Complication Pattern After Percutaneous Cement Discoplasty: Identification of Factors Influencing Reoperation and Length of Hospital Stay

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■ OBJECTIVE: **Percutaneous cement discoplasty (PCD) was introduced to treat symptomatic vertical instability of the lumbar spine in a minimally invasive way. The aim of the present study was to analyze the complication pattern after PCD and to identify factors that predict the chance of cement leakage, reoperation, and length of hospital stay (LOS).**

■ METHODS: **patients were treated with PCD within the study period. Clinical features and complications were analyzed by applying descriptive statistics, whereas perioperative factors predictive of cement leakage, reoperation, and LOS were identified by regression models.**

■ RESULTS: **Cement leakage rate was 30.4% in the total cohort; however, only fifth of them were symptomatic. Cement leakage itself did not have a significant influence on clinical outcome. Other complications and nonsurgical adverse events were registered only in 2.0% of cases. Age, subcutaneous fat tissue thickness, low viscosity cement, lower level of surgeon's experience and the number of operated levels were identified as risk factors of cement leakage ($P < 0.01$; c-index = 0.836). Type of procedure, Charlson comorbidity score, reoperation, and nonsurgical adverse events significantly increased the LOS ($P < 0.01$). Cement leakage, early surgical practice, and increased subcutaneous fat tissue thickness were risk factors for reoperation ($P < 0.01$; c-index = 0.72).**

■ CONCLUSIONS: **PCD is a relatively safe and effective procedure for treating spinal instability caused by advanced-stage disc degeneration characterized by vacuum phenomenon. Cement leakage is not uncommon but is only a radiologic complication without clinical consequences in most cases. On the other hand, it can increase the LOS and is a significant risk factor for reoperation.**

INTRODUCTION

Advanced disc degeneration and related diseases such as degenerative instability and spinal canal stenosis are more frequent in the elderly population. Standard surgical treatment for segmental instability is a spinal fusion procedure that can be performed in several different ways depending on the type of intervertebral fusion technique and stabilization implants. However, elderly individuals often also experience severe comorbidities, which increases the risk of complications after an invasive surgical procedure. Percutaneous cement discoplasty (PCD), introduced by Varga et al.[1] in 2015, is a minimally invasive surgical method for treating symptomatic vertical instability related to advanced disc degeneration characterized by intervertebral vacuum phenomenon in aged patients. Advanced disc degeneration manifests in vacuum phenomenon and causes structural changes in the zygoapophyseal joints leading to altered spinal mobility, which then may lead to segmental

Key words
- Cement leakage
- Complications
- Length of hospital stay
- Percutaneous cement discoplasty
- Predictive factors

Abbreviations and Acronyms
BMI: Body mass index
CCI: Charlson comorbidity index
CT: Computed tomography
LL: Lumbar lordosis
LOS: Length of hospital stay
OR: Operating room
PCD: Percutaneous cement discoplasty
PMMA: Polymethyl methacrylate
SFTT: Subcutaneous fat tissue thickness

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instability.[2,3] Typical indications for PCD technique are elderly patients with mechanical low back pain with or without leg pain; index intervertebral disc characterized by advanced disc degeneration and vacuum sign in >50% of the disc space; vertical instability characterized by pain aggravating in standing position; significant comorbidities that relatively contraindicate more invasive surgeries. The clinical effectiveness of the procedure has been described by several investigators. Sola et al.[4] summarized the rationale of PCD in the elderly, who have an increased risk of postoperative complications related to standard surgical treatment. Kiss et al.[5] reported their clinical results highlighting the improvement of lumbar alignment and indirect foraminal decompression after PCD. Willhuber et al.[6] reported a significant pain reduction at 1-year follow-up based on their 82 cases. The biomechanical aspects of PCD were examined by Techens et al.[7,8] and Éltes et al.[9] and a collagen-modified polymethyl methacrylate (PMMA) was also introduced by Yang et al.[10] to enhance the biointegration of the cement after the procedure. We can conclude that biomechanical evidence supports the use of the method and PCD proved to be efficient regarding disability avoidance and pain reduction. However, the early and late complications of PCD as well as their clinical consequences (e.g., hospital stay, reoperation rate) have not been described.

The primary aim of the present study was the analysis of the complication pattern related to PCDs in a large cohort. Furthermore, we aimed to identify the perioperative variables that can predict the major complications and the length of hospital stay (LOS).

METHODS

Study Design

A retrospective study was carried out at a tertiary-care spine referral center with a population of 10 million. All patients treated surgically between 2009 and 2020 with PCD alone or PCD combined with decompression or vertebroplasty were included in the study. All cases had at least a 1-year follow-up. Procedures in which PCD was combined with transpedicular fixation, cases in which PCD was performed during revision surgery, and patients with previous stabilization surgery or with previous PCD in another segment were all excluded from the study (Figure 1). This study was reviewed by the National Institute of Pharmacy and Nutrition (reference number OGYÉI/163–4/2019) and the need for patient informed consent was not required because of the retrospective nature of the study and de-identified data used.

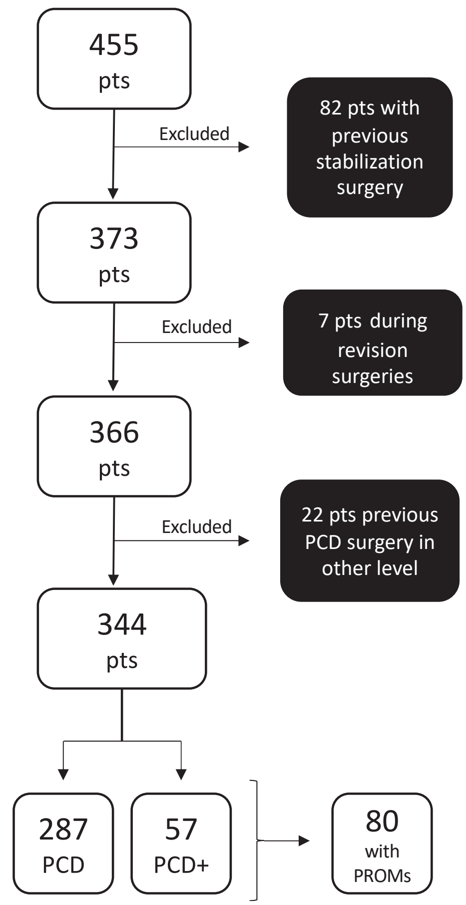

Figure 1. Study cohort. PCD, percutaneous cement discoplasty; PROM, patient-reported outcome measure; pts, patients.

