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Clinical Studies

Anterior lumbar spinal fusion surgery associated with lower risk of stroke, pneumonia, and infection compared to posterior lumbar spinal fusion surgery

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ABSTRACT

Background: Prior studies, comparing anterior and posterior approaches to lumbar fusion surgery, found similar fusion rates and clinical outcomes, but are limited by sample size. Further evaluation of the postoperative complications of each approach is necessary.

Methods: The MSpine database by PearlDiver was queried using ICD-9, ICD-10, and CPT codes to identify patients who had undergone single-level anterior or posterior lumbar interbody fusion surgery. Readmission rates, ileus, lower extremity DVT, infection, pneumonia, and stroke were used to compare post-operative complications of an anterior vs. posterior approach.

Results: 112,023 patients were included in this study, with 38,529 (34.4%) in the anterior group (ALIF/LLIF) and 73,494 (65.6%) in the posterior group (PLIF/TLIF). At both 30 and 90-days postoperative, patients undergoing an anterior approach to lumbar interbody fusion had a higher odds ratio of lower extremity DVT (30-day OR: 1.19, 90-day OR: 1.16; P<0.05) and ileus complication (30-day OR: 1.87, P= <.05; 90-day OR: 1.81, P<.05). At both 30 and 90-days postoperative, patients undergoing a posterior approach had a higher odds ratio of stroke (30-day: OR: 0.79, 90-day OR: 0.87; P<0.05), transfusion (30-day OR: 0.66, 90-day OR: 0.69; P<.05), infection (30-day OR: 0.88, 90-day OR: 0.91; P <.05), and pneumonia (30-day OR: 0.85, 90-day OR: 0.90; P<.05). There was no statistically significant difference in myocardial infarction or pulmonary embolism between both approaches at 30 and 90-days postoperative.

Conclusions: Anterior and posterior approaches for lumbar interbody fusion were associated with differences in postoperative complications at 30 and 90-days. The complication profiles associated with each approach can inform surgeon treatment decisions based on patient profiles.

Introduction

Patients with discogenic low back pain, lumbar degenerative spinal deformity including spondylolisthesis and degenerative scoliosis, and radiculopathy due to foraminal stenosis can be treated surgically with lumbar interbody fusion [1] by stopping lumbar segment motion and creating a biomechanically lasting interbody union [2]. An anterior vs. posterior approach to surgery depends on the patient's anatomy, pathology, and the surgeon's preference [3]. While there have been several studies comparing outcomes to determine the superiority of either approach, they utilize extrapolated data and relatively small sample size, allowing for the possibility of type II errors due to low statistical power [3,6,14]. Thus, it remains unclear whether one approach truly confers better outcomes for specific patient profiles.

This study presents a retrospective analysis of the MSpine database by PearlDiver to determine differences in the 30-day and 90-day postoperative outcomes between a single-level anterior and posterior approach to lumbar interbody fusion surgery (LIF). The MSpine database is com-

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prised of about 121 million de-identified patients in the United States and contains all payer types, including commercially insured, Medicare, Medicaid, self-pay, and government plans. To the authors' knowledge, this is the largest study to date comparing direct patient outcomes of lumbar fusion surgery from 2010-2018, with a sample size of ~112,000 patients. Given the large sample size of direct outcomes, this study found statistically significant differences between the two approaches where previous studies have not, secondary to a lack of statistical power. These findings identify specific risk factors for each approach to lumbar fusion, which can help inform surgeon treatment decision making for individual patient profiles.

Materials and methods

Data source

The PearlDiver MSpine Patient Records Database (PearlDiver Inc. Fort Wayne, IN) was used to conduct a retrospective database review of patients who underwent anterior and posterior lumbar interbody fusion surgeries between 2010-2018. The MSpine Patient Records Database was queried using diagnosis and procedures codes from the International Classification of Diseases, 9th revision (ICD-9-CM) and 10th (ICD-9-CM) revision, and Current Procedural Terminology (CPT) codes. Using these codes, two study groups were created: patients who underwent single-level anterior lumbar interbody fusion (ALIF)/lateral lumbar interbody fusion (LLIF) surgery, and patients who underwent single-level transforaminal lumbar interbody fusions (TLIF)/posterior lumbar interbody fusion (PLIF) surgery.

