

Endplate injury as a risk factor for cage retropulsion following transforaminal lumbar interbody fusion

An analysis of 1052 cases

Zhi-Jie Zhou, MD, PhD^{a,b}, Ping Xia, MD^c, Feng-Dong Zhao, MD^{a,b}, Xiang-Qian Fang, MD^{a,b}, Shun-Wu Fan, MD, PhD^{a,b}, Jian-Feng Zhang, MD^{a,b,*} 

Abstract

Although transforaminal lumbar interbody fusion (TLIF) is a widely accepted procedure, major complications such as cage retropulsion (CR) can cause poor clinical outcomes. Endplate injury (EI) was recently identified as a risk factor for CR, present in most levels developing CR. However, most EIs occurred in non-CR levels, and the features of EIs in CR levels remain unknown.

The aim of this study was to identify risk factors for CR following TLIF; in particular, to investigate the relationship between EIs and CR, and to explore the features of EIs in CR.

Between October 2010 and December 2016, 1052 patients with various degenerative lumbar spinal diseases underwent bilateral instrumented TLIF. Their medical records, radiological factors, and surgical factors were reviewed and factors affecting the incidence of CR were analyzed.

Twenty-one patients developed CR. Nine had back pain or leg pain, of which six required revision surgery. A pear-shaped disc, posterior cage positioning and EI were significantly correlated with CR ($P < .001$, $P = .001$, and $P < .001$, respectively). Computed tomography (CT) scans revealed the characteristics of EIs in levels with and without CR. The majority of CR levels with EIs exhibited apparent compression damage in the posterior part of cranial endplate on the decompressed side (17/18), accompanied by caudal EIs isolated in the central portion. However, in the control group, the cranial EIs involving the posterior part was only found in four of the total 148 levels ($P < .001$). Most of the injuries were confined to the central portion of the cranial or caudal endplate or both endplates (35 in 148 levels, 23.6%). Additionally, beyond cage breaching into the cortical endplate on lateral radiographs, a characteristic appearance of coronal cage misalignment was found on AP radiographs in CR levels with EIs.

A pear-shaped disc, posterior cage positioning and EI were identified as risk factors for CR. EI involving the posterior epiphyseal rim had influence on the development of CR. Targeted protection of the posterior margin of adjacent endplates, careful evaluation of intraoperative radiographs, and timely remedial measures may help to reduce the risks of CR.

Abbreviations: AP = anteroposterior, CR = cage retropulsion, CT = computed tomography, DH = disc height, EI = endplate injury, MRI = magnetic resonance imaging, PEEK = polyetheretherketone, TLIF = transforaminal lumbar interbody fusion.

Keywords: cage retropulsion, complications, disc shape, endplate injury, lumbar spine, risk factors, transforaminal lumbar interbody fusion

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^a Department of Orthopaedic Surgery, Sir Run Run Shaw Hospital, School of Medicine, Zhejiang University, ^b Key Laboratory of Musculoskeletal System Degeneration and Regeneration Translational Research of Zhejiang Province, ^c Department of Neurology, Sir Run Run Shaw Hospital, School of Medicine, Zhejiang University, Hangzhou, China.

* Correspondence: Jian-Feng Zhang, Department of Orthopaedic Surgery, Sir Run Run Shaw Hospital, School of Medicine, Zhejiang University, 3 East Qingchun Road, Hangzhou 310016, China (e-mail: zjf19760316@163.com).

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1. Introduction

Transforaminal lumbar interbody fusion (TLIF) has become a widely accepted treatment for degenerative lumbar diseases.^[1,2] However, TLIF may be associated with certain complications. Cage migration is a major post-TLIF complication that can be classified as posterior, anterior, or sagittal migration.^[3,4] Posterior cage migration, especially cage retropulsion (CR), in which the cage moves backwards into the spinal canal or foramen, is more troublesome because it can cause neurological deterioration and nonunion.^[5,6]