Operative Procedure

During PCD, patients are placed in a prone position and fluoroscopy is used to check the surgical steps. First, the index lumbar segment is determined by fluoroscopic imaging and after a small skin incision, a Jamshidi needle is inserted into the index intervertebral disc, then a K-wire is adjusted through the needle. In the next step, a trocar or a cementing needle is guided over the K-wire, which is then removed. For instance, the index segment is double-checked by fluoroscopy. PMMA paste is injected through the trocar or cementing needle into the disc space under fluoroscopic control. In the case of multilevel procedures, the previous steps are repeated. After the PMMA has solidified, the trocar can be removed. A final radiographic image was made to check the result in the operating room (OR). The procedure is performed under local or general anesthesia depending on the general condition of the patient.

Data Collection

Preoperative, intraoperative, and postoperative clinical data were collected from medical charts including age, comorbidities, body mass index (BMI, calculated as weight in kilograms divided by the square of height in meters), subcutaneous fat tissue thickness (SFTT), preoperative symptoms, OR time, operated levels, type of PMMA (high-viscosity vs. low-viscosity PMMA), and complications. LOS was defined as the number of nights spent in hospital after surgery. SFTT was defined as the vertical distance from the tip of the spinous process of the L1 vertebra to the skin on preoperative T2-weighted axial lumbar magnetic resonance imaging.[11,12] Standing lumbar lateral radiography was carried out to detect spondylolisthesis and measure the spinopelvic parameters: pelvic incidence, sacral slope, pelvic tilt, and lumbar lordosis (LL) (L1-S1 LL, between L1 and S1 vertebrae; L4-S1 LL, between L4 and S1 vertebrae). Anteroposterior standing radiography was used to measure lumbar scoliosis with the Cobb method. All the radiologic measurements were performed with eRAD PACS (picture archiving and communication system) viewer 8.0 (eRAD, Greenville, South Carolina, USA).

Intraoperative, early (<40 days), and late (>40 days) complications were collected. Cement leakage was diagnosed by fluoroscopy or postoperative radiography and computed tomography (CT) scans. Leakage was categorized as asymptomatic or symptomatic and by its anatomic location (neuroforamen, spinal canal, and paravertebral region) (Figure 2). Clinical outcome was evaluated on the prospectively collected data of a subset of percutaneously operated patients. The Oswestry Disability Index for function and visual analog scale for pain were completed preoperatively and 6 months after the index surgery.

Statistical Analysis

For analysis of the demographics and surgical characteristics and evaluation of complications, patients were divided into 2 subgroups (procedure type variables): patients with only PCD (PCD) and patients with an additional procedure such as decompression or vertebroplasty (PCD+). The differences between the 2 subgroups were calculated by using the Mann-Whitney U test for continuous and χ^2 test for categorical variables. The effect of several perioperative variables on the presence of symptomatic cement leakage was analyzed by a multivariate logistic regression model. The enter method of logistic regression was used to examine the effect of age, SFTT, pelvic incidence, sacral slope, lumbar scoliosis, LL, spondylolisthesis, OR time, type of PMMA, level of surgeon's experience, number of operated levels, and procedure type (PCD, PCD+). Because PCD is a fairly new procedure the level of experience variable was created with a cutoff at 5 years from inception. Similarly, in a multiple linear regression model, the effect of several perioperative variables on LOS was studied. Postoperative recurrent pain and postoperative motor and sensory deficit were analyzed as a united variable called "postoperative symptoms." All complications that were not related directly to surgery (e.g., hypokalemia, arrhythmia, and urinary tract infection) were analyzed also as "nonsurgical adverse events" united variable. Risk factors for a subsequent surgery (reoperation) were analyzed in a backward conditional multivariate logistic regression model by using demographic and perioperative variables. The probability of logistic regressions was used as a test variable in a receiver operating characteristic analysis to calculate the c-index of the model. Results of the Oswestry Disability Index and visual analog scale questionnaires were analyzed applying paired t tests according to the occurrence of cement leakage. All statistical analyses were conducted with SPSS version 27.0 (IBM Corp., Armonk, New York, USA) and P values <0.05 were considered significant.

Figure 2. Demonstrative case before after percutaneous cement discoplasty procedure. (**A** and **B**) Preoperative computed tomography scan showing the typical signs of advanced disc degeneration at LI/II: vacuum phenomenon in the intervertebral disc reduced disc height and sclerotic end plate changes; (**C** and **D**) Postoperative radiographs showing the injected polymethyl methacrylate in the index disc and the increased disc height.

RESULTS

Demographic Data

In the study period, 344 patients were treated with the PCD technique. Fifty-seven of 344 (16.6%) underwent an additional procedure such as decompression or vertebroplasty (PCD+), whereas 287 (83.4%) underwent only PCD (PCD). The female/male ratio was 257:87, and the mean age was 72 years (range, 41–90) within the whole cohort. The median BMI was 30 kg/m² (range, 19–63) in the PCD group and 28 kg/m² (range, 18–43) in the PCD+ group. The median SFTT was 15.5 mm (range, 3.0–26.4) in the PCD group and 17.2 mm (range, 2.3–45.1) in the PCD+ group. The median Charlson Comorbidity Index (CCI) was 4 (range, 0–11). Fifty patients (17.4%) in the PCD group and 12 patients (21.1%) in the PCD+ group had undergone previous lumbar surgery such as discectomy or decompression. Detailed characteristics of the 2 groups are presented in Table 1.

In both groups, most of the patients had typical mechanically induced symptoms before surgery. All of the patients' spinal pain was exacerbated in standing or sitting positions. Back pain proved to be dominant in 73.3% of patients (252). Concomitant leg pain was more common (47.4% vs. 32.1%; P = 0.031) in the PCD+ group and these patients also experienced preoperative sensory deficit more frequently (28.1% vs. 15.3%; P = 0.028).

