lumbar instrumentation and fusion in patients with diabetes mellitus. *Spine J*. 2003;3(6): 496-501.
22. Golinvaux NS, Varthi AG, Bohl DD, Basques BA, Grauer JN. Complication rates following elective lumbar fusion in patients with diabetes: insulin dependence makes the difference. *Spine (Phila Pa 1976)*. 2014;39(21):1809-1816.
23. He X, Fei Q, Sun T. Metabolic syndrome increases risk for perioperative outcomes following posterior lumbar interbody fusion. *Medicine (Baltimore)*. 2020;99(38):e21786.
24. Zhuang T, Feng AY, Shapiro LM, Hu SS, Gardner M, Kamal RN. Is uncontrolled diabetes mellitus associated with incidence of complications after posterior instrumented lumbar fusion? A national claims database analysis. *Clin Orthop Relat Res*. 2021;479(12):2726-2733.
25. Taree A, Mikhail CM, Markowitz J, et al. Risk factors for 30- and 90-day readmissions due to surgical site infection following posterior lumbar fusion. *Clin Spine Surg*. 2021;34(4): E216-E222.
26. Khan SA, Choudry U, Salim A, Nathani KR, Enam SA, Shehzad N. Current management trends for surgical site infection after posterior lumbar spinal instrumentation: a systematic review. *World Neurosurg*. 2022;164:374-380.
27. Kim CH, Chung CK, Shin S, et al. The relationship between diabetes and the reoperation rate after lumbar spinal surgery: a nationwide cohort study. *Spine J*. 2015;15(5):866-874.
28. Wang SK, Wang P, Li XY, Kong C, Niu JY, Lu SB. Incidence and risk factors for early and late reoperation following lumbar fusion surgery. *J Orthop Surg Res*. 2022;17(1):385.
29. Wukich DK. Diabetes and its negative impact on outcomes in orthopaedic surgery. *World J Orthop*. 2015;6(3):331-339.
30. Cinotti G, Postacchini F, Weinstein JN. Lumbar spinal stenosis and diabetes. Outcome of surgical decompression. *J Bone Joint Surg Br*. 1994;76(2):215-219.
31. Arinzon Z, Adunsky A, Fidelman Z, Gepstein R. Outcomes of decompression surgery for lumbar spinal stenosis in elderly diabetic patients. *Eur Spine J*. 2004;13(1):32-37.
32. Cancienne JM, Werner BC, Chen DQ, Hassanzadeh H, Shimer AL. Perioperative hemoglobin A1c as a predictor of deep infection following single-level lumbar decompression in patients with diabetes. *Spine J*. 2017;17(8):1100-1105.
33. Ogura Y, Kitagawa T, Kobayashi Y, et al. Risk factors for persistent numbness following decompression surgery for

lumbar spinal stenosis. *Clin Neurol Neurosurg*. 2020;196:105952.
34. Silverstein MP, Miller JA, Xiao R, Lubelski D, Benzel EC, Mroz TE. The impact of diabetes upon quality of life outcomes after lumbar decompression. *Spine J*. 2016;16(6):714-721.
35. Khan JM, Michalski J, Basques BA, et al. Do clinical outcomes and sagittal parameters differ between diabetics and nondiabetics for degenerative spondylolisthesis undergoing lumbar fusion? *Global Spine J*. 2020;10(3):286-293.
36. Moazzeni K, Kazemi KA, Khanmohammad R, Eslamian M, Rostami M, Faghih-Jouibari M. Comparison of surgical outcome between diabetic versus nondiabetic patients after lumbar fusion. *Int J Spine Surg*. 2018;12(4):528-532.
37. Takahashi S, Suzuki A, Toyoda H, et al. Characteristics of diabetes associated with poor improvements in clinical outcomes after lumbar spine surgery. *Spine (Phila Pa 1976)*. 2013;38(6):516-522.
38. Smith EJ, Inkrott BP, Du JY, Kim CY, Ahn UM, Ahn NU. The effect of diabetes mellitus on revision discectomy after single-level lumbar discectomy. *J Surg Orthop Adv*. 2020;29(3):159-161.
39. Regev GJ, Lador R, Salame K, Mangel L, Cohen A, Lidar Z. Minimally invasive spinal decompression surgery in diabetic patients: perioperative risks, complications and clinical outcomes compared with non-diabetic patients' cohort. *Eur Spine J*. 2019;28(1):55-60.
40. Senker W, Stefanits H, Gmeiner M, Trutschnig W, Radl C, Gruber A. The impact of type 2 diabetes on the peri- and postoperative outcomes of minimally invasive fusion techniques in the lumbar spine. *J Neurosurg Sci*. 2020;64(6):509-514.
41. Hathi K, Bigney E, Richardson E, et al. Minimally invasive vs. open surgery for lumbar spinal stenosis in patients with diabetes—a Canadian Spine Outcomes and Research Network study. *Global Spine J*. 2023;13(6):1602-1611.
42. Narain AS, Haws BE, Jenkins NW, et al. Diabetes does not increase complications, length of stay, or hospital costs after minimally invasive transforaminal lumbar interbody fusion. *Clin Spine Surg*. 2020;33(7):E307-E311.
43. Kim KT, Cho DC, Sung JK, Kim CH, Kang H, Kim DH. Changes in HbA_{1c} levels and body mass index after successful decompression surgery in patients with type 2 diabetes mellitus and lumbar spinal stenosis: results of a 2-year follow-up study. *Spine J*. 2017;17(2):203-210.

