Turk Neurosurg 34(2):274-282, 2024

Original Investigation

DOI: 10.5137/1019-5149.JTN.43124-23.2

Received: 14.01.2023
Accepted: 21.03.2023

Published Online: 08.08.2023

Risk Factors Associated with Cage Retropulsion After Lumbar Interbody Fusion

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ABSTRACT

AIM: To identify the cage retropulsion (CR)-associated risk factors following lumbar interbody fusion (LIF).

MATERIAL and METHODS: Clinical data of patients who underwent LIF between January 2014 and December 2018 at three medical centers were retrospectively analyzed. Patients were divided into CR group and non-CR (NCR) group according to whether they experienced CR or not. This study analyzed radiological and surgical parameters to identify the risk factors associated with CR.

RESULTS: The enrolled 823 patients who underwent LIF had a total of 1205 disk levels. There were 387 men and 436 women, with a mean age of 58.8 (range, 33-86) years old. The average follow-up time was 16.6 (range, 12-27) months. CR was found in 21 patients (9 men and 12 women, 21 levels). Besides, 14 patients complained of radicular pain postoperatively, of whom 10 patients were recovered after conservative treatment, while the remaining 4 patients further required revision surgery. The mean age was 62.3 ± 8.1 (range, 44-74) years old in the CR group and 59.7 ± 9.7 (range, 33-86) years old in the NCR group. The incidence of CR was higher in patients with osteoporosis than those with a normal bone mineral density (BMD). Moreover, 12 of 21 patients had osteoporosis (57.1%), however, only 29.2% of patients without CR had osteoporosis. The cages of retropulsion were all placed at the posterior disk space by immediately postoperative X-ray or computed tomography (CT) scan. On the contrary, only 35.6% of cages were placed at the posterior disk space in the NCR group. Pear-shaped disk was found in 10 of 21 patients in the CR group (47.6%), whereas it was noted in only 13.4% of cases in the NCR group. Furthermore, 13 out of 21 patients in the CR group experienced intraoperative endplate injury (61.9%), while only 13.4% of patients experienced that in the NCR group. Risk factors for CR were osteoporosis [odds ratio (OR)=8.7, 95% confidence interval (CI) (3.42-34.6), P=0.01], posterior cage position [OR=5.8, 95%CI (2.12-24.6), p=0.03], pear-shaped disk [OR=9.9, 95%CI (6.21-46.42), p<0.001], and intraoperative endplate injury [OR=9.9, 95%CI (6.21-46.42), p<0.001].

CONCLUSION: Intraoperative endplate injury, pear-shaped disk, osteoporosis, and posterior cage position were noted as CR-associated risk factors after LIF.

KEYWORDS: Cage retropulsion, Risk factors, Endplate injury, Lumbar interbody fusion

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INTRODUCTION

The number of patients with severe lumbar degenerative disease (LDD) is annually growing with the widespread of population aging across the world (12,27). Patients with LDD mainly undergo posterior lumbar interbody fusion (PLIF) or transforaminal lumbar interbody fusion (TLIF). PLIF and TLIF are widely accepted as treatments for LDD, and they have achieved a satisfactory prognosis. The fusion of adjacent vertebral bodies in the affected level can restore the disk height and the sagittal and coronal alignment, promoting the indirect release of compressed nerve roots from the stenotic spinal canal. Cage retropulsion (CR) is a postoperatively serious complication that can develop to lumbar or foraminal stenosis. Several studies have concentrated on the possible etiologies and risk factors associated with CR.

Smoking has shown detrimental effects on the bone healing of spinal fusion. Berman et al. suggested that smoking significantly increased the risk of CR (3). However, Lee et al. assessed the relationship between smoking and CR and found no statistically significant relationship (12). Zhuang and Ku confirmed that smoking cessation could reduce smoking effects on the lumbar fusion-associated complications (30).

Zhang et al. analyzed data of 10 patients who required revision surgery of CR after PLIF and concluded that the possible risk factors were small cage, posterior cage position, and inadequate placement of 2 cages (27). Zhao et al. confirmed that fusion with two cages at a single level might result in CR based on the results of univariate analysis, which was consistent with Zhang et al.'s findings (28). In a retrospective analysis of 18 cases with CR from January 2012 to June 2018, Lu et al. demonstrated that CR was mainly associated with multiple factors, including osteoporosis and obesity (14). In 2013, Duncan and Bailey performed a prospective study on 116 patients undergoing TLIF, and they suggested that unilateral fixation was a risk factor (4). Yuan et al. conducted a meta-analysis, and they found that unilateral and bilateral pedicle screw fixation could achieve satisfactory fusion rate and complication rate (25).