Inclusion criteria

112,023 patients were included in this study, with 38,529 (34.4%) in the final ALIF/LLIF group and 73,494 (65.6%) in the final PLIF/TLIF group. The single-level ALIF/LLIF group was selected with CPT code 22558 and the single-level PLIF/TLIF group was selected with CPT codes 22630 and 22633. In both groups, patients with additional multilevel fusion and revision procedures (using CPT codes shown in Appendix A) were excluded and patient inclusion criteria was narrowed to the first instance of single-level ALIF/LLIF or PLIF/TLIF. To select for elective fusion procedures, instances of trauma, infection, and metastasis in the spine (using ICD-9, ICD-10 codes as shown in Appendix B) were also excluded in both ALIF/LLIF and PLIF/TLIF groups. Patients with a concomitant degenerative disease (Appendix C) were selected to create the ALIF/LLIF and PLIF/TLIF groups for the study. Instances of PLIF/TLIF were excluded from the ALIF/LLIF group and instances of ALIF/LLIF were excluded from the PLIF/TLIF group in order to exclude patients who had dual anterior and posterior surgery, colloquially referred to as "front-back" procedures.

Outcome measures

Both the ALIF/LLIF and PLIF/TLIF cohorts were queried for older age (65 years of age or older), sex, and preexisting comorbidities including congestive heart failure (CHF), peripheral vascular disease (PVD), chronic pulmonary disease, chronic kidney disease (CKD), diabetes mellitus (DM), liver disease, obesity, and active smoking status. After adjusting for older age, sex, and CCI, the following 30 and 90-day complications were queried: ileus, lower extremity deep vein thrombosis (DVT), transfusion, and infection, stroke, myocardial infarction (MI), pneumonia (PNA), pulmonary embolism (PE). The 30-day and 90-day hospital readmission rates and complication rates were then determined. An overall 90-day complication rate was calculated by adding the complications investigated in the anterior or posterior cohorts and dividing by the total number of patients in each group. In addition, for both groups, in-hospital/30-day/90-day Medicare reimbursements were determined and compared statistically.

Statistical analysis

Pearson chi-square analysis was used to compare both groups regarding age (65 and over), sex, and comorbidities. A linear regression model using R (The R project for statistical computing), through the PearlDiver Database software, was used to determine the differences between the two groups for in-hospital, 30 and 90-day complications. Variations in comorbidities were adjusted for with Charlson Comorbidity Index Scores (CCI), sex, and age. A logistic regression model using R was used to perform multivariable analysis when assessing the statistical significance of odds ratios (ORs) of complications and readmission rates when comparing the ALIF/LLIF group to the PLIF/TLIF group. Variations were adjusted with CCI score, sex, and age for analyses, significance was set at $P < 0.05$.

Results

Patient characteristics and comorbidities

The final anterior approach group consisted of n = 38,529 patients, and the final posterior approach group consisted of n = 73,494 patients. Within the total number of patients, 0.23% were self-pay, 65.32% were paid by commercial insurance, 2.81% were insured by the government, 6.70% were Medicaid, 22.93% were Medicare, and 2.01% were unknown. The anterior approach cohort contained a significantly smaller number of males than the posterior approach group (15,293 vs. 29,946, P <.05). The average age for patients undergoing anterior approach was lower at 53.9 years vs. 57.7 years for the posterior approach cohort. (P <0.05). Patients in the posterior approach group had slightly higher rates of pre-existing comorbidities (CHF, PVD, CKD, DM; P <0.05). Differences in comorbidities between the two groups were not significant for the following conditions: COPD (P=0.608), liver disease (P =0.384), smoking (P =0.834), and obesity (P = 0.132). Complications were adjusted for age, sex, and CCI. Demographic characteristics related to age, gender, and comorbidities can be found in Table 1.

