Original Article

National trends in postoperative complications for lumbar spinal fusion from 2009 to 2022

ABSTRACT

Background: Although posterior lumbar fusions (PLFs) have risen in popularity due to minimally invasive techniques and favorable outcomes, complications still arise. Studies show relatively constant rates of postoperative complications from 2006 to 2016, but there are limited studies evaluating outcomes after 2016. Consequently, we aim to investigate trends in postoperative complications for PLFs from 2009 to 2022.

Methods: The American College of Surgeons National Surgical Quality Improvement Program was queried for single-level PLFs between 2006 and 2022. Patients between 2006 and 2008 were excluded due to limited sample size. Inclusion criteria included >18 years old and Current Procedural Terminology code 22612. Baseline demographics and comorbidities were recorded. Annual 30-day complication rates of wound infection, readmission, reoperation, length of stay, intraoperative blood transfusions (IBTs), and mortality were recorded. Analysis of variance and multivariable Poisson log-linear regression were performed to compare complication rates between years and outcomes between 2020–2022 and 2017–2019.

Results: Wound infection rates declined from 3.7% in 2009 to 2.7% in 2019, with an increase to 3.0% by 2022 ($P = 0.015$). IBT decreased significantly, from 20.58% in 2010 to 9.40% in 2022 ($P < 0.001$). Sepsis rates fell from 2.15% in 2009 to 0.88% in 2022 ($P = 0.017$). The average length of stay decreased from 2009 to 2019 ($P < 0.001$). Wound infection ($P = 0.006$) and pneumonia ($P = 0.039$) rates significantly increased between 2020 and 2022.

Conclusion: Rates of older age, diabetes, and hypertension increased among PLF patients between 2009 and 2022, while most complication rates remained constant. Rates of wound infection, IBT, sepsis, and average length of stay have improved since 2009 despite an increase in wound infection and pneumonia from 2020 to 2022.

Keywords: American College of Surgeons National Surgical Quality Improvement Program, COVID-19, posterior lumbar spinal fusion, postoperative complications

INTRODUCTION

Lumbar fusion is a commonly performed orthopedic procedure used to treat and manage degenerative disk disease, instability, spondylolisthesis, and pseudoarthrosis.[1,2] With its increasing utilization and evolving techniques, understanding complications after posterior lumbar spinal fusions (PLFs) is important for optimizing patient outcomes and safety. The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database offers extensive patient sample sizes that can be used to assess trends in postoperative complications over time.

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Previous studies using the ACS-NSQIP database from 1998 to 2008 identified certain risk factors, such as diabetes, smoking, and obesity, that affect complications following elective PLF.[3] During that time, the average length of stay and in-hospital mortality decreased significantly, while the average age of patients undergoing fusion increased.[4] Further investigations from 2009 to 2013 revealed a growing trend of older patients with comorbidities, such as hypertension, undergoing PLF, suggesting that these procedures can be safely performed in higher-risk patients.[5]

While these trends suggest improvements, the COVID-19 pandemic highlighted new challenges. Studies found that higher rates of complications, including morbidity, pneumonia, deep venous thrombosis, and sepsis, as well as longer operative times and increased nonhome discharge rates, occurred during this period.[6] These findings underscore the importance of continuously monitoring and analyzing postoperative outcomes.

Despite the insights gained from these studies, there remains a gap in understanding the longitudinal trends of PLF complications following multiple end points and comorbidities.[5,7-10] We hypothesize that clinical outcomes and complications would improve from 2009 to 2022 due to overall quality improvement, better instrumentation techniques, technological advancements, and enhanced safety measures in spine fusion procedures.[2,11]

METHODS

Study design and data source

A retrospective observational study was conducted on patients who underwent single-level primary lumbar decompression and fusion from 2006 to 2022, utilizing the ACS-NSQIP database. This outcome-based, national surgical database captures clinically significant perioperative variables and 30-day outcomes from more than 600 participating institutions, including academic settings, private practices, community hospitals, tertiary centers, and both inpatient and outpatient medical centers.[12-14] Patient demographics and 30-day perioperative outcome data are recorded directly from the electronic medical record by clinical reviewers.[15]

Study population

Adult patients undergoing single-level PLF between 2006 and 2022 were identified using Current Procedural Terminology (CPT) billing code 22612. Patients undergoing surgery between 2006 and 2008 were excluded due to limited sample size. Cases involving nonlumbar regions of the spine were excluded using CPT codes.