However, other researchers reported controversial findings. Aoki et al. followed up 125 patients (144 discs) who underwent TLIF from April 2006 to January 2008, and they demonstrated that the incidence of CR was not significantly different between unilateral and bilateral fixation groups (2). Kimura et al. retrospectively analyzed data of 1070 PLIF cases from April 2006 to July 2010, and they confirmed that the risk factors included fusion at the L5/S1 level, lumbar instability, multilevel fusion, and pear-shaped disk (11). Liu et al. performed a meta-analysis of 10 articles related to CR, and their conclusion was completely contradictory to Kimura et al.'s finding (11,13). Finally, in 2019, Park et al. demonstrated that the intraoperative endplate injury could be associated with CR (17).

The causes of CR have not yet been fully clarified. Intraoperative endplate injury in the fusion level was found in the majority of patients who have had CR after PLIF and TLIF in our center. The present study aimed to retrospectively analyze the CR-associated risk factors.

MATERIAL and METHODS

Study Design and Clinical Data

The clinical data of patients who underwent PLIF or TLIF at three medical centers between January 2014 and December 2018 were retrospectively collected and analyzed. The inclusion criteria were as follows: 1) patients with LDD who underwent PLIF or TLIF with posterior pedicle screws; 2) availability of postoperative computed tomography (CT) and X-ray data; and 3) postoperative follow-up time >12 months. The exclusion criteria were as follows: 1) patients who underwent transforaminal endoscopic discectomy or fenestration discectomy; 2) patients who underwent anterior, direct lateral, or oblique lateral fusion; 3) unavailability of postoperative imaging data. This study was approved by the ethics committee of our hospital [No:(2023)-165].

Patients were divided into CR group and non-CR (NCR) group according to whether they experienced CR or not (Figure 1B).

Age and gender could be two main confounding factors. Multivariate logistic regression analysis was used to adjust for the two variables. In the present study, 4 patients from the NCR group were matched with each CR patient by gender, age (< ±2 years), and the same fusion level (i.e., the fusion level of NCR patients included the segment where CR occurred), and assigned to each of 21 matched groups. As the ratio of CR to NCR was 1:4, a total of 84 patients were selected from the NCR group. The purpose of this arrangement was to eliminate the influences of different ages, genders, and fusion levels (Figure 2).

Multivariate clinical factors were reviewed for each patient, including mean age, gender, body mass index (BMI), preoperative diagnosis, osteoporosis, fusion level, diabetes, and smoking status (Table I).

Osteoporosis was defined as a bone mineral density (BMD) of 2.5 standard deviations below that of a young adult. Patients who aged 55 years or older underwent dual-energy X-ray absorptiometry (DEXA) scan. Those cases who were younger than 55 years were considered to have a normal BMD. For a patient who was younger than 55 years, DEXA scan was performed even if the patient had a disease or received medication that could cause osteoporosis.

Type of Fusion Cage

Data including the type of fusion cage were collected from medical records. Two types of fusion cage were used, such as bullet-shaped cages [Capstone® PEEK cage (Medtronic Sofamor Danek, Memphis, TN, USA), Concorde Bullet® PEEK cage (DePuy Spine Inc., New Brunswick, NJ, USA), HalisTM 9MM Lumbar Bullet® PEEK cage (SANYOU Medical Co., Ltd., Shanghai, China), Lumbar Bullet® PEEK cage (DOUBLE Medical Co., Ltd., Xiamen, Fujian, China), Lumbar Bullet® PEEK cage (LIBEIER Co., Ltd., Beijing, China), MILESTONE® PEEK cage (WEGO Co., Ltd., Shandong, China), and Lumbar Bullet® PEEK cage (WALKMAN Medical Co., Ltd., Tianjin, China)], and kidney-shaped cages [Dica Direction Changeable Lumbar PEEK cages (SANYOU Medical Co., Ltd.)].