Readmission rates

Rates of readmission at both 30 and 90-days were slightly increased with the anterior approach. At 30 days, 6.23% of patients undergoing the anterior approach (n=2400) vs. 6.01% of patients undergoing the posterior approach (n=4417) were readmitted, with an odds ratio of 1.12 (95% CI: 1.06 – 1.18, P < 0.05). The rates at 90 days postoperatively were 7.47% (n=2878) in the anterior group vs. 7.44% (n=5468) in the posterior group, with an odds ratio of 1.08 (95% CI: 1.03–1.13, P < 0.05).

Adjusted Complications

Odds ratios of complications at both 30 and 90- days adjusted for CCI, age, and sex postoperatively are given in Tables 2 and 3, respectively. Patients undergoing an anterior approach to lumbar interbody fusion had a higher odds ratio of postoperative lower extremity DVT complication at both 30-days (OR: 1.19, P<0.05) and 90-days (OR: 1.16, P<0.05). Additionally, the odds ratio of postoperative ileus complication was significantly higher in patients undergoing the anterior approach to lumbar interbody fusion at both timepoints (30-day OR: 1.87, P= <.05; 90-day OR: 1.81, P<.05).

The odds ratio of stroke complication was significantly greater in the posterior approach at both 30-days (OR: 0.79, P<0.05) and 90-days (OR: 0.87, P<0.05) postoperative. Additionally, patients undergoing a posterior approach to lumbar fusion had a higher odds ratio of postoperative transfusions (30-day OR: 0.66, 90-day OR: 0.69, P<.05), infection (30-day OR: 0.88, 90-day OR: 0.91, P= <.05), and pneumonia (30-day OR: 0.85, 90-day OR: 0.90, P<.05) at both 30 and 90-days postoperative. There was no statistically significant difference in myocardial infarction

Table 1
Patient Characteristics/Comorbidities of ALIF/LLIF and PLIF/TLIF Groups

	ALIF/LLIF (N= 33,703)		PLIF/TLIF (N = 64,966)		
	N	%	N	%	
Demographics					
Male Sex	15,293	39.69%	29,946	40.75%	P <0.05
Average Age (years)	53.88 (SD=16.53)		57.72 (SD=14.55)		P <0.05
Comorbidities					
Congestive Heart Failure (CHF)	1,354	3.51%	3,107	4.23%	P <0.05
Peripheral Vascular Disease (PVD)	2,523	6.55%	6,772	9.21%	P <0.05
Chronic Pulmonary Disease (COPD)	9,415	24.44 %	18,061	24.57%	P= 0.608
Chronic Kidney Disease	1,807	4.69%	4,362	5.94%	P <0.05
Diabetes Mellitus	9,754	25.32%	21,790	29.65%	P <0.05
Liver disease	3,030	7.86 %	5,672	7.72%	P = 0.224
Smoking	9,241	23.98%	17,287	23.52%	P <0.05
Obesity	7,664	19.89%	14,898	20.27%	P = 0.203

Table 2
Odds of 30-Day Complications in ALIF/LLIF Compared with PLIF/TLIF Group Adjusted for with CCI, Age, and Sex

30 Day Complication	OR	95%	P
Ileus	1.87	(1.65, 2.12)	P= <.05
Lower Extremity DVT	1.19	(1.07, 1.34)	P <0.05
Transfusion	0.66	(0.57, 0.77)	P <0.05
Infection	0.88	(0.81, 0.97)	P <0.05
Stroke	0.79	(0.67, 0.92)	P <0.05
Myocardial infarction	0.80	(0.62, 1.04)	P = 0.101
Pneumonia	0.85	(0.76, 0.96)	P <0.05
Pulmonary Embolism	0.94	(0.77, 1.14)	P = 0.525
Readmission Rate	1.12	(1.06, 1.18)	P<0.05