In most surgery, low-viscosity PMMA was used (60.8%). A significant difference was found in the distribution of the operated

Table 1. Demographic and Surgical Characteristics of the Patients

	Total Cohort (N = 344)	PCD (N = 287)	PCD+ (N = 57)
Gender (male/female)	87:257	72:215	15:42
Age (years), median (range)	72 (41–90)	72 (41–90)	72 (53–87)
Body mass index (kg/m²), median (range)	30 (18–63)*	30 (19–63)	28 (18–43)
Subcutaneous fat tissue thickness (mm), median (range)	16.9 (2.3–45.1)	15.5 (3–26.4)	17.2 (2.3–45.1)
Charlson Comorbidity Index, median (range)	4 (1–11)	4 (1–11)	4 (2–7)
Previous lumbar surgery, n (%)	62 (18)	50 (17.4)	12 (21.1)
Back pain, n (%)	252 (73.3)	210 (73.2)	42 (73.7)
Leg pain, n (%)	119 (34.6)*	92 (32.1)	27 (47.4)
Motor deficit, n (%)	10 (2.9)	7 (2.4)	3 (5.3)
Sensory deficit, n (%)	60 (17.4)*	44 (15.3)	16 (28.1)
Operated level, n (%)			
1	124 (36)	92 (32.1)	32 (56.1)
2	116 (33.7)	96 (33.4)	20 (35.1)
3	41 (11.9)	39 (13.6)	2 (3.5)
4	47 (13.7)	45 (15.7)	2 (3.5)
5	11 (3.19)	10 (3.5)	1 (1.8)
6	5 (1.5)	5 (1.7)	0 (0.0)
Cement type, n (%)			
Low viscosity	209 (60.8)	176 (61.3)	33 (57.9)
High viscosity	135 (39.2)	111 (38.7)	24 (42.1)
Operating room time (minutes), median (range)	30 (10–225)*	30 (10–160)	70 (15–225)
Additional procedure, n (%)			
Decompression	48 (13.9)	N/A	48 (84.2)
Vertebroplasty	9 (2.6)	N/A	9 (15.8)
Length of hospital stay (days), median (range)			
Median	3 (1–21)*	3 (1–16)	3 (3–21)
In case of no complication	3 (1–14)	2.5 (1–9)	3 (2–15)
In case of any complication	4 (2–21)	4 (2–16)	5 (3–21)

PCD, percutaneous cement discoplasty; N/A, not applicable.
*Significant difference between surgical subgroups ($P < 0.05$).

levels between the subgroups. Of the PCD+ group patients, 91.2% had only 1-level or 2-level surgery, whereas 34.5% of the patients in the PCD group had more than 2-level (3—6) surgery. In the PCD+ group, 22 patients (38.6%) had concomitant unilateral decompression, 26 (45.6%) had bilateral (over-the-top) decompression, and 9 (15.8%) had vertebroplasty combined with the PCD. In the PCD group, the median OR time was 30 minutes (range, 10—160), which was significantly shorter than in the PCD+ group, for whom the median OR time was 70 minutes (range, 15—225).

Table 2 shows the results of spinopelvic parameters before and after PCD. L1-S1 lordosis was significantly improved as a result of the surgery.

Complications

Table 3 shows the early and late postoperative complications in the cohort. In 1 case (0.3%), a conversion to open surgery was needed because of the inability to perform the PCD. No intraoperative complication was found in the PCD+ group.

However, cement leakage noticed in the early postoperative period was not uncommon: 33.7% of PCD patients and 12.2% of PCD+ patients had any type of cement leakage from the disc space even if most of them were asymptomatic (82 asymptomatic [23.8%], "radiologic leakage" vs. 22 symptomatic [6.4%], "clinical leakage" cases). Among patients with postoperative symptoms (radicular pain and/or neurologic symptoms), cement leakage was observed on the postoperative CT scans in 22 patients (75.8%), but there was no cement leakage in 7 patients (24.2%). Surgical site infection was found in only 2 patients (0.6%), both in the PCD+ group. There was no wound infection in the PCD group ($P <$ 0.001). During index hospitalization, 8 patients (2.3%) required revision surgery, all of which was a result of symptomatic cement leakage. Nonsurgical adverse events were registered in 2% of the total cases. Early rehospitalization was defined as readmission within the first 40 days after discharge. The reason for readmission was residual/recurrent pain syndrome in all cases. Nonsurgical treatment was needed in 7 patients (2%) because of minor foraminal cement leakage. Reoperation (decompression) was needed in 7 patients (2%), because of cement leakage into the spinal canal.

Patients requiring subsequent spine surgery in the late postoperative period (>40 days) were analyzed in more detail. Fifty-four surgeries were performed, representing 15.6% of the total cohort. The median time to reoperation was 11 months after the index PCD. The indication for the late reoperation was nerve root compression at the PCD level in 31 patients (9.0%), segmental instability because of cement subsidence in 12 (3.4%), adjacent segment disease in 8 (2.3%, and vertebral compression fracture in 3 (0.9%). Open stabilization was required in 15 patients (27.7% of reoperations), whereas 5 patients (1.5%) were treated with a repeated PCD at the index level.

Table 2. Preoperative and Postoperative Radiologic Parameters of the Cohort

	Preoperative, Median (Range)	Postoperative, Median (Range)
Pelvic incidence (°)	54 (14—92)	54 (15—94)
Sacral slope (°)	34 (17—61)	35 (16—63)
L1-S1 LL (°)	41 (9—80)	46 (20—85)*
L4-S1 LL (°)	33 (7—61)	33 (10—65)
Lumbar scoliosis (°)	9 (1—36)	8 (1—35)

LL, lumbar lordosis.
*Significant difference between the 2 measurements ($P < 0.05$).

Risk Factors for Cement Leakage

Table 4 shows the effect of several perioperative variables on the occurrence of cement leakage. Older age, higher SFTT, low-viscosity PMMA, number of operated levels, and surgery performed in the first 5 years (first 5-year practice) showed significant risk for cement leakage in a significant model ($P < 0.01$; $R^2 = 0.42$; c-index = 0.836) (Figure 3).

Predictors of LOS

The median LOS was 3 days in the total cohort (range, 1—21), with a significant difference between the 2 surgical subgroups ($P < 0.001$). Patients without any complications were discharged significantly earlier compared with those who had any complication (median LOS, 2.5 vs. 4 in PCD and 3 vs. 5 days in PCD+ cohort; $P < 0.01$). PCD+, high CCI, early reoperation, postoperative symptoms, and nonsurgical adverse events had a significant effect on LOS ($P < 0.01$; $R^2 = 0.40$) (Table 5).

Effect of Cement Leakage on Treatment Outcome

Eighty patients were included in the prospective clinical data collection by completing the patient questionnaires on disability and pain. The ratio of radiologic cement leakage was the same in this subcohort (29 of 80 patients; 36.3%) as in the total cohort ($\chi^2 = 0.167$; degree of freedom = 1; $P = 0.68$). Both spinal function and pain significantly improved after the PCD ($P < 0.01$), independently of the occurrence of cement leakage (Figure 4).

Risk Factors for Reoperation

Occurrence of cement leakage, increased SFTT, and first 5-year practice were independent risk factors for reoperation, whereas PCD+ surgery had a trend to a significant protective effect in the whole model ($P < 0.001$; $R^2 = 0.22$; c-index = 0.717) (Table 6).