Previous studies have reported several risk factors for CR, including undersized cages, unilateral pedicle fixation, a pear-shaped disc, and posterior cage positioning.^[7–9] In a recent multicenter study of 784 patients, Park et al^[3] identified endplate injury (EI) as an important risk factor for CR following TLIF, with the largest odds ratio (18.7) among all the significant factors. Other authors have indicated the importance of preserving the bony endplate to prevent CR, although they did not perform statistical analysis due to the small number of migrated cases.^[5,10] The incidence of EI has been reported to be as high as 70.6% (12/17) in levels with CR.^[3] Nevertheless, the majority (86.7%, 78 of 90 levels) of EIs occurred in mild forms of cage migration (17 levels) and non-migrated cases (61 levels), which were less likely to contribute to poor clinical outcomes. Therefore, we wondered whether the Es appearing in levels with CR represented a more severe form and could be distinguished from the milder forms on the basis of certain radiological features. Such a distinction may facilitate the development of targeted efforts to prevent EIs and allow the use of corresponding remedial measures for this “specific” type of EI to better reduce the risks of CR.

In this study, we aimed to investigate the relationship between EIs and CR, in particular the features of EIs in levels with CR, and we also aimed to identify other risk factors for CR.

2. Methods

2.1. Patient population

This study was a retrospective review of patients who underwent TLIF from October 2010 to December 2016 at Sir Run Run Shaw Hospital. All patients experienced low back pain with or without radicular pain that was unresponsive to conservative therapy for

>3 months. The pain was considered to be attributable to the following diagnoses: lumbar disc herniation, lumbar spinal stenosis, or low-grade lumbar spondylolisthesis (I° or II°). Patients with prior spinal surgery (n=39), preoperative EI at fusion levels (n=32), or a follow-up period of <1 year (n=8) were excluded. Finally, 973 (1313 disc levels) of 1052 patients were included. The mean follow-up period was 28.5 months (range, 12–83 months). Patient characteristics were collected (Table 1). All patients provided informed consent before treatment. This study was approved by the institutional review board of our hospital.

2.2. Surgical technique

All patients underwent TLIF with bilateral pedicle screw fixation. An incision was made to provide an operative field and achieve pedicle-to-pedicle exposure. After pedicle screw fixation, a connecting rod was installed on the contralateral side to distract the intervertebral space. Adequate decompression was achieved by laminectomy and facetectomy on the decompressed side. If necessary, contralateral undercutting decompression was achieved from the decompressed side. After discectomy and endplate preparation, an autologous bone graft harvested from the posterior spinal elements was packed into the disc space, and a polyetheretherketone (PEEK) cage packed with the autograft was installed in place. Recombinant human bone morphogenetic protein-2 was added to the autograft if insufficient. Finally, bilateral compression was applied to the disc space by pedicle instrumentations. The cages used were the kidney-shaped cages: Crescent (Medtronic Sofamor Danek), and Travios (Synthes GmbH); and the bullet-shaped cages: Capstone (Medtronic Sofamor Danek), and Plivios (Synthes GmbH).

2.3. Imaging evaluation and follow-up

Preoperative percentage slippage, range of motion, translation, lumbar lordosis, segmental lordosis, and scoliotic curvature were measured using established methods on lumbar radiographs.^[11–14] The disc height (DH) was measured on computed tomography (CT) scans as the distance between the midpoints of the superior and inferior endplates on a mid-sagittal plane.^[3] Disc shape was categorized as biconcave, linear-, or pear-shaped

Table 1
Characteristics of patients who developed CR among 973 patients who underwent transforaminal lumbar interbody fusion.

	CR Group	Non-CR Group	Control Group	P
No. of patients	21	952	100	
Sex (M/F)	12/9	451/501	48/52	.67
Age (years)	59.6±9.3	57.2±10.6	58.1±9.7	.32
Body mass index (kg/m ²)	24.2±2.7	23.6±2.5	23.2±2.5	.42
Bone mineral density (T-score)	-1.0±1.8	-0.9±1.5	-1.2±1.6	.28
Combined with diabetes (Y/N)	5/16	143/809	19/81	.33
Smoke (Y/N)	4/17	139/813	17/83	.71
Pre-operative diagnosis				.75
LDH	8	283	31	
LSS	8	421	48	
Spondylolisthesis (I°/II°)	5 (3/2)	248 (143/105)	21 (11/10)	
Fusion level (L ₂₋₃ /L ₃₋₄ /L ₄₋₅ /L ₅ -S ₁)	0/2 (1)/17 (15)/9 (5)	20/139/765/389	3/28/72/45	.07
No. of fusion levels (1/2/3)	14/7/0	628/287/37	58/36/6	.43

Values given are mean ± SD unless otherwise specified.