Table 3
Odds of 90- Day Complications in ALIF/LLIF Compared with PLIF/TLIF Group Adjusted for with CCI, Age, and Sex

90 Day Complication	OR	95%	P
Ileus	1.81	(1.59, 2.04)	P <0.05
Lower Extremity DVT	1.16	(1.06, 1.28)	P <0.05
Transfusion	0.69	(0.60, 0.81)	P <0.05
Infection	0.91	(0.85, 0.99)	P <0.05
Stroke	0.87	(0.77, 0.97)	P <0.05
MI	0.84	(0.68, 1.03)	P = 0.094
Pneumonia	0.90	(0.82, 0.99)	P <0.05
Pulmonary Embolism	0.91	(0.77, 1.07)	P = 0.272
Readmission Rate	1.08	(1.03, 1.13)	P<0.05

or pulmonary embolism between both approaches at 30 and 90-days post-op. The greatest odds ratio differences were found in postoperative ileus (30-day OR: 1.87, P= <.05; 90-day OR: 1.81, P<.05) and transfusion (30-day OR: 0.66, 90-day OR: 0.69, P<.05). While there was a statistical difference in the overall 90-day complication rate between the anterior (9.6%, n=3699) and posterior (10.6%, n=7790) approach, the difference was relatively small.

Discussion

The question of approach to lumbar fusion is debated amongst spine surgeons, and there are advantages and disadvantages to both posterior and anterior approaches [4]. While prior studies have shown slight differences in outcomes between the anterior and posterior approaches, such as improved restoration of disc height in the anterior approach [1] and a lower cage subsidence rate in the posterior approach [5], the majority of studies have concluded that both approaches have similar fusion rates and clinical outcomes [1,4,6–10]. Conversely, the risks of each approach is unique. The anterior approach carries the risk of retrograde ejaculation, visceral and vascular injury, and other complications [6–7,11–15], while the risk from the posterior approach consists of nerve root injury, dural tears, and injury to paraspinal musculature [16]. To get a more complete picture of the advantages and disadvantages of each approach, complications and readmissions must also be investigated. As such, this study aimed to determine differences in postoperative complications and readmissions between the different approaches to lumbar interbody fusion, in order to help the surgeon make a more informed decision regarding the preferred approach for a patient's spinal pathology.

In the largest study of direct outcomes comparing the 30 and 90-day postoperative complications between an anterior vs. posterior approach from 2010-2018, this study found higher odds of stroke, infection, transfusion, and pneumonia in the posterior approach at 30 and 90 days postoperative. Other studies have found no differences in these complications, secondary to lacking statistical power and the possibility of type II errors. This study also found no significant differences in rates of pulmonary embolus or myocardial infarction between both groups and higher odds of lower extremity DVT and ileus in the anterior approach.

Readmissions

Although the anterior approach offered a statistically significant increase in the odds of readmission, the difference in readmission rates was so small that it would unlikely be clinically significant. Qureshi et al. also found the readmissions rate to be higher in the anterior approach group, with a much higher odds ratio of 3.77 (95% CI 3.46-4.10, p<0.001) [4].

Ileus

Ileus was found to be more common in the anterior group at both 30 and 90 days. Scaduto et al, while utilizing a similar methodology but a much smaller sample size of 119 patients within one institution, found that ileus was the most common postoperative complication in the anterior approach cohort (6% of ALIF patients vs. 0% of PLIF patients) [3]. Qureshi et al. also found higher odds of postoperative ileus odds with their anterior cohort, with an odds ratio of 2.09 (95% CI: 1.93-2.27, P<0.001) [4]. Although the anterior approaches utilized today are retroperitoneal, retraction of the abdominal contents is known to result in postoperative ileus.