DISCUSSION

Complication patterns and risk factors associated with poor surgical outcomes are important considerations of surgical procedures even in the case of a minimally invasive technique. PCD is a new minimally invasive surgery procedure mostly applied to patients for whom traditional spinal stabilization surgery is relatively or absolutely contraindicated. The demographic characteristics of our cohort support this aspect. PCD was performed in an elderly population characterized by a relatively high BMI, increased SFTT, and a median of 4 points on CCI. The CCI corresponds with a 10-year mortality of 47% of cases.[13] Complications in such a population are not rare after spinal surgery. Hon et al.[14] reported a 43.8% and 56.7% complication rate among patients aged ≥65 and ≥80 years after lumbar spinal fusion. In the

Table 3. Summary of Complications and Reoperations

	Total Cohort (N = 344), n (%)	PCD (N = 287), n (%)	PCD+ (N = 57), n (%)
Early complications (<40 days)			
Conversion to open surgery	1 (0.3)	1 (0.3)	Not applicable
Cement leakage	104 (30.2)*	97 (33.7)	7 (12.3)
Asymptomatic cement leakage	82 (23.8)*	76 (26.5)	6 (10.5)
Neuroforamen	56 (16.3)	52 (18.1)	4 (7)
Spinal canal	16 (4.7)	16 (5.6)	—
Paravertebral region	14 (4.1)	13 (4.5)	2 (3.5)
Symptomatic cement leakage	22 (6.4)*	21 (7.3)	1 (1.8)
Neuroforamen	18 (5.2)	16 (5.6)	2 (3.5)
Spinal canal	9 (2.6)	8 (2.8)	1 (1.8)
Symptoms in cement leakage subgroup	22 (6.4)*	21 (7.3)	1 (1.8)
Leg pain	18 (5.2)	17 (5.9)	1 (1.8)
Back pain	2 (0.6)	2 (0.7)	—
Motor deficit	4 (1.2)	3 (1)	1 (1.8)
Sensory deficit	9 (2.6)	9 (3.1)	—
Symptoms without cement leakage	7 (2)	4 (1.4)	3 (5.3)
Leg pain	3 (0.9)	1 (0.3)	2 (50.2)
Back pain	—	—	—
Motor deficit	—	—	—
Sensory deficit	4 (1.2)	3 (1)	1 (1.8)
Wound infection	2 (0.6)*	—	2 (3.5)
Reoperation during hospitalization	8 (2.3)	7 (2.4)	1 (1.8)
Nonsurgical adverse events	7 (2)*	4 (1.4)	3 (5.3)
Hypokalemia	6 (1.7)	2 (0.7)	4 (7)
New-onset arrhythmia	5 (1.5)	2 (0.7)	3 (5.3)
Urinary tract infect	4 (1.2)	3 (1)	1 (1.8)
Early rehospitalization	14 (4.1)	12 (4.2)	2 (3.5)
Nonsurgical treatment	7 (2)	6 (2.1)	1 (1.8)
Early reoperation	7 (2)	6 (2.1)	1 (1.8)
Late complications requiring subsequent surgery (>40 days)			
Late revision surgeries	54 (15.6)	44 (15.3)	10 (17.5)
Indication for late reoperation			
Nerve root compression	31 (9)	27 (9.4)	4 (7)
Cement subsidence	12 (3.4)	11 (3.8)	1 (1.8)
Adjacent segment disease	8 (2.3)	5 (1.7)	3 (5.3)
Vertebral fracture in adjacent vertebras	3 (0.9)*	1 (0.3)	2 (3.5)

Continues

Table 3. Continued

	Total Cohort (N = 344), n (%)	PCD (N = 287), n (%)	PCD+ (N = 57), n (%)
Surgical treatment of late complications			
Decompression in PCD level	31 (9)*	27 (9.4)	4 (7)
Open stabilization surgery	15 (4.4)	11 (3.8)	4 (7)
Re-PCD	5 (1.5)	5 (1.7)	—
Vertebroplasty	3 (0.8)*	1 (0.3)	2 (3.5)
Months to subsequent surgery	11 (1.5—87)	10 (1.5—87)	13 (4—74)

PCD, percutaneous cement discoplasty.
*Significant difference between surgical subgroups ($P < 0.05$).

elderly severely frail subgroup, a complication rate of 60% was reported by Moses et al.,[15] who studied single-level transforaminal interbody fusion. Deyo et al.[16] found an 18% complication rate after analyzing a heterogeneous cohort of spine surgeries in patients older than 75 years. Carreon et al.[17] identified prolonged LOS with a high complication rate in elderly patients after posterior lumbar decompression and arthrodesis. Balabaud et al.[18] found any type of complication in 29.7% of the analyzed instrumented lumbar surgeries in elders, whereas Becker et al.[19] showed an 18.9% minor and 14.7% major complication rate after instrumented lumbar fusion in elderly patients. Benz et al.[20] reported a total complication rate of 40% after posterior lumbar spine procedures in a cohort with a mean age >75 years.

In this context, the overall complication rate related to PCDs in our cohort was relatively low (35%), emphasizing that most (68%) of the complications (asymptomatic cement leakage) did not require medical interventions and did not affect the patient's hospital stay or long-term surgical outcome. Only 1 PCD (0.3%) in the total cohort had to be converted to an open procedure because of the anatomic circumstances. Some nonsurgical adverse events that are frequent after spinal surgeries (e.g., thromboembolism, pneumonia, and sepsis) did not occur in the cohort, whereas other medical conditions such as hypokalemia, arrhythmia, and urinary tract infection were also rare (1%—2%). Similar findings were reported by Camino-Willhuber et al.,[21] who found a low (16%) short-term complication rate after PCD; most of the complications were minor and the reoperation rate was relatively low (5.7%).