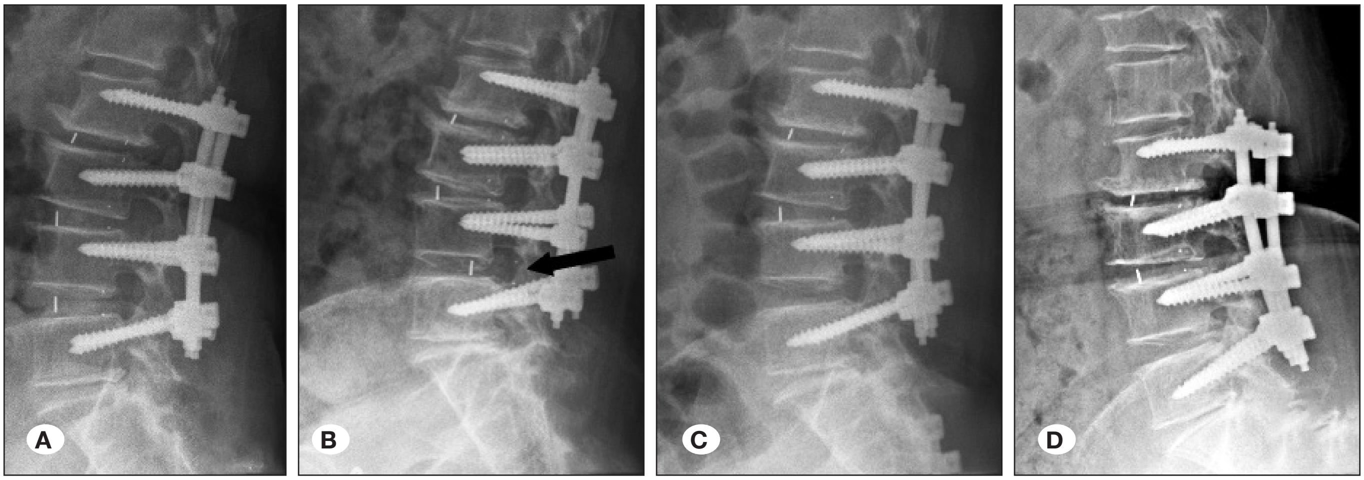

Figure 1: Cage retropulsion after lumbar interbody fusion for lumbar stenosis. Lateral lumbar radiographs in a 65-year-old woman. **A)** Five days after surgery. **B)** At 1 month after surgery, cage retropulsion could be observed at the L4/5 segment (arrow). **C)** One month after revision surgery and removal of the cage. **D)** Eight months after revision surgery.