Lower extremity DVT and pulmonary embolism

This study found a greater odds ratio for lower extremity DVT at both 30 and 90 days in the anterior group. Similarly, the studies performed by Qureshi et al. and Shillingford et al. also found lower extremity DVT to be higher for ALIF patients (OR=1.48, P<0.001 and OR=2.03, p=0.017, respectfully) [4,14].

Interestingly, while higher odds of DVT were found in the anterior approach group, this study found no significant differences between the approaches for developing a postoperative pulmonary embolism. Qureshi et al, [4] Katz et al, [6] and Shillingford et al. [14] also found no significant differences in pulmonary embolism complications between the approaches after adjusting for CCI, age, and sex. One explanation may be that when performing an ALIF or LLIF, many surgeons start chemical DVT prophylaxis earlier than they would with a posterior approach due to decreased worry of an epidural hematoma. Chemical DVT prophylactic agents may decrease the risk the DVT propagation and embolization. Additionally, smaller, more distal DVTs typically do not embolize.

Transfusion rates

This study showed significantly higher transfusion rates utilizing the posterior approach. Compared to the other complications, the odds ratio of transfusion was the second highest of all postoperative complications, and the findings confirmed previous publications concluding that the odds of transfusion are much higher utilizing a posterior approach to lumbar interbody fusion [4,6,18]. These findings suggest that utilizing an anterior approach to lumbar interbody fusion may help reduce the odds of requiring a postoperative transfusion.

A difference in transfusion rates is expected because of the increased muscle disruption during a posterior approach, leading to increased bleeding. The anterior approaches, however, have a higher risk of potentially catastrophic bleeding due to the proximity of major vascular structures. Thankfully, catastrophic bleeding is not a common complication.

Stroke rates

This study found that odds of stroke were lower with the anterior approach at both 30 and 90 days. Katz et al, while utilizing a smaller sample than this study (n = 8,273 ALIF/LLIF patients) also found a lower stroke rate with the anterior approach at 30 days [6]. Conversely, Qureshi et al. and Shillingford et al. found statistically similar odds of postoperative stroke between the two approaches [4,14], perhaps due to the lowered statistical power resulting from an uneven sample size in Qureshi et al. and an overall small sample size in Shillingford et al (n = 2,372 ALIF/LLIF patients) [17]. The findings suggest that patients with a high risk of stroke might benefit from an anterior approach to lumbar interbody fusion.

Pneumonia and infection rates

Pneumonia rates were lower in the anterior cohort at both 30 days and 90 days postoperatively. Qureshi et al. found no difference in odds of developing postoperative pneumonia between both approaches [4]. Infection rates were also lower in the anterior group at both 30 days and 90 days postoperatively. Qureshi et al. also found higher odds of infection in the anterior cohort [4], but with a much higher odds ratio of 1.97 ($p<0.001$). Katz et al. did not find any statistically significant differences between the approaches for postoperative infection [6]. The findings suggest that patients with a high risk for infection and pneumonia may benefit from an anterior approach to lumbar interbody fusion.

This study focused on comparing 30 and 90-day postoperative complications between an anterior and posterior approach to lumbar interbody fusion. It differed from previous smaller-scale studies on the same subject in that it utilized the largest sample of direct outcomes in the past decade from a mixed private and public payer database. With significant statistical power and sample size, this study found differences in odds of postoperative complications where other studies have not. This study found higher odds of stroke, infection, transfusion, and pneumonia in the posterior approach, higher odds of lower extremity DVT and ileus in the anterior approach, and no differences in odds of pulmonary embolus or myocardial infarction between both approaches.

Given that there is no overall agreement on the superiority of an approach and that both approaches have been shown to result in similar fusion rates, [1, 4, 6-10] these findings can help inform surgeons' treatment approach decision-making for certain patient risk profiles. Specifically, the findings suggested that patients with a high risk for stroke, pneumonia, and infection may benefit from using the anterior approach to lumbar interbody fusion. The anterior approach was also associated with a reduced the odds of a postoperative transfusion, suggesting that patients with a high likelihood of requiring transfusion, such as patients with anemia, may benefit from the anterior approach. Conversely, patients with a higher risk for developing lower extremity DVT may benefit from using the posterior approach. Both approaches did not increase the odds of developing other major complications such as pulmonary embolisms or myocardial infarctions.