Demographics, comorbidities, and clinical outcomes

Patient demographics and comorbidities, including age, race, ethnicity, body mass index (BMI), functional dependence, diabetes mellitus, smoking status, chronic obstructive pulmonary disease, steroid use, hypertension requiring medications, congestive heart failure (CHF), and American Society of Anesthesiologists (ASA) class, were recorded. Outcomes and complications, including wound infection, pneumonia, unplanned intubation, urinary tract infection, blood transfusions, deep vein thrombosis, sepsis, reoperation, readmission, mortality, and length of stay, were also collected. Annual data between 2009 and 2022 were assessed for differences in complications by year.

Statistical analysis

Annual complication rates and outcomes were assessed for differences across the 2009–2022 period using analysis of variance (ANOVA) tests. Baseline demographics and comorbidities were similarly assessed by year. Differences in clinical outcomes and complications were evaluated between 2017–2019 and 2020–2022 using the Chi-squared tests for categorical variables (e.g. wound infection and pneumonia) and *t*-tests for continuous variables (e.g. length of stay). To determine whether the years 2020–2022 were associated with poorer outcomes than 2017–2019, multivariable Poisson log-linear regression was employed, adjusting for all baseline demographics and comorbidities included in Table 1. Statistical significance was set at $P < 0.05$. All statistical analyses were performed using IBM Statistical Package for the Social Sciences (SPSS) version 29.0 (IBM Corp., Armonk, NY, USA).

RESULTS

In total, 49,146 patients undergoing PLF from 2009 to 2022 were included. The mean age and BMI were 62.77 ± 12.82 years and 30.70 ± 6.91 kg/m^2, respectively. The study cohort consisted of 26,738 female (53.8%) and 22,909 (46.1%) male patients, of whom 40,076 (80.7%) were White. The average patient age gradually increased from 59.0 years in 2009 to 64.6 years in 2022 ($P < 0.001$). The proportion of male patients slightly increased over the study period ($P < 0.001$), while the proportion of White patients decreased from 82.2% in 2009 to 76.9% in 2022 ($P < 0.001$). BMI increased from 29.7 to 30.7 kg/m^2 across the study period, along with multiple comorbidities, including ASA class >2, diabetes, CHF, hypertension, and conditions requiring steroid use, notably trending upward [all $P < 0.001$; Table 1]. Rates of smoking decreased from 26% to 12.7% from 2009 to 2022. Annual demographics and comorbidities of the patient cohort are summarized in Table 1.

Variations in the annual rates of 30-day pneumonia, unplanned intubation, urinary tract infection, deep vein

Table 1: Baseline demographics and comorbidities of patients undergoing posterior lumbar spinal fusion from 2009 to 2022