Among the complications cement leakage was the most frequent; however, most of the extravasations were asymptomatic and were detected by coincidence on routine postoperative radiography/CT. The cement leakage rate was similar after vertebroplasty in previous studies.[22,23] We did not find any significant

Table 4. Multivariate Logistic Regression Analysis of Selected Factors on Cement Leakage ($P < 0.01$; Wald = 28.893; $R^2 = 0.43$; c-index = 0.836)

	B (Standard Error)	Wald	Odds Ratio (Confidence Interval)	*P*
Age	0.035 (0.011)	10.540	1.035(1.014—1.057)	**0.001**
Subcutaneous fat tissue thickness	0.072 (0.025)	8.420	1.075 (1.024—1.129)	**0.004**
First 5-year practice	1.130 (0.383)	8.720	1.376 (1.014—1.867)	**0.003**
Spondylolisthesis	—2.069 (1.296)	1.000	0.998 (0.789—2.233)	0.999
Sacral slope	0.032 (0.028)	1.350	1.033 (0.978—1.091)	0.245
Pelvic incidence	—0.021 (0.018)	1.405	0.979 (0.946—1.014)	0.236
L1-S1 LL	0.018 (0.017)	1.036	1.018 (0.984—1.053)	0.309
L4-S1 LL	0.015 (0.018)	0.673	1.015 (0.979—1.053)	0.412
Lumbar scoliosis	—0.006 (0.027)	0.058	0.994 (0.943—1.047)	0.809
Type of cement	0.319 (0.156)	4.206	1.376 (1.014—1.867)	**0.040**
No of operated levels	1.058 (0.540)	3.838	2.880 (1.005—8.297)	**0.049**
Procedure type	0.256 (0.400)	0.408	1.291 (0.589—2.830)	0.523
Operating room time	0.008 (0.006)	1.604	0.992 (0.981—1.004)	0.205

Bold values indicates significant values, $P < 0.05$.
LL, lumbar lordosis.

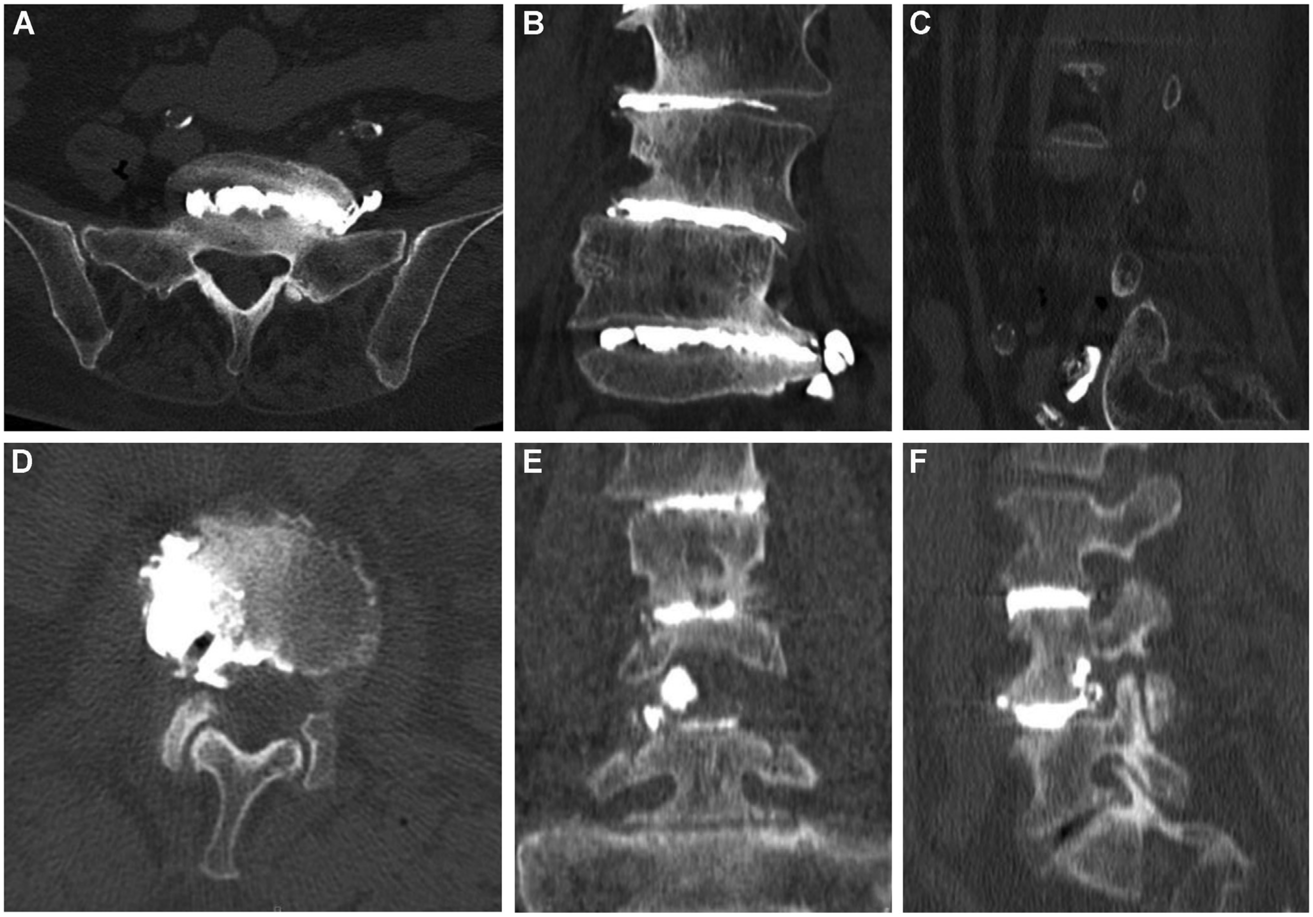

Figure 3. Typical types of cement leakage. (**A**–**C**) Asymptomatic, paravertebral leakage at LV/SI level on the postoperative computed tomography scan (radiologic cement leakage). (**D**–**E**) Symptomatic leakage at LIV/V level resulted in central spinal canal and neuroforamen stenosis requiring a surgical decompression.

influence of cement leakage itself on long-term clinical outcomes; general improvement in spinal function and pain after PCD was the same independently from the occurrence of cement leakage. On the other hand, cement leakage can cause clinically relevant adverse events such as motor or sensory deficit and/or pain and it was significantly associated with a 5-fold risk for reoperation. In

Table 5. Multiple Linear Regression Analysis of Certain Factors on Length of Hospital Stay ($P < 0.01$; $R^2 = 0.40$)

	B (Standard Error)	*t*	*P*
Age	0.001 (0.002)	2.912	0.922
Number of operated levels	0.017 (0.036)	0.467	0.634
Procedure type (percutaneous cement discoplasty +)	0.184 (0.045)	4.075	**<0.001**
Subcutaneous fat tissue thickness	0.016 (0.005)	0.665	0.667
Charlson Comorbidity Index	0.037 (0.011)	3.374	**0.001**
Reoperation	0.490 (0.115)	4.157	**<0.001**
Postoperative symptoms	0.429 (0.063)	5.757	**<0.001**
Nonsurgical adverse event	0.574 (0.084)	6.849	**<0.001**

Bold values indicates significant values, $P < 0.05$.