Limitations

Because the cohorts were selected using CPT codes, no distinction can be made between an anterior, oblique, or lateral approach, which are all included in the same "anterior" code. This is problematic because each of these procedures carries with it unique risks. Additionally, while care was taken to ensure the codes used in the study included or excluded the correct patients, there is an unknown level of error inherent in this system. Error such as failure to code for a complication, over-coding, or under-coding also may skew results, and is impossible to control for in this type of study. Additionally, statistical significance is easier to achieve when such a large cohort is examined, care should be taken not to misinterpret statistical significance for clinical significance.

Conclusions

This is the largest study to date of direct outcomes comparing the 30 and 90-day postoperative complications between an anterior vs. posterior approach to lumbar interbody fusion from 2010-2018. By utilizing a mixed private and public payer database with a sample size of ~112,000 patients, this study found differences in postoperative complications between anterior and posterior approaches, such as increased rates of stroke, transfusion, pneumonia, and infection in the posterior approach. Other studies have found no differences in these complications, secondary to not having enough statistical power, leading to type II errors. This study also confirmed previous publications concluding higher odds of lower extremity DVT and ileus in the anterior approach and no difference in pulmonary embolism or myocardial infarction between approaches. These statistically powered results can be utilized to inform surgeon treatment decisions in the future through the comparison of patients' risk for certain complications. The findings suggest that patients with high risk for strokes, pneumonia, infections or patients with a high likelihood of requiring postoperative transfusion may benefit from using the anterior approach to lumbar interbody fusion. Patients with a high risk for developing lower extremity DVT may benefit from using the posterior approach while both approaches do not lead to increased odds of developing other major complications such as pulmonary embolus or myocardial infarction.

Ethics Approval

This project was classified as "Not Human Subjects Research" by Tulane University Biomedical IRB. As such, review and approval from IRB were waived.

Conflicts of Interest and Source of Funding

No external sources of funding were used for this study. Dr. Saifi reported consulting fees from Nuvasive Inc, support for meeting atten-

dance from Medtronic PLC and Nuvasive Inc, and stock options in Vertera LLC (acquired by Nuvasive Inc.), Alphatec Holdings, Inc, and Huxley Medical, Inc. Dr. Cyriac reported consulting fees from ATEC INC, and teaching arrangements from STRYKER, ATEC INC, and Medtronic PLC.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.xnsj.2022.100182.

Appendix A

Procedure	CPT
Multilevel Fusion (3-7 Level)/(8+Level)/ Revision/Cervical and Thoracic Procedures	CPT-22610, CPT-22585, CPT-22846, CPT-22847, CPT-22847, CPT-22634, CPT-22551, CPT-22554, CPT-22856, CPT-22600, CPT-22590, CPT-22843, CPT-22844, CPT-63050, CPT-22614