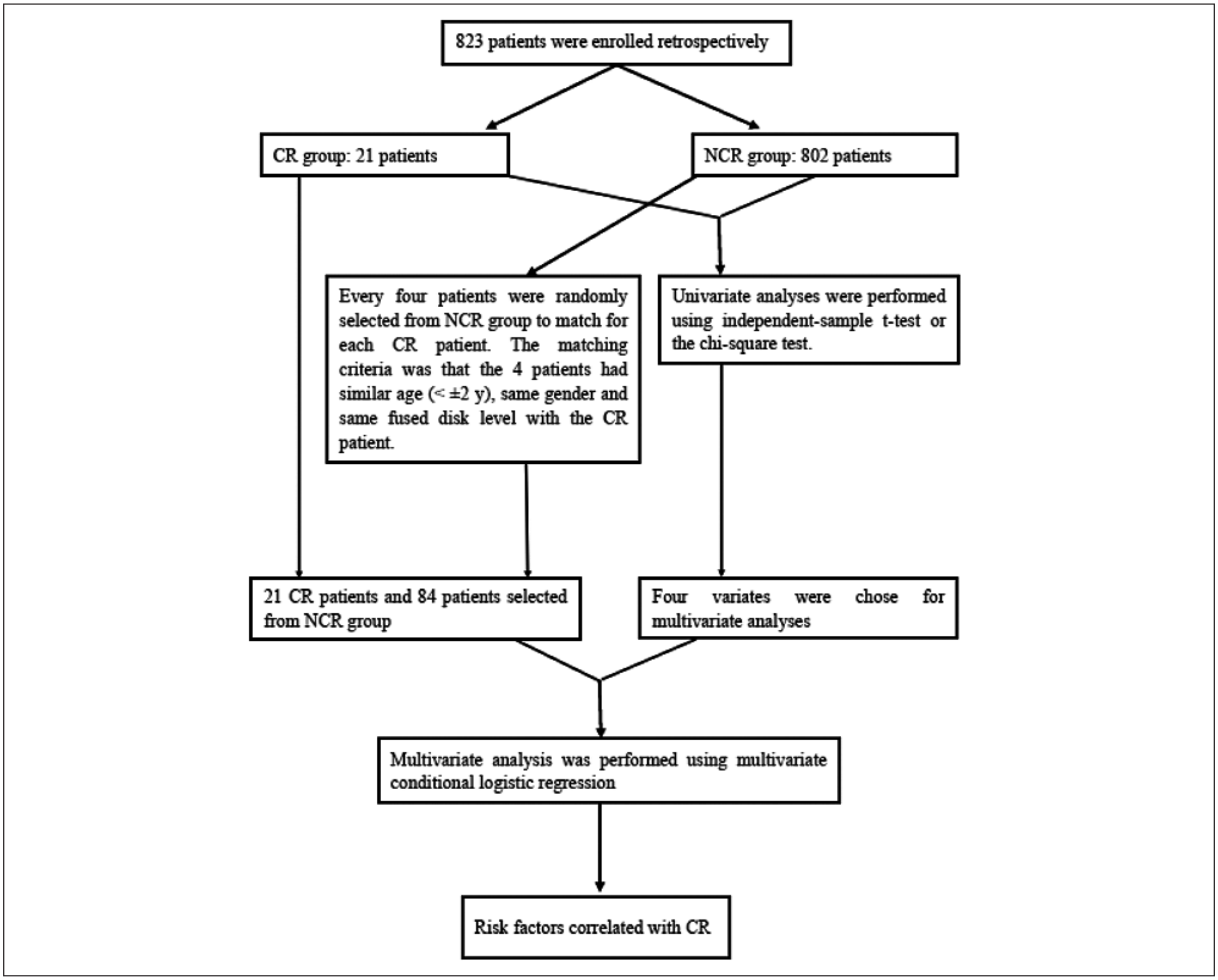

Figure 2: The flowchart of study design.

Table I: Baseline of Characteristics of Patients with Cage Retropulsion Group and No Cage Retropulsion Group

	Cage Retropulsion (+)	Cage Retropulsion (-)	p-value
No. of patients	21	802	
Mean age (years)	62.3 ± 8.1	59.7 ± 9.7	0.160
Gender			0.698
Male	9 (42.3%)	378 (47.1%)	
Female	12 (57.7%)	424 (52.9%)	
BMI	25.7 ± 2.1	24.9 ± 2.5	0.540
Preoperative Diagnosis			0.272
Spinal stenosis	17 (81.0%)	560 (69.8%)	
Spondylolisthesis	2 (9.5%)	156 (19.5%)	
Lumbar instability	2 (9.6%)	86 (10.7%)	
No. of Fused levels			0.794
1	14 (66.7%)	556 (69.3%)	
≥2	7 (33.3%)	246 (30.7%)	
Osteoporosis			**0.006**
>-2.5	9 (42.3%)	568 (70.8%)	
≤-2.5	12 (57.1%)	234 (29.2%)	
Diabetes	3	169	0.629
Smoking	5	238	0.561

Assessment of Radiological and Surgical Factors

X-ray and CT findings were obtained on the first day, and at 3, 6, and 12 months after surgery. Several variables were defined on preoperative and postoperative radiographs. CR was defined as movement of the posterior margin of the cage into the spinal canal or foramen by postoperative X-ray (Figure 1B) (17). Spinal range of motion was measured with preoperative dynamic lateral flexion-extension radiographs. Disk height (DH) was measured between the midpoints of the superior and inferior endplates on the lateral lumbar X-ray, and a small cage was defined as cage height (CH) <DH. Cage position was classified as either anterior or posterior based on the relationship between the midpoint of the body and the midpoint of the cage on the first postoperative sagittal X-ray. In the anterior cage position, the midpoint of the cage was forward to that of the body, and in the posterior cage position, the midpoint of the cage was backward to that of the body. Pear-shaped disk (Figure 3) was defined as a disk with a convex surface in the posterior halves and a concave surface in the anterior halves according to preoperative lateral X-ray (12). Endplate injury was defined as the cage moved into the cortical endplate on the postoperative X-ray or CT scan (Figures 4, 5) (17,20,29). Finally, up to 12 radiological and surgical variables were evaluated for each patient (Table II).

Statistical Analysis

The statistical analysis was performed by SPSS 19.0 software (IBM Corp., Armonk, NY, USA). Univariate analysis of clinical, radiological, and surgical parameters was carried out using independent-sample t-test or the Chi-square test. Multivariate logistic regression analysis (Forward: LR) was then carried out to identify independent risk factors for CR in patients with CR and without CR using significant variables identified by univariate analysis. Statistical significance was set at $P<0.05$.

RESULTS

Demographic Characteristics

Finally, 823 patients (1205 disk levels) were retrospectively enrolled. There were 387 men and 436 women, with a mean age of 58.8 (range, 33-86) years old. The average follow-up time was 16.6 (range, 12-27) months. Besides, 568 (69.1%) patients underwent DEXA scan. It was found that 522 patients aged over 55 years old, and 48 patients had conditions that could cause osteoporosis.

There were 21 patients (9 men and 12 women, 21 levels) who experienced CR. In addition, 14 patients complained of radicular pain postoperatively, of whom 10 patients were recovered after conservative treatment, while the remaining 4 patients required further revision surgery. The mean age