	2009 (*n*=650), *n* (%)	2010 (*n*=969), *n* (%)	2011 (*n*=1898), *n* (%)	2012 (*n*=2278), *n* (%)	2013 (*n*=2989), *n* (%)	2014 (*n*=4110), *n* (%)	2015 (*n*=4464), *n* (%)	2016 (*n*=4508), *n* (%)	2017 (*n*=4574), *n* (%)	2018 (*n*=4637), *n* (%)	2019 (*n*=5031), *n* (%)	2020 (*n*=4136), *n* (%)	2021 (*n*=4395), *n* (%)	2022 (*n*=4507), *n* (%)	*P*
Age (years)	59.0±14.0	61.1±13.7	60.3±13.7	61.3±13.7	62.2±13.1	61.1±13.1	61.7±13.0	62.3±13.0	63.1±12.5	64.0±12.1	63.6±12.5	63.9±12.2	64.1±12.4	64.6±12.0	<0.001
Male sex	311 (47.8)	416 (43.0)	831 (43.8)	951 (41.8)	1391 (46.5)	1903 (46.3)	1994 (44.7)	2092 (46.4)	2089 (45.7)	2134 (46.0)	2324 (46.2)	1944 (47.0)	2124 (48.3)	2170 (48.1)	<0.001
Race (% White)	534 (82.2)	801 (82.8)	1595 (84.0)	1910 (83.9)	2566 (85.8)	3455 (84.1)	3765 (84.4)	3744 (82.9)	3643 (79.8)	3753 (80.9)	3991 (79.3)	3203 (77.5)	3359 (76.4)	3472 (76.9)	<0.001
BMI	29.7±7.4	30.1±7.5	30.1±6.8	30.3±7.1	30.5±6.9	30.7±6.6	30.9±6.7	30.9±7.0	30.8±7.1	30.8±7.1	31.0±6.6	30.8±6.9	30.5±7.1	30.7±7.0	<0.001
Functional dependence	34 (5.2)	70 (7.2)	93 (4.9)	61 (2.7)	93 (3.1)	97 (2.4)	95 (2.1)	73 (1.6)	110 (2.4)	156 (3.4)	107 (2.1)	112 (2.7)	127 (2.9)	130 (2.9)	<0.001
ASA class >2	292 (44.9)	464 (48.0)	960 (50.6)	1137 (49.9)	1584 (53.0)	2238 (54.5)	2369 (53.1)	2496 (55.3)	2570 (56.3)	2721 (58.9)	2952 (58.6)	2465 (59.6)	2763 (62.6)	2844 (63.0)	<0.001
Diabetes	107 (16.5)	183 (18.9)	339 (17.9)	383 (16.8)	538 (18.0)	769 (18.7)	852 (19.1)	891 (19.7)	926 (20.3)	1019 (22.0)	1064 (21.1)	860 (20.8)	964 (21.9)	1013 (22.5)	<0.001
Smoking	169 (26)	191 (19.8)	427 (22.5)	475 (20.9)	552 (18.5)	815 (19.8)	869 (19.5)	818 (18.1)	779 (17.1)	703 (15.2)	742 (14.7)	611 (14.8)	629 (14.3)	574 (12.7)	<0.001
COPD	32 (4.9)	38 (3.9)	79 (4.2)	103 (4.5)	160 (5.4)	232 (5.6)	218 (4.9)	240 (5.3)	244 (5.3)	241 (5.2)	244 (4.8)	206 (5.0)	229 (5.2)	202 (4.5)	0.096
CHF	1 (0.1)	1 (0.1)	6 (0.3)	6 (0.3)	7 (0.2)	18 (0.4)	11 (0.2)	15 (0.3)	21 (0.5)	27 (0.6)	22 (0.4)	24 (0.6)	109 (2.5)	141 (3.1)	<0.001
Hypertension	345 (53.1)	596 (61.2)	1109 (58.4)	1331 (58.5)	1803 (60.3)	2474 (60.2)	2690 (60.3)	2761 (61.2)	2790 (61.1)	2874 (62.0)	3096 (61.5)	2560 (61.9)	2714 (61.7)	2874 (63.7)	<0.001
Steroid use	26 (4)	30 (3.1)	63 (3.3)	97 (4.3)	157 (5.3)	191 (4.7)	195 (4.4)	186 (4.1)	211 (4.6)	253 (5.5)	256 (5.1)	203 (4.9)	267 (6.1)	263 (5.8)	<0.001

BMI - Body mass index; COPD - Chronic obstructive pulmonary disorder; ASA - American Society of Anesthesiologists; CHF - Congestive heart failure

thrombosis, reoperation, readmission, and mortality between 2009 and 2022 were nonsignificant. Rates of wound infection gradually decreased from 3.7% in 2009 to 2.7% in 2019, with a slight increase between 2020 and 2022, reaching 3.0% in 2022 [$P = 0.015$; Figure 1]. Intraoperative blood transfusions (IBTs) decreased consistently from 20.58% in 2010 to 9.40% in 2022 [$P < 0.001$; Figure 2]. The occurrence of sepsis decreased from 2.15% in 2009 to 0.88% in 2022 [$P = 0.017$; Figure 3]. The average length of stay decreased from its peak of 5.87 days in 2012 to 3.34 days in 2019, before increasing between 2020 and 2022 – 4.13 days in 2022 [Figure 4]. Annual complication rates are summarized in Table 2.