Appendix B

Diagnosis	ICD-9- D	ICD-10
Bone Cancer	170.0- 170.9	C410, C411, C412, C413, C414, C419, C4000, C4010, C4020,C4030,
Infection	730.08, 730.18,730.28, 730.88, 730.98	M8618, M8628, M8668, M4620, M9088, M4630,
Metastasis	198.3- 198.5, 192.2	C7931,C7932, C720, C721, C7951, C7952, C7949
Traumatic Spinal Injury	805, 805.01- 805.08, 805.1-805.18, 805.2-805.9, 806.00-806.09, 806.10-806.19, 806.20-806.29, 806.30-806.39,806.4-806.6, 806.61, 806.62, 806.69, 806.70-806.72, 806.79, 806.8,806.9, 952.00- 952.09, 952.10-952.19, 952.2-952.4, 952.8, 952.9	S129XXA, S12000A, S12100A, S12001A, S12200A, S12101A, S12201A, S12300A, S12301A, S12400A, S12500A, S12600A, S12401A,S12501A, S12601A, S12000B, S12100B, S12200B, S12300B, S12400B, S12500B, S12600B, S12001B, S12101B, S12301B, S12401B, S22009A, S22009B, S32009A, S32009B, S3210XA, S3210XB, S322XXA, S322XXB, S14101A, S14111A, S14131A, S14121A, S14151A, S14105A, S14115A, S14135A, S14125A, S14155A, S22019A, S22069A, S22019B, S22069B, S32039A, S32039B, S24101A, S24111A, S24131A, S24151A, S24103A, S24113A, S24133A, S24153A, S24109A, S24139A, S343XXA, S14109A, S22079A, S22079B, S34103A, S22029A, S22039A, S22089A, S22029B, S22039B, S22089B, S22049B, S22059B, S14102A, S14112A, S14106A, S14122A, S14116A, S14132A, S14152A, S14136A, S14126A, S14156A, S22049A, S22059A, S24104A, S24154A, S24134A, S24114A, S34119A, S34113A, S24102A, S24112A, S24132A, S24152A, S34131A, S14103A, S14113A, S14123A, S14133A, S14153A, S14107A, S14117A, S14127A, S14137A, S14157A, S14154A, S14134A, S14124A, S14114A, S14104A,

(continued on next page)

Diagnosis	ICD-9- D	ICD-10
		S14108A, S14118A, S14128A, S14158A, S34132A, S34123A, S34129A, S34101A, S34104A, S34111A, S34114A, S32019A, S32049A, S32029A, S32019B, S32049B, S34121A, S34124A, S32059A, S32029B, S32059B, S34102A, S34105A, S34112A, S34115A, S34122A, S34125A

Appendix C

Diagnosis	ICD-9 -D	ICD-10
Degenerative Disease	722.10, 722.51, 722.52, 722.73, 724.02, 724.03, 738.4	72210, 72251, 72252, 72273, 72402, 72403, 7384, M4300, M4306, M4307, M4309, M4310, M4316, M4317, M4319, M4320, M4326, M4327, M435 × 6, M435 × 7, M435 × 9, M438 × 7, M43 × 9, M5105, M5106, M5116, M5117, M5126, M5127, M5136, M5137, M5146, M5147, M5186, M5187, M4800, M4806, M48061, M48062, M4807, M4810, M4816, M4817, M4819, M4820, M4826, M4827, M488 × 6, M488 × 7, M488 × 9

References

[1] Mobbs RJ, Phan K, Malham G, Seex K, Rao PJ. Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MI-TLIF, OLIF/ATP, LLIF and ALIF. J. Spine Surg 2015;1(1):2–18. doi:10.3978/j.issn.2414-469X.2015.10.05.

[2] Schnake KJ, Rappert D, Storzer B, Schreyer S, Hilber F, Mehren C. Lumbar fusion-Indications and techniques. Orthopade Jan 2019;48(1):50–8 German. doi:10.1007/s00132-018-03670-w.

[3] Scaduto AA, Gamradt SC, Yu WD, Huang J, Delamarter RB, Wang JC. Perioperative complications of threaded cylindrical lumbar interbody fusion devices. J Spinal Disord Tech 2003;16(6):502–7. doi:10.1097/00024720-200312000-00003.

[4] Qureshi R, Puvanesarajah V, Jain A, Shimer AL, Shen FH, Hassanzadeh H. A comparison of anterior and posterior lumbar interbody fusions. Spine 2017;42(24):1865–70. doi:10.1097/brs.0000000000002248.

[5] Teng I, Han J, Phan K, Mobbs R. A meta-analysis comparing Alif, PLIF, TLIF and LLIF. J Clin Neurosci 2017;44:11–17. doi:10.1016/j.jocn.2017.06.013.