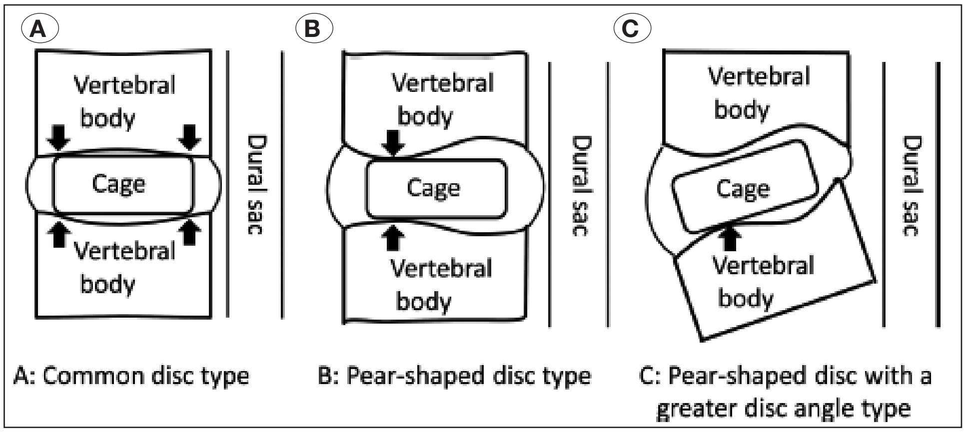

Figure 3: A) Normal disc; **B)** Pear-shaped disc; **C)** Pear-shaped disc with a greater disc angle (The above-illustrated figure was extracted from Hiroaki Kimura, MD).

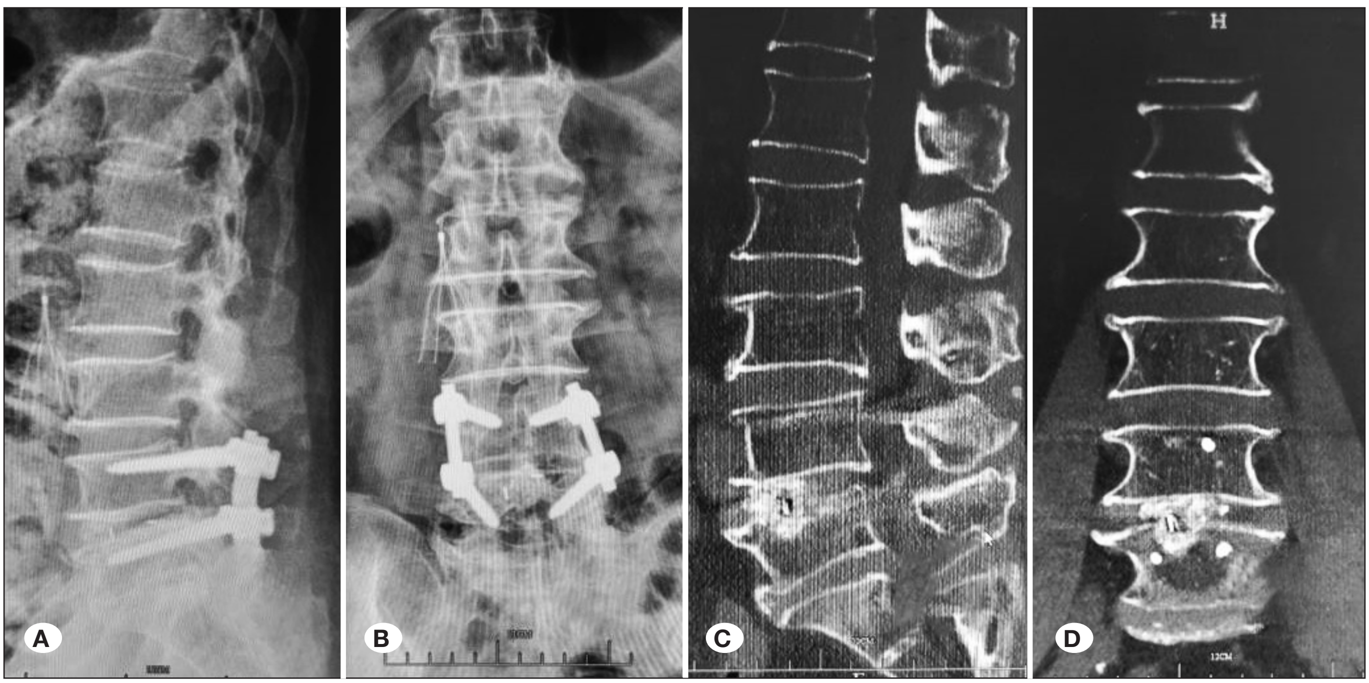

Figure 4: Endplate injury at immediately postoperative X-ray and CT scan. Endplate injury was defined as the cage moved toward the cortical endplate on the postoperative X-rays (***A:*** lateral, **B:** anteroposterior) or CT scan **(C, D)**. It was evaluated from the sagittal (C) and coronal (D) views.

was 62.3 ± 8.1 (range, 44-74) years old in the CR group and 59.7 ± 9.7 (range, 33-86) years old in the NCR group. The incidence of CR was higher in patients with osteoporosis than those with a normal BMD. In the CR group, 12 of 21 patients had osteoporosis (57.1%). Osteoporosis showed significant differences, however, mean age, gender, BMI, preoperative diagnosis, and fusion level exhibited no statistically significant difference by univariate analysis (Table I).