Multiple complications, including wound infection, pneumonia, deep vein thrombosis, sepsis, and length of stay increased from 2020 to 2022. To assess whether the 3-year period following the COVID-19 pandemic was associated with increased postoperative complications, we compared complication rates in 2020–2022 with those of the preceding years from 2017 to 2019. Notably, on multivariable analysis, rates of wound infection increased from 2.6% to 3.4% ($P = 0.006$) and the rate of pneumonia increased from 0.7% to 1.0% [$P = 0.039$; Table 3].

DISCUSSION

The number of PLFs performed for degenerative spine conditions has increased significantly within the last two decades.[9] With increasing case volume, the optimization of patient outcomes and modifiable patient risk factors is especially important to consider. Previous studies conducted by Yamaguchi *et al*. and Oezel *et al*. demonstrated that comorbidities, including age, BMI, and ASA class, significantly increased over time using data from the ACS-NSQIP between 2006 and 2019.[5,16] Despite this trend, there were significant decreases in blood transfusions and length of stay, with

Figure 1: Annual wound infection rates following lumbar fusion from 2009 to 2022

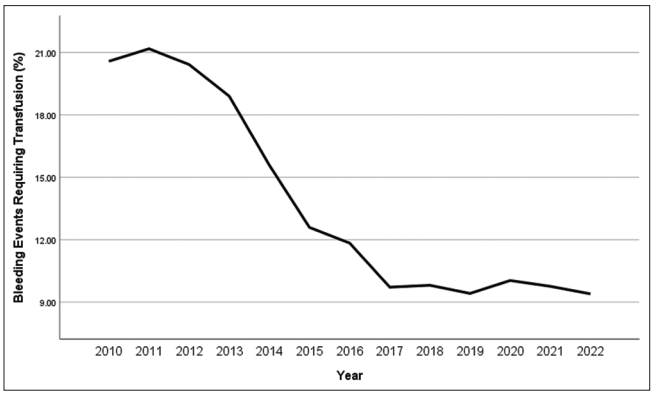

Figure 2: Annual blood transfusion rates following lumbar fusion from 2009 to 2022

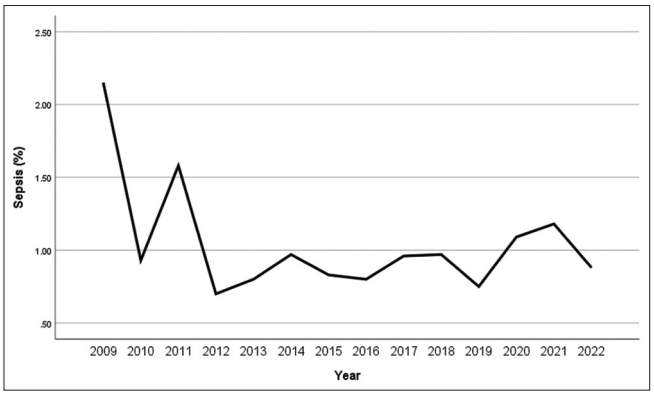

Figure 3: Annual sepsis rates following lumbar fusion from 2009 to 2022

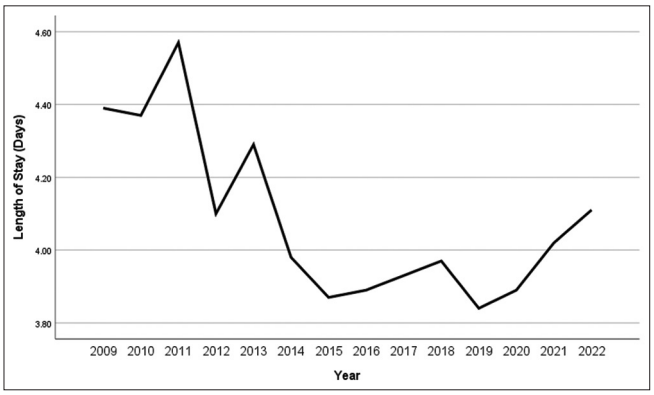

Figure 4: Average length of stay by year following lumbar fusion from 2009 to 2022