CR=cage retropulsion, LDH=lumbar disc herniation, LSS=lumbar spinal stenosis, No.=number, M/F=male/female, Y/N=Yes/No.

according to sagittal magnetic resonance imaging (MRI).^[15,15] Modic changes were also evaluated according to MRI.^[16]

Lumbar radiographs and CT scans were obtained on the first day after surgery. The latter were originally used for evaluating the relative positions of the screws to the pedicles in another study. Here, they were used to assess the depth and loosening of pedicle screws, and the EIs. The depth of the bilateral pedicle screws was measured on axial CT scans and divided by the corresponding anteroposterior (AP) diameters of the vertebral body along the screw path, and a mean value was obtained. Cage positioning was assessed using the “depth ratio” and “coronal ratio” as described by Hu et al.^[3] The cage center on the radiograph was first defined according to the radiopaque markers. The depth ratio was measured on lateral radiographs as the distance between the cage center and the disc center divided by the caudal endplate length. This value was deemed positive for cages located more anteriorly than the disc center, and was otherwise considered negative. The coronal ratio was measured similarly. EI was defined as the iatrogenic damage to the cortical endplate detected on the immediate postoperative sagittal or coronal CT scans, which was absent preoperatively. To describe the severity of EI, we measured the degree of EI on two-dimensional CT scans. By comparing the pre- and postoperative sagittal/coronal CT scans, the degree of compression or collapse of the endplate was measured, with the aid of a picture archiving and communication system (PACS). The difference between the cage height and the preoperative DH was obtained for analysis. Postoperative radiographs were also obtained at 1, 3, 6, and 12 months, with additional radiological follow-up for some cases. CR was defined as the movement of the posterior margin of the cage past the posterior margin of either adjacent vertebral body.^[11]

To compare the radiological and surgical factors of patients with and without CR, 100 control patients (148 disc levels) were randomly selected from 952 patients without CR. An orthopedist blinded to the study design selected this group. The group without CR and the control group showed no significant differences in sex ratio, age, diagnosis, or fusion levels (Table 1).

2.4. Statistical analysis

One-way analysis of variance (ANOVA) was used to evaluate differences in continuous variables among multiple groups. The Student’s *t* test or Mann–Whitney nonparametric *U* test was used to evaluate differences in continuous variables between the two groups. The χ^2 test or Fisher’s exact test was used to compare the distributions of categorical variables. Variables with *P* values <.05 in univariate analyses were entered into a multivariate logistic regression analysis. All data analyses were performed using the SPSS 16.0 statistics software (Chicago, IL). *P* <.05 was considered statistically significant.

3. Results

Twenty-one patients (2.2%; 12 men and 9 women; mean age, 59.6 ± 9.3 years) developed CR 41.8 ± 16.5 days postoperatively (range, 15–90 days), with one patient showing CR at L₃₋₄, 15 at L₄₋₅ and five at L_{5-S}₁. Twelve patients had no symptoms, and nine had back pain or leg pain, of which six required revision surgery. The patients’ characteristics, including sex, age, bone mineral density, diagnosis, and fusion level, were not statistically significant risk factors for CR (Table 1). Radiological factor

Table 2
Radiological analyses between levels in CR and control group.

	CR group (n = 21)	Control group (n = 148)	<i>P</i>
Disc height (mm)	10.8 ± 2.3	10.5 ± 2.1	.24
Slippage (%)	7.0 ± 4.5	6.7 ± 4.1	.25
Translation (%)	2.5 ± 2.1	2.7 ± 1.6	.42
Range of motion (°)	7.6 ± 3.7	8.1 ± 4.2	.52
Scoliotic curvature (°)	3.3 ± 2.6	2.1 ± 2.2	.31
Lumbar lordosis (°)	43.9 ± 16.8	40.3 ± 15.7	.36
Segmental lordosis (°)	6.1 ± 4.3	6.6 ± 3.3	.28
Disc shape (biconcave/linear-/pear-shaped)	9/8/4	82/61/5	.01
Modic changes (Y/N)	4/17	42/106	.44

Values given are mean ± SD unless otherwise specified.
CR = cage retropulsion, Y/N = Yes/No.

analyses showed that a pear-shaped disc was correlated with CR (*P* = .01). Other preoperative parameters were not statistically different between the CR and control groups (Table 2).