Those 21 patients with CR underwent fixation by bilateral pedicle screws and fusion by Bullet cages. No patient who received implantation of two cages in a level or with unilateral fixation experienced CR during the follow-up. The cages of retropulsion were all placed at the posterior disk space using immediately postoperative X-ray or CT scan. On the contrary, only 35.6% of cages were placed at the posterior disk space in the NCR group. Pear-shaped disk was found in 10 of 21 patients with CR (47.6%), while it was identified in only 8.1% of patients in the NCR group. Moreover, 13 out of 21 patients with CR experienced endplate injury (61.9%), while only 13.4% of patients experienced that in the NCR group. Univariate analysis revealed that posterior cage position, pear-shaped disk, and endplate injury showed significant differences. Other radiological and surgical factors were not significantly correlated with CR according to the results of the univariate analysis (Table II).

Multivariate Logistic Regression Analysis

Totally, 84 patients (117 levels) were selected from the NCR group. Multivariate logistic regression analysis was performed on 21 patients with CR and 84 patients without CR. It was revealed that osteoporosis [odds ratio (OR)=8.7, 95% confidence interval (CI) (3.42-34.6), p=0.01], posterior cage position [OR=5.8, 95%CI (2.12-24.6), p=0.03], pear-

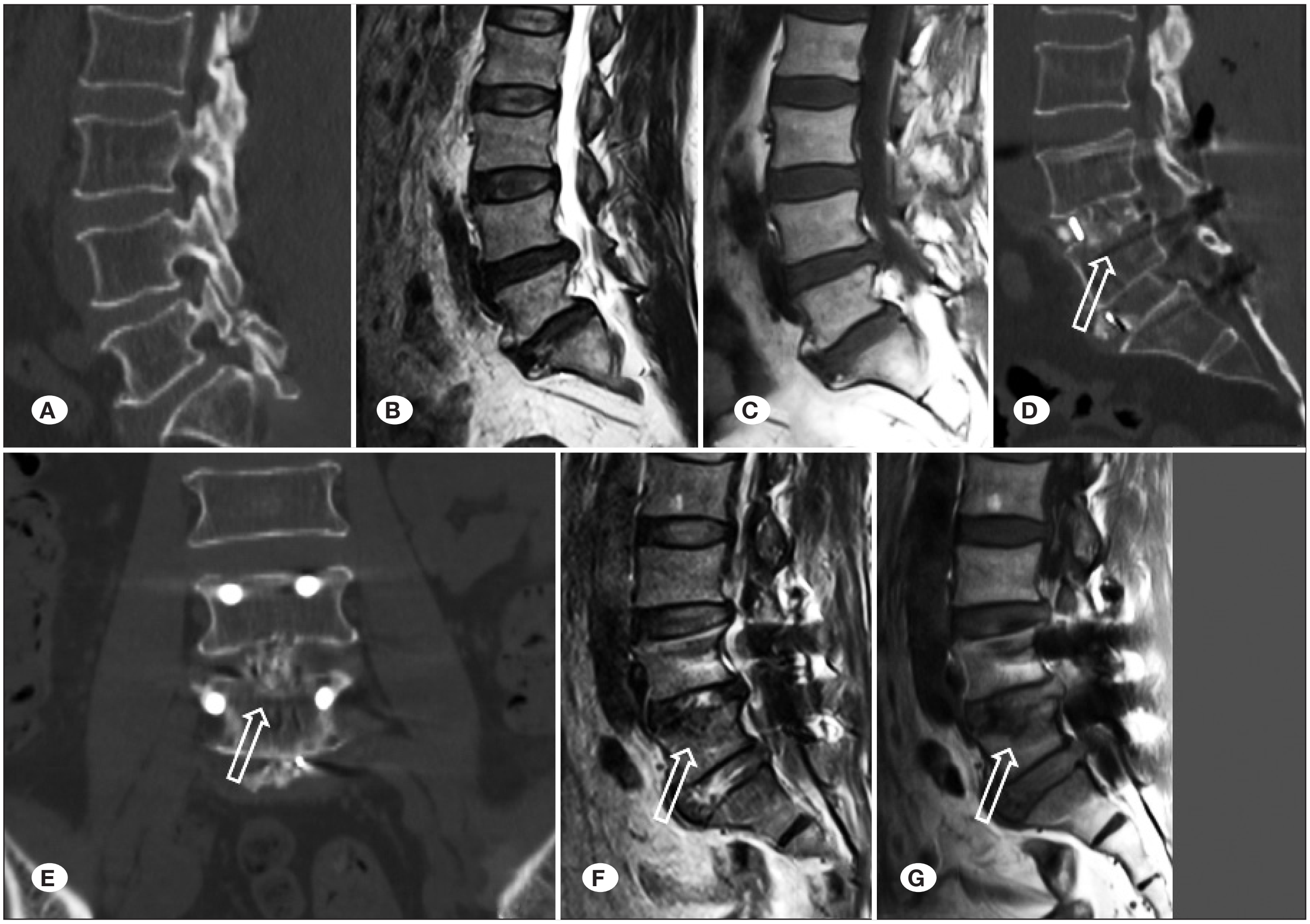

Figure 5: Peri-endplate injury for lumbar spondylolysis (L5). Lumbar radiographs (pre) in a 58-year-old woman. **A-C)** Superior endplate of L5 was intact in preoperative CT **(A)** and MRI (**B:** T2W-sagittal, **C:** T1W-sagittal) scans and MRI. **D-G)** At five days after surgery, endplate injury could be observed at the superior endplate of L5 (arrow) (**D:** Sagittal, **E:** coronal CT; **F:** T2W-sagittal, **G:** T1W-sagittal).

shaped disk [OR=9.9, 95%CI (6.21-46.42), p<0.001], and endplate injury [OR=14.9, 95%CI (6.30-86.9), p<0.001] were independent risk factors for CR (Table III).

DISCUSSION

The present study revealed that osteoporosis, posterior cage position, pear-shaped disk, and endplate injury were independent risk factors for CR, following TLIF and PLIF. This finding contributes to the prevention of CR from lumbar fusion postoperatively.