no differences in other clinical outcomes. However, with Yamaguchi *et al*. only including ACS-NSQIP data until 2016, and Oezel *et al*. comparing cohorts from 2009 to 2013 and 2015 to 2019, there is a scarcity of data evaluating trends in comorbidities and clinical outcomes following PLF. In this retrospective study, we noted several important trends. First, patient comorbidities, including age, ASA class, diabetes, CHF, and hypertension, significantly increased between 2009 and 2022. Second, blood transfusions, length of stay, and wound infection rates have decreased over the study period. Finally,

Table 2: Annual complication rates of patients undergoing posterior lumbar spinal fusion from 2009 to 2022

	2009 (*n*=650), *n* (%)	2010 (*n*=969), *n* (%)	2011 (*n*=1898), *n* (%)	2012 (*n*=2278), *n* (%)	2013 (*n*=2989), *n* (%)	2014 (*n*=4110), *n* (%)	2015 (*n*=4464), *n* (%)	2016 (*n*=4508), *n* (%)	2017 (*n*=4574), *n* (%)	2018 (*n*=4637), *n* (%)	2019 (*n*=5031), *n* (%)	2020 (*n*=4136), *n* (%)	2021 (*n*=4395), *n* (%)	2022 (*n*=4507), *n* (%)	*P*
Wound infection	24 (3.7)	24 (2.5)	47 (2.5)	55 (2.4)	75 (2.5)	110 (2.7)	108 (2.4)	113 (2.5)	113 (2.5)	127 (2.7)	128 (2.7)	135 (3.3)	153 (3.5)	136 (3.0)	0.015
Pneumonia	4 (0.6)	9 (0.9)	18 (0.9)	17 (0.7)	23 (0.8)	33 (0.8)	39 (0.9)	34 (0.8)	35 (0.8)	33 (0.7)	34 (0.7)	35 (0.8)	49 (1.1)	49 (1.1)	0.510
Intubation	2 (0.3)	1 (0.1)	15 (0.8)	11 (0.5)	17 (0.6)	16 (0.4)	17 (0.4)	18 (0.4)	17 (0.4)	27 (0.6)	20 (0.4)	18 (0.4)	20 (0.5)	24 (0.5)	0.582
UTI	15 (2.3)	20 (2.1)	47 (2.5)	42 (1.8)	48 (1.6)	71 (1.7)	82 (1.8)	97 (2.2)	79 (1.7)	76 (1.6)	88 (1.7)	70 (1.7)	78 (1.8)	92 (2.0)	0.607
Blood transfusions	N/A	200 (20.6)	401 (21.1)	465 (20.4)	565 (18.9)	641 (15.6)	562 (12.6)	534 (11.8)	446 (9.8)	455 (9.8)	472 (9.4)	416 (10.1)	428 (9.7)	423 (9.4)	<0.001
Deep vein thrombosis	12 (1.8)	9 (0.9)	17 (0.9)	18 (0.8)	34 (0.8)	36 (0.9)	36 (0.8)	44 (1.0)	46 (1.0)	35 (0.8)	33 (0.7)	34 (0.8)	37 (0.8)	46 (1.0)	0.256
Sepsis	14 (2.2)	9 (0.9)	30 (1.6)	16 (0.7)	24 (0.8)	40 (1.0)	38 (0.9)	35 (0.8)	44 (1.0)	45 (1.0)	38 (0.8)	46 (1.1)	51 (1.2)	40 (0.9)	0.017
Reoperation	N/A	N/A	N/A	86 (3.8)	100 (3.3)	153 (3.7)	173 (3.9)	172 (3.8)	154 (3.4)	160 (3.5)	183 (3.6)	166 (4.0)	160 (3.6)	142 (3.2)	0.691
Readmission	N/A	N/A	N/A	141 (6.2)	173 (5.8)	240 (5.8)	273 (6.1)	289 (6.4)	258 (5.6)	264 (5.7)	310 (6.2)	287 (6.9)	273 (6.2)	266 (5.9)	0.489
Mortality	3 (0.5)	2 (0.2)	8 (0.4)	5 (0.2)	11 (0.4)	19 (0.5)	15 (0.3)	12 (0.3)	16 (0.3)	22 (0.5)	23 (0.5)	18 (0.4)	28 (0.6)	22 (0.5)	0.564
Length of stay (days)	4.39±4.0	4.37±3.9	4.57±5.3	4.10±5.9	4.29±3.8	3.98±3.9	3.87±4.1	3.89±4.3	3.93±3.7	3.97±3.6	3.84±3.3	3.89±3.8	4.02±4.1	4.11±4.2	<0.001