[6] Katz AD, Mancini N, Karukonda T, Greenwood M, Cote M, Moss IL. Approach-based comparative and predictor analysis of 30-day readmission, reoperation, and morbidity in patients undergoing lumbar interbody fusion using the ACS-NSQIP DATASET. Spine 2019;44(6):432–41. doi:10.1097/brs.0000000000002850.

[7] Goz V, Weinreb JH, Schwab F, Lafage V, Errico TJ. Comparison of complications, costs, and length of stay of three different lumbar interbody fusion techniques: An analysis of the nationwide inpatient sample database. Spine J 2014;14(9):2019–27. doi:10.1016/j.spinee.2013.11.050.

[8] Phan K, Thayaparan GK, Mobbs RJ. Anterior lumbar interbody fusion versus transforaminal lumbar interbody fusion – systematic review and meta-analysis. Br J Neurosurg 2015;29(5):705–11. doi:10.3109/02688697.2015.1036838.

[9] Udby PM, Bech-Azeddine R. Clinical outcome of stand-alone alif compared to posterior instrumentation for degenerative disc disease: a pilot study and a literature review. Clin Neurol Neurosurg 2015;133:64–9. doi:10.1016/j.clineuro.2015.03.008.

[10] Lee N, Kim KN, Yi S, Ha Y, Shin DA, Yoon DH, Kim KS. Comparison of outcomes of anterior, posterior, and transforaminal lumbar interbody fusion surgery at a single lumbar level with degenerative spinal disease. World Neurosurg May 2017;101:216–26 Epub 2017 Feb 9. PMID: 28189865. doi:10.1016/j.wneu.2017.01.114.

[11] Garg J, Woo K, Hirsch J, Bruffey JD, Dilley RB. Vascular complications of exposure for anterior lumbar interbody fusion. J Vasc Surg 2010;51(4):946–50. doi:10.1016/j.jvs.2009.11.039.

[12] Xu DS, Walker CT, Godzik J, Turner JD, Smith W, Uribe JS. Minimally invasive anterior, lateral, and oblique lumbar interbody fusion: a literature review. Ann Transl Med 2018;6(6):104. doi:10.21037/atm.2018.03.24.

[13] Ye Y-P, Hu J-W, Zhang Y-G, Xu H. Impact of lumbar interbody fusion surgery on postoperative outcomes in patients with recurrent lumbar disc herniation: analysis of the US National Inpatient Sample. J Clin Neurosci 2019;70:20–6. doi:10.1016/j.jocn.2019.10.001.

[14] Shillingford JN, Laratta JL, Lombardi JM, et al. Complications following single-level interbody fusion procedures: An ACS-NSQIP study. J Spine Surg 2018;4(1):17–27. doi:10.21037/jss.2018.03.19.
[15] Manjila SV. Lumbar Interbody Fusions. Elsevier; 2019.
[16] Seong J-H, Lee J-W, Kwon K-Y, Rhee J-J, Hur J-W, Lee H-K. Comparative study of posterior lumbar interbody fusion via unilateral and bilateral approaches in patients with unilateral leg symptoms. J Korean Neurosurg Soc 2011;50(4):363. doi:10.3340/jkns.2011.50.4.363.
[17] Rusticus SA, Lovato CY. Impact of sample size and variability on the power and type i error rates of equivalence tests: a simulation study. Pract Assess Res Eval 2014;19(11). doi:10.7275/4s9m-4e81.
[18] Pradhan BB, Nassar JA, Delamarter RB, Wang JC. Single-level lumbar spine fusion: A comparison of anterior and posterior approaches. J Spinal Disord Tech 2002;15(5):355–61. doi:10.1097/00024720-200210000-00003.

Further reading

[1] Inamasu J, Guiot BH. Vascular injury and complication in neurosurgical spine surgery. Acta Neurochir (Wien) 2005;148(4):375–87. doi:10.1007/s00701-005-0669-1.