Endplate injury could be associated with CR, which is consistent with previously reported findings (10,17,29). Endplate is a thin structure of cortical bone at the cranial and caudal surfaces of vertebral bodies. Fully removal of endplate could attenuate the structural properties of the vertebral bodies (8,10). Endplate injury would be more likely to induce degeneration of adjacent intervertebral discs (22). Intraoperative endplate injury mainly would occur during endplate preparation intraoperatively and an aggressive attempt was made to restore DH with a tall cage (23), in which reamer and scraper were used in this procedure. Reamer was moved to the disc space and rotated to clean up the nucleus pulposus, and scraper was utilized to prepare the endplates later. During the procedure, the two instruments might cause damage to the cranial and caudal endplates of the space, so that the disk space was enlarged (10,26,29). If the endplate injury would occur in the vertebral body, the interface between the cage and the vertebral body might have insufficient strength to stabilize cage (Figure 5A-G). Therefore, the cage might move to the spinal canal or foramen easily if the fusion would fail (17).

Posterior cage position is an important risk factor for CR (9,21,27). Zhang et al. suggested that the distance between the posterior margins of lumbar vertebrae and cage should be larger than 3 mm. Cage may exceed the posterior margin of lumbar vertebrae easily if there is a short distance (27). Polly et al. found that anteriorly located cages in disc space had significantly tolerated more stress in the axial compression than posteriorly located cages (18). Han et al. demonstrated that transverse cage implantation exhibited a higher peak stress than oblique cage implantation (6). Hu et al. concluded that anteriorly located cages had tolerated more stress as gravity was transmitted and generated a greater friction to prevent CR (9). Singhatanadgige et al. pointed out that the

Table II: Radiological and surgical factors of patients (levels) between CR and NCR groups

	Cage Retropulsion (+)	Cage Retropulsion (-)	p-value
No. of levels (patients)	21 (21)	1184 (802)	
ROM (°)	9.4 ± 5.3	8.2 ± 4.6	0.512
Lumbar lordosis (LL, °)	43.4 ± 14.2	41.3 ± 13.5	0.461
Scoliotic curvature (°)	2.7 ± 1.9	1.9 ± 1.4	0.273
Length of cage			0.698
22 mm	8 (38.1%)	501 (42.3%)	
26 mm	13 (61.9%)	683 (57.7%)	
Fused level (The disk space of cage insertion)			0.914
L2/3	0	54 (4.6%)	
L3/4	3 (14.3%)	160 (13.5%)	
L4/5	11 (52.4%)	621 (52.4%)	
L5/S1	7 (33.3%)	349 (29.5%)	
Cage shape			1.00
Bullet (n)	21	1127 (95.1%)	
Kidney (n)	0	57 (4.9%)	
Cage position			**<0.001**
Anterior	0	763 (64.4%)	
Posterior	21	421 (35.6%)	
No. of cages in a single space			1.00
Single	21	1172 (99.0%)	
Double	0	12 (1.0%)	
Fixation of pedicle screws			1.00
Unilateral	0	44 (3.7%)	
Bilateral	21	1140 (96.3%)	
Small cage	1 (4.8%)	108 (9.1%)	0.759
Pear-shaped disk	10 (47.6%)	96 (8.1%)	**<0.001**
Endplate injury	13 (61.9%)	159 (13.4%)	**<0.001**