Analysis of surgical factors identified posterior cage positioning and EI as risk factors for CR (Table 3). The depth ratio was significantly smaller in the CR group than in the control group (*P* < .001). However, no significant difference was observed in the coronal ratio (*P* = .78). EI was found in 18 of the 21 levels showing CR (85.7%), compared to 39 of the 148 levels in the control group (26.4%, *P* < .001). Cage height, cage type, cage height minus DH, screw depth, and screw loosening were not significantly correlated with CR. Multivariate analysis revealed that a pear-shaped disc, posterior cage positioning, and EI were significantly associated with a higher risk of CR (Table 4).

Subsequently, the characteristics of EIs were examined on postoperative CT scans. Among the 18 CR levels with EIs, 17 showed apparent damage in the posterior part of cranial endplate, which was accompanied by different degrees of caudal EIs in the central portion. The posterior part of these 17 cranial endplates showed a compression injury on the decompressed side, leading to wedging of the cranial vertebra and a wide space facilitating posterior cage migration (Fig. 1). However in the control group, the cranial EI involving the posterior part was only found in four of the total 148 levels, and the injury appeared mild,

Table 3
Surgical factors analyses between levels in CR and control group.

	CR group (n = 21)	Control group (n = 148)	<i>P</i>
Cage height (mm)	10.9 ± 1.2	10.6 ± 1.0	.54
Cage positioning			
Depth ratio	−0.13 ± 0.07	0.01 ± 0.06	<.001
Coronal ratio	−0.07 ± 0.08	−0.05 ± 0.05	.78
Cage type			.78
Kidney-shaped (Travios/Crescent)	16 (12/4)	117 (72/45)	
Bullet-shaped (Plivios/Capstone)	5 (2/3)	31 (14/17)	
Cage height-DH (mm)	0.1 ± 1.8	0.1 ± 1.5	.40
Usage of rh-BMP (Y/N)	6/15	36/112	.79
Endplate injury (Y/N)	18/3	39/109	<.001
Screw depth	0.74 ± 0.21	0.81 ± 0.23	.28
Screw loosening	0/42	2/294	1.000

Values given are mean ± SD unless otherwise specified.
CR = cage retropulsion, DH = disc height, Rh-BMP = recombinant human bone morphogenetic protein, Y/N = Yes/No.

Table 4		
Multivariate analysis of risk factors for CR.		
Risk factors	Odds ratio [95% CI]	P
Pear-shaped disc	7.29 (2.56–20.76)	<.001
Posterior cage positioning (depth ratio)	3.58 (1.21–10.59)	.001
Endplate injury	3.76 (1.74–8.13)	<.001

Values given are mean ± SD unless otherwise specified.
CR = cage retropulsion.

except at one level. Most of the injuries in the control group were confined to the central portion of the cranial or caudal endplate or both endplates (35 in 148 levels, 23.6%) (Fig. 2). The degree of EI in the 18 injured endplates in the CR group was 3.9 ± 1.0 mm (range, 2–5.8 mm). In contrast, the degree of EI in the 39 injured levels in the control group was 0.3 ± 1.2 mm (range, 0–2.7 mm), with only one EI exceeding 2 mm. The degree of EI significantly differed between the two groups ($P < .001$). An EI > 2 mm appeared to strongly indicate the subsequent development of CR. Interestingly, apart from cage breaching into the cortical endplate on lateral radiographs, apparent coronal misalignment of the



Figure 1. A case with EI developed CR following TLIF. (A) Immediately postoperative lateral radiographs showed cage breaching into the caudal endplate (black arrow). (B) AP radiographs showed apparent coronal cage misalignment, with the cage of the decompressed side (left side) located more superiorly than the contralateral side. (C) Sagittal CT scan revealed a compression injury in the posterior part of cranial endplate on the decompression side (long black arrow), apart from caudal EI in the central portion (short black arrow). (D) On the contralateral side, EI was only seen in the central portion of the caudal endplate (black arrow), and the cranial endplate was not injured. (E) Coronal CT scan confirmed asymmetric EI, only present on the decompressed side of the cranial endplate (black arrow). (F) CR developed 6 weeks after surgery.