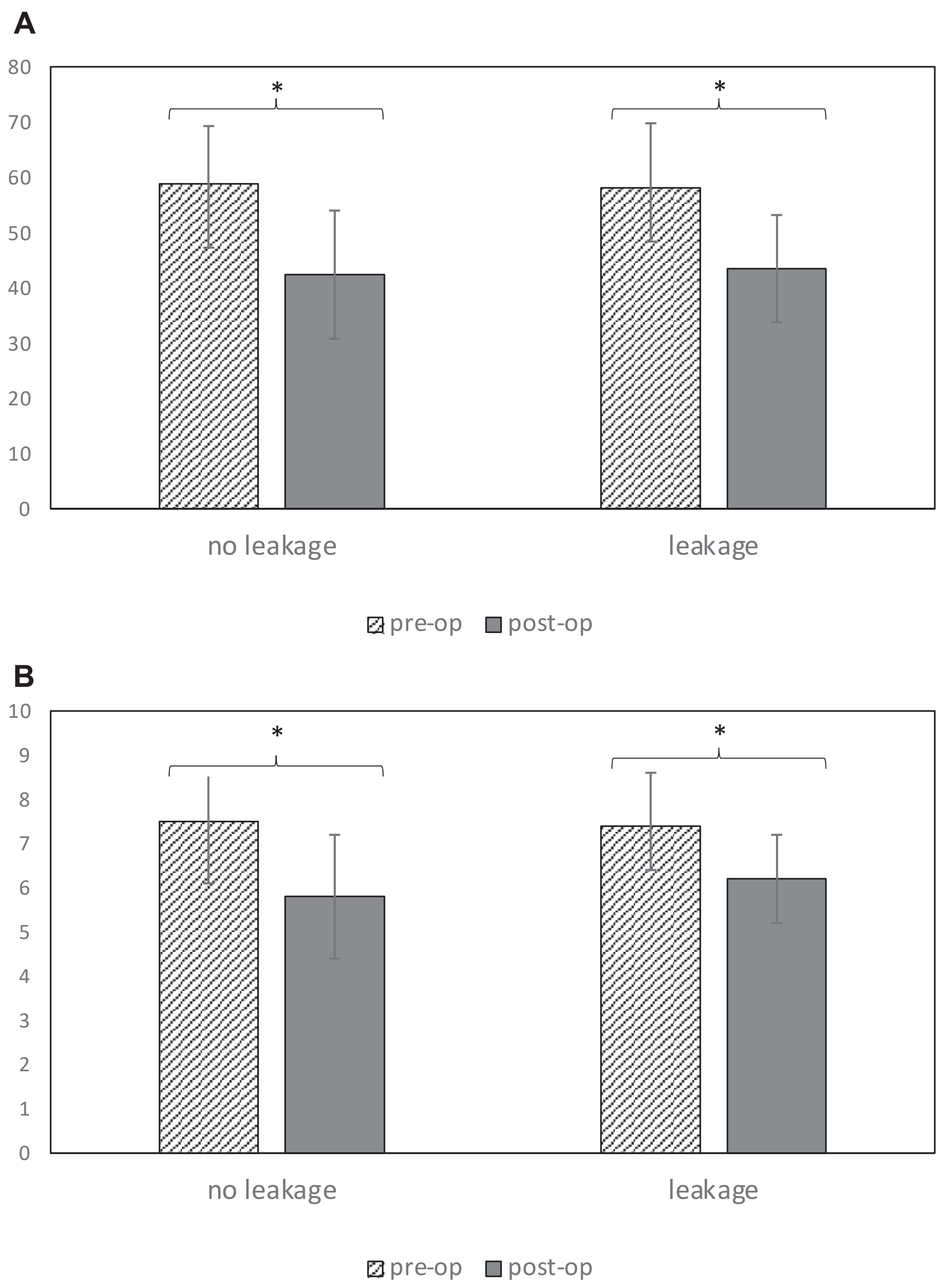

Figure 4. Preoperative (pre-op) and postoperative (post-op) Oswestry Disability Index (**A**) and pain visual analog scale scores (**B**). Oswestry Disability Index and visual analog scale scores decreased significantly among patients both with cement leakage and without cement leakage. *shows the significant difference between the 2 measurements ($P < 0.01$).

our analysis, the probability of cement leakage was significantly related to the viscosity of the injected bone cement and, hence, low-viscosity type PMMA meant a potential hazard for leakage. Similarly, Ding et al.[24] also identified low viscosity as a risk factor for certain types of cement leakage after vertebroplasty. Bohl et al.[25] highlighted the importance of waiting time before

Table 6. Final Result of the Backward Multivariate Logistic Regression Analysis on Risk for Reoperation ($P < 0.01$; $R^2 = 0.22$; c-index = 0.72)

	B (Standard Error)	Wald	Odds Ratio (Confidence Interval)	*P*
First 5-year practice	0.700 (0.328)	4.543	2.017 (1.058—3.860)	**0.036**
Percutaneous cement discoplasty+	−0.865 (0.449)	3.706	0.431 (0.15—1.016)	0.054
Cement leakage	1.621 (0.353)	21.093	5.057 (2.532—10.098)	**<0.001**
Subcutaneous fat tissue thickness	0.056 (0.029)	3.900	1.077 (1.033—1.211)	**0.049**

Bold values indicates significant values, $P < 0.05$.

injecting the PMMA during vertebroplasty, because higher viscosity reduces the probability of leakage. The number of operated levels was also associated with the risk of cement leakage in our cohort, in which the association is obvious.

Patient-reported outcome measures significantly improved after surgery in our subgroup, which is in correlation with previous studies that have examined the effect of PCD on quality of life.[1,4-6]

An important factor in all types of surgical intervention is the experience of the surgeon/surgical team in the implementation of a particular intervention. Many investigators have described that the risk for complications as well as for revision surgeries is higher at the beginning of the surgical practice (i.e., learning curve or training phase), which supports our results.[26-28] We found that PCDs performed in the first 5 years after the development of the technique (training phase) were characterized by a higher risk for cement leakage and reoperation compared with the surgery carried out later.

Two patient-specific factors (age and SFTT) were associated with the risk for cement leakage and increased SFTT also predisposed the patient to reoperation. Older age had already been reported by others as a risk factor for cement leakage after vertebroplasties[22,23] and age was independently associated with other complications after different spinal surgeries.[29-31] After Berikol et al.,[11] we used SFTT to describe obesity and local fat thickness. SFTT can be a more reliable tool to assess obesity-related surgical issues. In line with our results, the association of risk for cement leakage and obesity was previously reported in the case of vertebral augmentation procedures[32-34] and obesity is a well-described patient-specific risk factor for intraoperative and postoperative complications in open spine surgeriy.[35-37] Our findings support the previously reported data that obesity should be considered as a risk factor for complications and reoperations in percutaneous procedures, too.