Table III: Multivariate Logistic Analysis

Variables	Cage Retropulsion (+)	Cage Retropulsion (-)	OR	CI (95%)	p-value
Endplate injury	1 (4.8%)	13 (10.2%)	14.9	6.3-86.9	**<0.001**
Posterior cage position	10 (47.6%)	12 (9.4%)	5.8	2.12-24.6	**0.03**
Pear-shaped disk	13 (61.9%)	18 (14.2%)	9.9	6.21-46.42	**<0.001**
Osteoporosis	12 (57.1%)	26 (20.4%)	8.7	3.42-34.6	**0.01**

***OR:** Odds ratio, **CI:** Confidence interval.*

instantaneous axis of rotation in the spinal level was at the posterior intervertebral space (21). The anterior cage position creates a longer moment arm and lesser compression force than posterior position. It is essential to place the center of cage anterior to the disc center to minimize the risk of CR.

The present study indicated that osteoporosis was noted as a risk factor for CR, which was consistent with previously reported findings (14,16,17,28). Although BMD of the majority of patients aging younger than 55 years old was not recorded in the present retrospective study, the incidence of CR in patients with osteoporosis was significantly higher than that in those with a normal BMD. The fixation of pedicle screws depends on the normal trabecular bone at the bone-screw interface. If BMD would be less than normal, the pedicle screws might have insufficient strength to stabilize the body. Without stabilization, the fusion might be failed (17). Besides, Satake et al. reported that a lower BMD was a risk factor for intraoperative endplate injury (19). Osteoporosis made the condition worse combined with intraoperative endplate injury. Therefore, it is essential to perform DEXA scan preoperatively.

BMD value of each vertebra was different even in a patient with osteoporosis. Okuyama et al. confirmed that BMD value below 0.674 ± 0.104 g/cm^3 could be indicative of a potential increased risk of screw loosening after PLIF (15), whereas no similar conclusion was reported. Posterior instruments in the vertebrae had the lowest BMD value lost stabilization firstly, and had no ability to restrict motion between the vertebrae (17, 24). When the fusion failed, the cage would move towards posterior or subside vertebrae (1). The patient felt clinical syndromes and went back to hospital at last. It was the possible reason that only one fused level occurred frequently in patients with osteoporosis who underwent implantation of multilevel cages.

Pear-shaped disk was found as a risk factor for CR in the present study, which was corroborated previously (11,13,17). A normal disk has a slightly convex surface in the superior and inferior positions. However, pear-shaped disk has wave-shaped superior and inferior endplates on the lateral radiographs, indicating that the shape of an anterior disk is apparently convex and the posterior part is concave (5). Hasegawa et al. demonstrated that a larger contact area between the cage and endplate improved fusion rate (7). Therefore, a possible mechanism is that the fusion rate may be lower in the pear-shaped disk than that in the normal space. In the pear-shaped disk space, the anterior space is narrow and the posterior space is very large, in which the cage without bony fusion may easily move backward after surgery, especially in combination with endplate injury. In the present study, the results of the statistical analysis confirmed this hypothesis. The cage should be therefore placed in the anterior space if the disk is pear-shaped.

Limitations

The limitations of this study were summarized as follows: (i) DEXA scan was performed on patients aging over 55 years, and only a limited number of patients who aged under 55 years with certain conditions underwent DEXA scan. Therefore, the incidence of osteoporosis might be underestimated; (ii) There were differences in surgical techniques between surgeons, especially in endplate preparation. Although all surgeons were proficient in endplate preparation, endplate preparation techniques were not individually assessed; (iii) There were only 21 patients with CR, indicating a small sample size.

CONCLUSION

In conclusion, radiological and surgical parameters were analyzed to identify risk factors correlated with CR. The results of the multivariate logistic regression analysis indicated that intraoperative endplate injury, pear-shaped disk, osteoporosis, and posterior cage position were significant risk factors for CR.

ACKNOWLEDGEMENTS

This study was financially supported by the Technological Project of Hunan Health Commission (Grant No. B2014-086), the Scientific Research Project of Hunan Education Department (Grant No. 21C0041), and the Scientific Research Project of Hunan Health Commission (Grant No. 2021040711140).

AUTHORSHIP CONTRIBUTION

Study conception and design: MZ, XL
Data collection: MZ, FZ, HM
Analysis and interpretation of results: MZ
Draft manuscript preparation: MZ
Critical revision of the article: XL
Other (study supervision, fundings, materials, etc...): GW, HL
All authors (MZ, XL, GW, HL, FZ, HM) reviewed the results and approved the final version of the manuscript

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