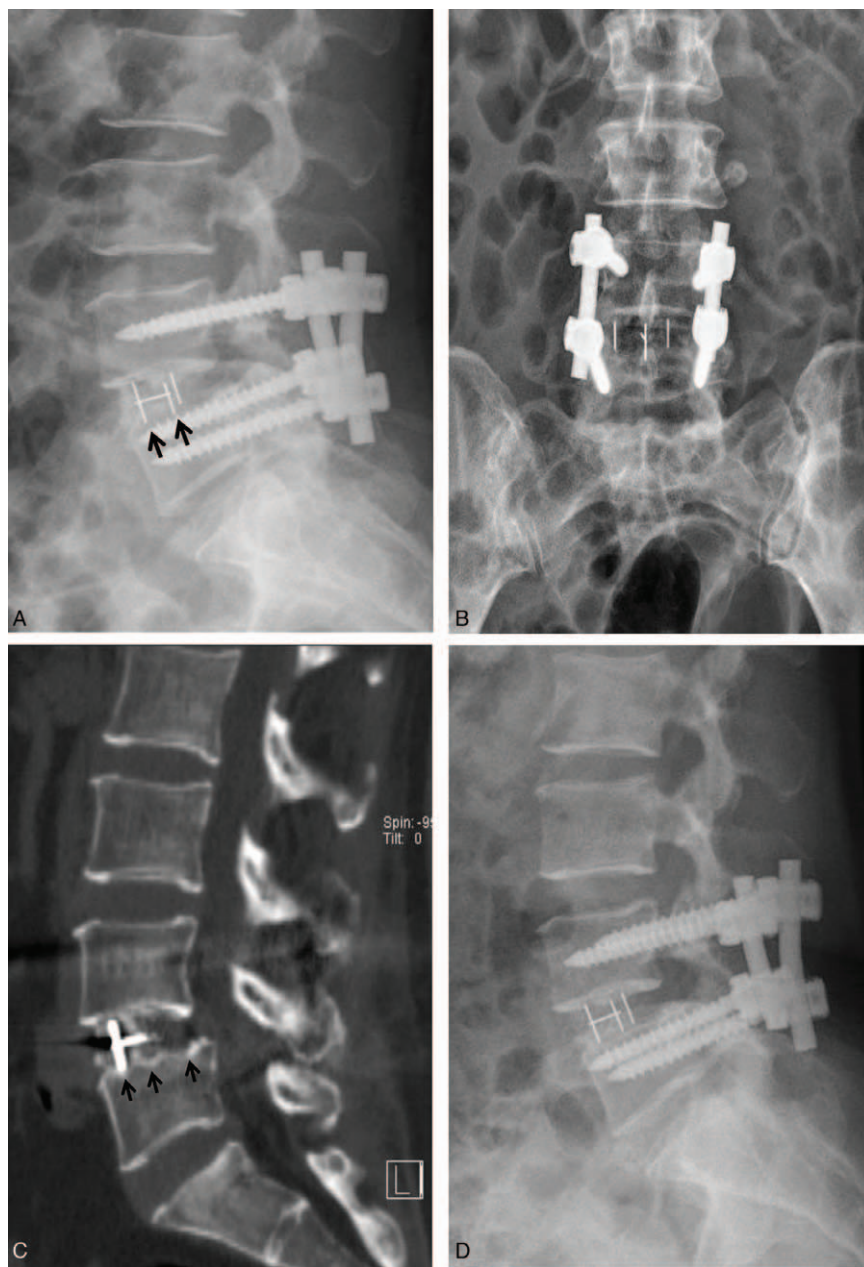


Figure 2. A case with EI in the control group. (A) Immediately postoperative lateral radiographs showed EI and minor cage subsidence into the caudal endplate (black arrows). (B) No coronal cage misalignment was observed on AP radiographs. (C) CT scan confirmed caudal EI isolated in the central portion, with depressions of varying sizes and an uneven endplate surface (black arrows). (D) CR was not found at 1 year follow-up.

cage was seen on AP radiographs in all the 17 CR levels with cranial EI, with the cage of the decompressed side located more superiorly than the contralateral side (Fig. 1). Coronal cage misalignment was only found at one level in the control group, which showed the most severe cranial EI.