Disclosures

Dr. Wang reported personal fees from DePuy Synthes, Stryker, Surgalign, Spineology, Pacira, and NuVasive; purchased stock from ISD, Kinesiometrics, and Medical Device Partners outside the submitted work; and patent for DePuy Synthes with royalties paid. Dr. Coric reported personal fees from Spine Wave, Medtronic, Globus Medical, Stryker, Acellus, and Premia Spine outside the submitted work. Dr. Sherrod reported grants from CSRS, AO Spine, and University of Utah Technology Transfer Office outside the submitted work; and patent for US 18/114,157 pending. Dr. C. Shaffrey reported personal fees from NuVasive, Medtronic, SI-Bone, and Proprio outside the submitted work. Dr. Than reported personal fees from DePuy, NuVasive, Accelus, SI-Bone, Bioventus, and Cerapedics outside the submitted work. Dr. Hussain reported personal fees from 3DBio, AO Spine, and OnPoint Surgical; and grants from AO Spine North America outside the submitted work. Dr. Virk reported being a consultant for DePuy Synthes; stock ownership in OnPoint Surgical; and grants from NIH/NINDS outside the submitted work. Dr. Agarwal reported personal fees from Thieme Medical Publishers and Springer International Publishing outside the submitted work. Dr. Glassman reported being a consultant for Medtronic and K2M/Stryker; and institutional support from Cerapedics, BiomUp, Empirical Spine, Stryker, and Medtronic. Dr. Park reported personal fees from Globus, Medtronic, NuVasive, DePuy, and Accelus; royalties from Globus; and grants from Cerapedics, ISSG, SI-Bone, and DePuy outside the submitted work. Dr. Foley reported royalties from Medtronic; consulting for Medtronic; and stock ownership in Medtronic, Discgenics, Accelus, DuraStat, DuraStat, NuVasive, and Spine Wave outside the submitted work; and patent for multiple patents with royalties paid from Medtronic. Dr. Chou reported personal fees from Globus and Orthofix outside the submitted work. Dr. Potts reported royalties and consulting for Medtronic outside the submitted work. Dr. Fu reported personal fees from Bioventus and ATEC outside the submitted work. Dr. Knightly reported being the NPA chair outside the submitted work. Dr. Mummaneni reported grants from NREF during the conduct of the study; personal fees from DePuy Synthes, Globus, Stryker, NuVasive, Brainlab, and SI-Bone; grants from ISSG, AO Spine, NIH, and Pacira; and stock in Spinicity/ISD outside the submitted work. Dr. Bisson reported personal fees from Stryker, Medtronic, and MiRus; and stock options in Proprio NView outside the submitted work. Dr. Asher reported personal fees from Globus outside the submitted work.

Author Contributions

Conception and design: Bydon, Mooney, Wang, CI Shaffrey, Than, Virk, Glassman, Slotkin, Potts, Haid, Knightly. Acquisition of data: Mooney, Wang, Coric, Chan, Sherrod, CI Shaffrey, Goldberg, Virk, ME Shaffrey, Park, Foley, Chou, Slotkin, Potts, Fu, Knightly, Mummaneni, Bisson, Asher. Analysis and interpretation of data: Mooney, Nathani, Zeitouni, Coric, Chan, Sherrod, Than, Goldberg, Virk, Glassman, Slotkin, Haid, Mummaneni. Drafting the article: Mooney, Nathani, Zeitouni, Agarwal, Haid. Critically revising the article: Bydon, Mooney, Zeitouni, Wang, Coric, Chan, Lu, Sherrod, CI Shaffrey, Than, Agarwal, Glassman, ME Shaffrey, Foley, Tumialán, Haid, Mummaneni, Bisson. Reviewed submitted version of manuscript: Bydon, Mooney, Nathani, Zeitouni, Michalopoulos, Coric, Chan, Lu, Sherrod, Gottfried, Than, Goldberg, Hussain, Agarwal, Glassman, ME Shaffrey, Park, Foley, Chou, Slotkin, Tumialán, Upadhyaya, Potts, Fu, Haid, Knightly, Mummaneni, Bisson, Asher. Approved the final version of the manuscript on behalf of all authors: Bydon. Statistical analysis: Nathani, Michalopoulos. Administrative/technical/material support: Bydon, Michalopoulos, CI Shaffrey. Study supervision: Bydon, Lu, CI Shaffrey, Potts, Mummaneni, Bisson.

Supplemental Information

Previous Presentations

The abstract of the study was presented as a poster at the 39th annual meeting of the AANS/CNS Section on Disorders of the Spine and Peripheral Nerves (Spine Summit), Miami, Florida, March 16–19, 2023.

Correspondence

Mohamad Bydon: Mayo Clinic, Rochester, MN.
bydon.mohamad@mayo.edu.