LOS is an important indicator of surgical procedures; however, it is influenced by different factors, including some nonmedical, such as coding rules and social and family issues. Nevertheless, identifying possible prolonging factors of LOS can help the surgeon and the medical institution in the preoperative planning, and the factors significantly influencing LOS can be determined on a homogenous, institutional cohort. Li et al.[38] described a mean hospital stay of 13 days in elderly patients that required lumbar spinal fusion. Son et al.[14] examined elderly (<65 and <80 years) and super-elderly (>80 years) spine patients with a mean of 27 and 33 days LOS. Zheng et al.[39] analyzed revision posterior lumbar fusion and decompression surgery and showed a mean hospital stay of 6 days. Rajpal et al.[40] described a mean of 4.1 days LOS after single-level lumbar fusion surgery. In our cohort, the median LOS was 3 days. So, patients spent generally 2 days in the hospital after the PCD (the first postoperative day is the start of mobilization and imaging control; the second is discharge to home). LOS showed a significant connection with the comorbidities and the complications/postoperative symptoms, supporting the findings of other investigators describing these associations in the cases of different spine surgeries.[40-44]

There are some limitations to this current study. First, despite the prospectively collected clinical data, the retrospective analysis is a possible limitation to the interpretation of the results. Second, the lack of a control group treated by an open fusion technique and its comparison with PCD may also be considered as a limitation; however, such analysis was not among the specific aims of this current study. Although the sample size was large, monocentric data collection and the lack of external validation can also limit the generalization of the results.

CONCLUSIONS

Besides the previously reported good clinical outcome,[4-6] we can conclude that PCD can be characterized by a relatively low postoperative complication rate and short LOS. Major surgical or nonsurgical complications, as well as reoperations, are rare in this cohort; however, our findings underline some important variables associated with poorer treatment outcomes: 1) cement leakage is asymptomatic in most cases, but it should be avoided because of its association with postoperative symptoms and risk for reoperation; 2) use of high-viscosity cement and surgeon's experience are the non—patient-dependent factors helping to avoid cement leakage, reoperation, and, thus, longer LOS; 3) obese patients have a higher risk for cement leakage as well as for reoperation and comorbidities are important factors on LOS even in the case of this minimally invasive surgery procedure.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Kristof Koch: Conceptualization, Methodology, Data curation, Writing — original draft. **Zsolt Szoverfi:** Conceptualization, Methodology, Data curation, Writing — original draft. **Gabor Jakab:** Supervision. **Peter Pal Varga:** Supervision. **Zoltan Hoffer:** Writing — review & editing. **Aron Lazary:** Writing — review & editing, Supervision.