4. Discussion

Our results showed that a pear-shaped disc, posterior cage positioning and EI were correlated with CR following TLIF. The majority of CR levels with EI exhibited obvious compression damage in the posterior part of the cranial endplate on the decompressed side, with simultaneous caudal endplate damage

isolated in the central portion. Beyond cage breaching into the endplate on lateral radiographs, a characteristic coronal cage misalignment was found on AP radiographs in this type of injury. Other factors, including bone mineral intensity, cage height, and type, were not associated with CR.

The presence of a pear-shaped disc significantly increased the risks of CR, which was consistent with the findings of previous studies.^[3,17] Generally, a pear-shaped disc does not make contact with all four corners of the cage in the sagittal plane, leading to a smaller contact area between the cage and endplate, and to a less uniform stress distribution on the cage, in comparison with that achieved using a concave or linear-shaped disc.^[5] Therefore, the cage in a pear-shaped disc tends to be unstable.

Sagittal cage positioning had a significant influence on CR. Park et al^[3] also reported that posterior cage positioning was a significant factor for CR. Here, we used quantitative measurements introduced by Hu et al^[8] to evaluate cage positioning. In accordance with their results,^[8] we found that sagittal, but not coronal cage positioning was correlated with CR. Biomechanical studies demonstrated that constructs with anterior cage placement were significantly stiffer than those with posterior cage placement, and that the cage shared more load under axial compression with anterior cage placement than with posterior cage placement.^[18] Greater stiffness and load-sharing generated greater interface friction between the cage and endplate to resist CR.^[19] However, coronal cage positioning appeared to have less influence on the stiffness of the constructs and the load-sharing of the cage.^[20,21] These factors may explain the greater importance of sagittal than coronal cage positioning in CR. Therefore, thorough removal of the disc materials and proper bone graft packing are required to achieve ideal cage positioning. The cage positioning should be monitored by intraoperative fluoroscopy, and anterior cage positioning should be pursued.

Our study confirmed that EI was associated with more frequent CR. In agreement with the results reported by Park et al^[3] (70.6%), we found that EI occurred in most of the levels with CR (85.7%). However, the incidence of EI in non-CR levels also appeared to be higher in this study (26.4%) than in their report^[3] (6.2%). This was probably because we used CT, which is supposed to be more sensitive for detecting EI, instead of radiography for evaluation.

Interestingly, the levels with and without CR showed different features of EI. The majority of EIs in the non-CR levels were limited to the central portion in either the adjacent endplate or both endplates and presented as depressions of varying sizes, with a relatively irregular and uneven surface (Fig. 2). We speculate that this may be caused by reaming or curetting during endplate preparation. This type of injury may result in cage subsidence or cage migration within the disc space rather than CR because the peripheral epiphyseal rim of the endplate that could restrict cage movement back into the spinal canal or foramen was intact.^[22,23] In contrast, almost all the EIs in the CR levels showed apparent damage in the posterior part of the cranial endplate on the decompressed side, with simultaneous caudal EI in the central part. The cranial EI extended from the epiphyseal rim to the central endplate, with a compressed but relatively flat surface (Fig. 1). Considering the high density^[24] and strength^[25] (>1000N for load failure) of the peripheral endplate and the surface morphology of the injured cranial endplate, it was less likely that this type of injury was caused by mere reaming or curetting. The greater force when striking the intervertebral space distractors or cage trials into the intervertebral space may also contribute to the injury, particularly when the intervertebral space is narrow and the insertion direction of the instruments is not parallel to that of the intervertebral space. More interestingly, coronal cage misalignment was present on AP radiograph of 17 CR levels and one non-CR level that showed severe cranial EI in the posterior part of the decompressed side. We supposed that the coronal cage misalignment probably reflected this specific severe EI created by the improper path of the inserting instruments. Since CT scans are not routinely performed postoperatively due to the radiation exposure and expense, this radiographic clue indicating a high probability of a specific type of EI and probable subsequent CR should receive sufficient attention.