UTI - Urinary tract infection; N/A - Not available

Table 3: A comparison of postoperative outcomes and complication rates from 2017 to 2019 and 2020 to 2022

Characteristic	2017–2019 (*n*=14,240), *n* (%)	2020–2022 (*n*=13,042), *n* (%)	Wald Chi-square	*P* (two-sided)
Wound infection	368 (2.6)	424 (3.4)	7.702	0.006
Pneumonia	102 (0.7)	133 (1.0)	4.248	0.039
Intubation	64 (0.4)	62 (0.5)	0.155	0.694
UTI	243 (1.7)	240 (1.8)	0.089	0.766
Blood transfusions	1373 (9.6)	1268 (9.7)	0.689	0.406
Deep vein thrombosis	114 (0.8)	117 (0.9)	0.498	0.480
Sepsis	127 (0.9)	137 (1.1)	1.067	0.302
Reoperation	497 (3.5)	468 (3.6)	<0.001	0.994
Readmission	832 (5.8)	826 (6.3)	0.745	0.388
Mortality	61 (0.4)	68 (0.5)	0.017	0.869
Length of stay (days)	3.91±3.54	4.01±4.05	1.160	0.282

UTI - Urinary tract infection

rates of wound infection and pneumonia increased after 2019, aligning with the start of the COVID-19 pandemic.

The univariate analysis across annual comorbidity rates demonstrated significant differences in age, sex, race, BMI, functional dependence, ASA class, diabetes, smoking, CHF, hypertension, and chronic conditions requiring steroid use. Notably, age, ASA class, rates of hypertension, CHF, and diabetes increased from 2009 to 2022, while smoking decreased. Increases in age, ASA class, BMI, as well as decreases in smoking have previously been reported among PLF patients.[3,5,16] The findings of this study are largely consistent with the literature, with PLF patients becoming progressively older and more medically complex with additional comorbidities. Of note, Sharfman *et al*. found that rates of CHF, a significant risk factor for lumbar fusion, did not change significantly between 2006 and 2016.[17,18] We noted a significant uptick in CHF from 2020 to 2022 which can explain this previously unobserved trend. With variations in risk factors, including age, sex, non-White race, hypertension, and smoking, which have been implicated in greater complication rates after lumbar fusion, surgeons should be aware of increased risk and interpret differences in outcomes accordingly.[3,19-21]

Among the clinical outcomes analyzed in this study, we found significant variations in length of stay, wound infection, sepsis, and blood transfusions. Each of these variables appeared to decrease during the 2009–2022 study period; however, wound infection, length of stay, and sepsis experienced an increase between 2020 and 2022. Oezel *et al*. previously reported decreases in blood transfusions and length of stay among PLF patients between 2009 and 2019.[5] Yamaguchi *et al*. reported significant variation in superficial surgical site infections, deep vein thrombosis, sepsis, and mortality in PLF patients from 2006 to 2016, with complication rates decreasing.[16] Our findings are largely consistent with previous findings; however, we did not find significant variation in mortality or deep vein thrombosis in our cohort. Improvements in length of stay and wound infection, two clinically significant outcomes, and consistent complication rates, despite an aging and more medically complex patient population, can be considered a success.