REFERENCES

1. Varga P, Jakab G, Bors I, Lazary A, Szövérfi Z. Experiences with PMMA cement as a stand-alone intervertebral spacer. Percutaneous cement discoplasty in the case of vacuum phenomenon within lumbar intervertebral discs. *Orthopade*. 2015;44:124-131.
2. Kanna RM, Hajare S, Thippeswamy PB, Shetty AP, Rajasekaran S. Advanced disc degeneration, biplanar instability and pathways of peri-discal gas suffusion contribute to pathogenesis of intradiscal vacuum phenomenon. *Eur Spine J*. 2022;31:755-763.
3. Ekşi MŞ, Özcan-Ekşi EE, Akkaş A, et al. Intradiscal vacuum phenomenon and spinal degeneration: a cross-sectional analysis of 219 subjects. *Curr Med Res Opin*. 2022;38:255-263.
4. Sola C, Willhuber GC, Kido G, et al. Percutaneous cement discoplasty for the treatment of advanced degenerative disk disease in elderly patients. *Eur Spine J*. 2018;30:2200-2208.
5. Kiss L, Varga PP, Szoverfi Z, Jakab G, Eltes PE, Lazary A. Indirect foraminal decompression and improvement in the lumbar alignment after percutaneous cement discoplasty. *Eur Spine J*. 2019;28:1441-1447.
6. Camino Willhuber G, Kido G, Pereira Duarte M, et al. Percutaneous cement discoplasty for the treatment of advanced degenerative disc conditions: a case series analysis. *Global Spine J*. 2020;10:729-734.
7. Techens C, Palanca M, Éltes PE, Lazáry Á, Cristofolini L. Testing the impact of discoplasty on the biomechanics of the intervertebral disc with simulated degeneration: an in vitro study. *Med Eng Phys*. 2020;84:51-59.
8. Techens C, Montanari S, Eltes P, Lazary A, Cristofolini L. Spine stability and disc strains after percutaneous cement discoplasty. *Brain and Spine*. 2021;1, 100079.
9. Eltes PE, Kiss L, Bereczki F, et al. A novel three-dimensional volumetric method to measure indirect decompression after percutaneous cement discoplasty. *J Orthop Translat*. 2021;28:131-139.
10. Yang L, Kong J, Qiu Z, et al. Mineralized collagen-modified PMMA cement enhances bone integration and reduces fibrous encapsulation in the treatment of lumbar degenerative disc disease. *Regen Biomater*. 2020;7:181-193.
11. Berikol G, Ekşi MŞ, Aydın L, Börekci A, Özcan-Ekşi EE. Subcutaneous fat index: a reliable tool for lumbar spine studies. *Eur Radiol*. 2022;32:6504-6513.
12. Özcan-Ekşi EE, Kara M, Berikol G, Orhun Ö, Turgut VU, Ekşi MŞ. A new radiological index for the assessment of higher body fat status and lumbar spine degeneration. *Skeletal Radiol*. 2022;51:1261-1271.
13. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chron Dis*. 1987;40:373-383.
14. Son HJ, Jo Y-H, Ahn HS, You J, Kang C-N. Outcomes of lumbar spinal fusion in super-elderly patients aged 80 years and over: comparison with patients aged 65 years and over, and under 80 years. *Medicine (Baltimore)*. 2021;100:e26812.
15. Moses ZB, Oh SY, Fontes RB, Deutsch H, O'Toole JE, Fessler RG. The modified frailty index and patient outcomes following transforaminal lumbar interbody fusion surgery for single-level degenerative spine disease. *J Neurosurg Spine*. 2021;1:1-7.
16. Deyo R, Cherkin D, Loeser J, Bigos S, Ciol M. Morbidity and mortality in association with operations on the lumbar spine. The influence of age, diagnosis, and procedure. *J Bone Joint Surg Am*. 1992;74:536-543.
17. Carreon LY, Puno RM, Dimar JR, Glassman SD, Johnson JR. Perioperative complications of posterior lumbar decompression and arthrodesis in older adults. *J Bone Joint Surg Am*. 2003;85:2089-2092.
18. Balabaud L, Pitel S, Caux I, et al. Lumbar spine surgery in patients 80 years of age or older: morbidity and mortality. *Eur J Orthop Surg Traumatol*. 2015;25:205-212.
19. Becker P, Bretschneider W, Tuschel A, Ogon M. Life quality after instrumented lumbar fusion in the elderly. *Spine (Phila Pa 1976)*. 2010;35:1478-1481.
20. Benz RJ, Ibrahim ZG, Afshar P, Garfin SR. Predicting complications in elderly patients undergoing lumbar decompression. *Clin Orthop Relat Res*. 2001;384:116-121.
21. Camino-Willhuber G, Norotte G, Bronsard N, et al. Percutaneous cement discoplasty for degenerative low back pain with vacuum phenomenon: amulticentric study with a minimum of 2 Years of follow-up. *World Neurosurg*. 2021;155:e210-e217.
22. Tang B, Cui L, Chen X, Liu Y. Risk factors for cement leakage in percutaneous vertebroplasty for osteoporotic vertebral compression fractures: an analysis of 1456 vertebrae augmented by low-viscosity bone cement. *Spine (Phila Pa 1976)*. 2021;46:216-222.
23. Zhang TY, Zhang PX, Xue F, Zhang DY, Jiang BG. Risk factors for cement leakage and nomogram for predicting the intradiscal cement leakage after the vertebra augmented surgery. *BMC Muscoskel Disord*. 2020;21:792.
24. Ding J, Zhang Q, Zhu J, et al. Risk factors for predicting cement leakage following percutaneous vertebroplasty for osteoporotic vertebral compression fractures. *Eur Spine J*. 2016;25:3411-3417.
25. Bohl MA, Sethi R, Leveque JC. Incidence and clinical risk of cement extravasation in adult patients undergoing prophylactic vertebroplasty during surgical spine reconstruction. *World Neurosurg*. 2020;134:e928-e936.
26. Marie-Hardy L, Wolff S, Frison-Roche A, Bergère A, Khalifé M, Riouallon G. Minimal invasive management of early revision after minimal invasive posterior lumbar fusion. *Orthop Traumatol Surg Res*. 2020;106:1209-1214.
27. Dhall SS, Wang MY, Mummaneni PV. Clinical and radiographic comparison of mini—open transforaminal lumbar interbody fusion with open transforaminal lumbar interbody fusion in 42 patients with long-term follow-up. *J Neurosurg Spine*. 2008;9:560-565.
28. Park Y, Ha JW. Comparison of one-level posterior lumbar interbody fusion performed with a minimally invasive approach or a traditional open approach. *Spine (Phila Pa 1976)*. 2007;32:537-543.
29. Phan K, Kim JS, Somani S, et al. Impact of age on 30-day complications after adult deformity surgery. *Spine (Phila Pa 1976)*. 2018;43:120-126.
30. Di Capua J, Somani S, Kim JS, et al. Hospital-acquired conditions in adult spinal deformity surgery: predictors for hospital-acquired conditions and other 30-day postoperative outcomes. *Spine (Phila Pa 1976)*. 2017;42:595-602.
31. Lee MJ, Konodi MA, Cizik AM, Bransford RJ, Bellabarba C, Chapman JR. Risk factors for medical complication after spine surgery: a multivariate analysis of 1,591 patients. *Spine J*. 2012;12:197-206.
32. Onyekwelu I, Glassman SD, Asher AL, Shaffrey CI, Mummaneni PV, Carreon LY. Impact of obesity on complications and outcomes: a comparison of fusion and nonfusion lumbar spine surgery. *J Neurosurg Spine*. 2017;26:158-162.
33. Jenkins NW, Parrish JM, Hrynewycz NM, Brundage TS, Singh K. Complications following minimally invasive transforaminal lumbar interbody fusion: incidence, independent risk factors, and clinical impact. *Clinical spine surgery*. 2020;33:E236-E240.
34. Vaidya R, Carp J, Bartol S, Ouellette N, Lee S, Sethi A. Lumbar spine fusion in obese and morbidly obese patients. *Spine (Phila Pa 1976)*. 2009;34:495-500.
35. Gaudelli C, Thomas K. Obesity and early reoperation rate after elective lumbar spine surgery: a population-based study. *Evid Based Spine Care J*. 2012;3:11-16.
36. Durand WM, Eltorai AE, Depasse JM, Yang J, Daniels AH. Risk factors for unplanned reoperation within 30 days following elective posterior lumbar spinal fusion. *Global Spine J*. 2018;8:388-395.
37. Klemencsics I, Lazary A, Szoverfi Z, Bozsodi A, Eltes P, Varga PP. Risk factors for surgical site infection in elective routine degenerative lumbar surgeries. *Spine J*. 2016;16:1377-1383.
38. Li P, Tong Y, Chen Y, Zhang Z, Song Y. Comparison of percutaneous transforaminal endoscopic decompression and short-segment fusion in the treatment of elderly degenerative lumbar scoliosis with spinal stenosis. *BMC Musculoskelet Disord*. 2021;22:1-9.
39. Zheng F, Cammisa FP Jr, Sandhu HS, Girardi FP, Khan SN. Factors predicting hospital stay, operative time, blood loss, and transfusion in patients undergoing revision posterior lumbar spine decompression, fusion, and segmental instrumentation. *Spine (Phila Pa 1976)*. 2002;27:818-824.

40. Rajpal S, Shah M, Vivek N, Burneikiene S. Analyzing the correlation between surgeon experience and patient length of hospital stay. *Cureus*. 2020;12:e10099.

41. Basques BA, Fu MC, Buerba RA, Bohl DD, Golinvaux NS, Grauer JN. Using the ACS-NSQIP to identify factors affecting hospital length of stay after elective posterior lumbar fusion. *Spine (Phila Pa 1976)*. 2014;39:497.

42. McGirt MJ, Parker SL, Chotai S, et al. Predictors of extended length of stay, discharge to inpatient rehab, and hospital readmission following elective lumbar spine surgery: introduction of the Carolina-Semmes Grading Scale. *J Neurosurg Spine*. 2017;27:382-390.

43. Gruskay JA, Fu M, Bohl DD, Webb ML, Grauer JN. Factors affecting length of stay after elective posterior lumbar spine surgery: a multivariate analysis. *Spine J*. 2015;15:1188-1195.

44. Lee KE, Martin TA, Peterson KA, Kittel C, Zehri AH, Wilson JL. Factors associated with length of stay after single-level posterior thoracolumbar instrumented fusion primarily for degenerative spondylolisthesis. *Surg Neurol Int*. 2021;12:48.

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