We observed a significant uptick in multiple complications between 2020 and 2022, coinciding with the outbreak of COVID-19. Song *et al*. demonstrated that the operation year 2020 following COVID-19 was associated with poorer perioperative outcomes and complications following PLF.[6] While adjusting for baseline characteristics resulted in no difference in bleeding transfusions and length of stay, the operation year 2020 was independently associated with morbidity, pneumonia, deep vein thrombosis, sepsis, operative time, and nonhome discharge. The authors attributed this to a likely increase in average case complexity and decreased healthcare efficiency during the COVID-19 pandemic. This is also consistent with previous findings that found an association between COVID-19 infection and pneumonia.[22] Our current study supports these findings with significantly increased complication rates, including wound infection and pneumonia, in the 2020–2022 period compared to 2017–2019. This suggests the impact of the COVID-19 pandemic on case complexity, and healthcare efficiency has had persisting effects through 2022.

Limitations

This study has several limitations. First, the retrospective design of the study may introduce an element of selection bias. CPT billing codes were used to identify PLF patients, which do not always accurately represent the intended patient population. Patients who did not meet CPT billing code criteria were not considered, even though their cases would be relevant to our study. Second, the ACS-NSQIP database is restricted to a 30-day postoperative period and limited to readmission at participating hospitals. Therefore, our study is limited in capturing longitudinal data beyond

the follow-up period or at institutions that do not participate in this program. Finally, the ACS-NSQIP database is not specifically collected for spine surgery, resulting in certain surgery-specific variables of interest, such as spinal muscular atrophy or cervical spine degenerative disk disease, not being included.

CONCLUSION

Rates of comorbidities, including age, diabetes, and hypertension, have increased among PLF patients between 2009 and 2022, while complications have largely remained constant. Notably, rates of wound infection, IBTs, sepsis, and average length of stay appear to have improved in this time frame, despite slight increases from 2020 to 2022. Increased complications, including rates of wound infection and pneumonia from 2020 to 2022, may be attributed to the persisting effects of the COVID-19 pandemic on case complexity and healthcare efficiency. These trends can inform surgeons and patients alike of postoperative complications where quality improvement has been successful, as well as areas for continued improvement.

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Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. DiPaola CP, Molinari RW. Posterior lumbar interbody fusion. J Am Acad Orthop Surg 2008;16:130-9.
2. Reisener MJ, Pumberger M, Shue J, Girardi FP, Hughes AP. Trends in lumbar spinal fusion-a literature review. J Spine Surg 2020;6:752-61.
3. Kia C, Yannopoulos A, Gulati S, Cremins M, Cote M, Moss I. Modifiable patient factors demonstrate no increased risk for 30-day complication rate for elective 1-2 level posterior lumbar fusion surgery: A comparison between a national database and local registry. Int J Spine Surg 2022;16:727-34.
4. Rajaee SS, Bae HW, Kanim LE, Delamarter RB. Spinal fusion in the United States: Analysis of trends from 1998 to 2008. Spine (Phila Pa 1976) 2012;37:67-76.
5. Oezel L, Okano I, Hughes AP, Sarin M, Shue J, Sama AA, *et al.* Longitudinal trends of patient demographics and morbidity of different approaches in lumbar interbody fusion: An analysis using the american college of surgeons national surgical quality improvement program database. World Neurosurg 2022;164:e183-93.
6. Song J, Katz AD, Qureshi SA, Virk SS, Sarwahi V, Silber J, *et al.* Lumbar fusion during the COVID-19 pandemic: Greater rates of morbidity and longer procedures. J Spine Surg 2023;9:73-82.
7. Luo ZW, Wu JB, Sun BL, Liao WJ, Huang SH, Zhang ZH, *et al.* Trend of unplanned reoperation rates after lumbar degenerative surgery from 2011 to 2019: A large patient population study. ANZ J Surg 2023;93:1658-64.
8. Wilson LA, Fiasconaro M, Liu J, Bekeris J, Poeran J, Kim DH, *et al.* Trends in comorbidities and complications among patients undergoing inpatient spine surgery. Spine (Phila Pa 1976) 2020;45:1299-308.
9. Deng H, Yue JK, Ordaz A, Suen CG, Sing DC. Elective lumbar fusion in the United States: National trends in inpatient complications and cost from 2002-2014. J Neurosurg Sci 2021;65:503-12.
10. Pumberger M, Chiu YL, Ma Y, Girardi FP, Mazumdar M, Memtsoudis SG. National in-hospital morbidity and mortality trends after lumbar fusion surgery between 1998 and 2008. J Bone Joint Surg Br 2012;94:359-64.
11. Grotle M, Småstuen MC, Fjeld O, Grøvle L, Helgeland J, Storheim K, *et al.* Lumbar spine surgery across 15 years: Trends, complications and reoperations in a longitudinal observational study from Norway. BMJ Open 2019;9:e028743.
12. Molina CS, Thakore RV, Blumer A, Obremskey WT, Sethi MK. Use of the national surgical quality improvement program in orthopaedic surgery. Clin Orthop Relat Res 2015;473:1574-81.
13. Khuri SF. The NSQIP: A new frontier in surgery. Surgery 2005;138:837-43.
14. NSQIP-Participating Hospitals Are Recognized for Meritorious Outcomes. ACS. Available from: https://www.facs.org/for-medical-profess ionals/news-publications/news-and-articles/acs-brief/november-7-2023-issue/78-nsqip-participating-hospitals-are-recognized-for-meritorious-outcomes/. [Last accessed on 2024 Jun 30].
15. Shiloach M, Frencher SK Jr., Steeger JE, Rowell KS, Bartzokis K, Tomeh MG, *et al.* Toward robust information: Data quality and inter-rater reliability in the American College of Surgeons National Surgical Quality Improvement Program. J Am Coll Surg 2010;210:6-16.
16. Yamaguchi JT, Weiss HK, Garcia RM, Driscoll C, Stein E, Hopkins B, *et al.* Trends in national utilization of posterior lumbar fusion and 30-day reoperation and readmission rates from 2006-2016. Clin Neurol Neurosurg 2020;199:106310.
17. Sharfman ZT, Gelfand Y, Shah P, Holtzman AJ, Mendelis JR, Shah N, *et al.* Early medical complications and delayed discharge after spinopelvic fusion: A comparative analysis of 887 NSQIP cases from 2006 to 2016. Spine Surg Relat Res 2020;4:314-9.
18. Wagner SC, Butler JS, Kaye ID, Sebastian AS, Morrissey PB, Kepler CK. Risk factors for and complications after surgical delay in elective single-level lumbar fusion. Spine (Phila Pa 1976) 2018;43:228-33.
19. Buerba RA, Fu MC, Gruskay JA, Long WD 3rd, Grauer JN. Obese class III patients at significantly greater risk of multiple complications after lumbar surgery: An analysis of 10,387 patients in the ACS NSQIP database. Spine J 2014;14:2008-18.
20. Lim S, Edelstein AI, Patel AA, Kim BD, Kim JY. Risk factors for postoperative infections after single-level lumbar fusion surgery. Spine (Phila Pa 1976) 2018;43:215-22.
21. Aladdin DE, Tangel V, Lui B, Pryor KO, Witkin LR, White RS. Black race as a social determinant of health and outcomes after lumbar spinal fusion surgery: A multistate analysis, 2007 to 2014. Spine (Phila Pa 1976) 2020;45:701-11.
22. Mercier MR, Koucheki R, Lex JR, Khoshbin A, Park SS, Daniels TR, *et al.* The association between preoperative COVID-19-positivity and acute postoperative complication risk among patients undergoing orthopedic surgery. Bone Jt Open 2023;4:704-12.