The influence of this severe EI on the development of CR may be interpreted as follows. First, the EI reduces the contact area and related friction between the cage and the endplate.^[18] Second, it could cause inappropriate cage placement, which decreased the axial pressure distributed on the cage and generated less friction to resist posterior cage migration.^[8] Third, the injury involving the posterior cranial endplate on the decompressed side provided a wide passage to facilitate CR.

EI in the posterior part occurred preferentially in the cranial region; this may be related to the orientation of the intervertebral space, which is usually non-horizontal on the sagittal plane in the lower lumbar spine, with the posterior part more superior than the anterior part.^[26,27] However, because of inertia, surgeons may handle operative instruments in a horizontal direction. Therefore, the cranial endplate rather than caudal endplate is more likely to be impacted in the posterior margin and compressed along the path of the instruments.

The protection of the epiphyseal rim at the posterior margin of the endplate should be given higher priority than the central portion. Accordingly, beyond general recommendations such as adequate preparation for fusion while preserving the bony endplate, the following aspects should be emphasized to contrapuntally avoid this specific type of EI:

1. the intervertebral space should be distracted sufficiently through contralateral instrumentation before intervertebral manipulation, especially for cases with a narrow intervertebral space;
2. the distractors should be used in sequentially increasing sizes to distract the intervertebral space, and be placed in intervertebral space as anteriorly as possible when being rotated so as to decrease direct contact with the posterior margin of the endplate;
3. oversized distractors, cage trails, or cages should not be used, and violent striking should be avoided when inserting them into the intervertebral space; and
4. the insertion direction of the operative instruments should be parallel to that of the intervertebral space. In addition, more attention should be paid to cage placement when reading the intraoperative radiographs.

If coronal misalignment of the cage with its decompressed side located more superiorly is observed, in addition to EI on lateral radiographs, the surgeons should be alert to the subsequent high risks of CR. In addition, better cage placement, adjustment of coronal alignment of the cage, and adjustment of the depth of the cage, if necessary, should be attempted. Moreover, remedial augmented compression by pedicle instrumentation should be applied to the intervertebral space on the decompressed side to effectively confine the cage within the intervertebral space.

Our study had several limitations. First, this was a retrospective study. Second, the small population of 21 migrated cases may be of high heterogeneity. Third, we did not investigate the association between the surface area of the cage and CR. The cage surface area directly affects the contact area to the bone face of the cage and the interface friction.^[28,29] However, because of the varying shape and irregular surface of the cage, the surface area of the cage as well as its contact area to the bone face could not be reliably evaluated. Nevertheless, the effect of this factor should not be excluded. Despite these limitations, three risk factors—a pear-shaped disc, posterior cage positioning, and EI, were identified, and the radiological features of EI in the levels with CR were demonstrated. EI involving the posterior epiphyseal rim

appeared to have a greater influence on CR than injury isolated in the central portion. Targeted protection of the posterior margin of adjacent endplates, careful evaluation of intraoperative radiographs, and timely remedial measures may help to reduce the risks of CR.

5. Conclusions

This study identified a pear-shaped disc, posterior cage positioning and EI as risk factors for CR. EI involving the posterior epiphyseal rim influenced the development of CR. Beyond cage breaching into the endplate on lateral radiographs, this type of EI showed a characteristic appearance of coronal cage misalignment on AP radiographs. Targeted protection of the posterior margin of adjacent endplates, careful evaluation of intraoperative radiographs, and timely remedial measures may help to reduce the risks of CR.

Author contributions

Conceptualization: Zhi-Jie Zhou, Jian-Feng Zhang.

Data curation: Zhi-Jie Zhou, Ping Xia, Jian-Feng Zhang.

Formal analysis: Zhi-Jie Zhou, Ping Xia, Shun-Wu Fan, Jian-Feng Zhang.

Funding acquisition: Zhi-Jie Zhou, Ping Xia.

Investigation: Zhi-Jie Zhou, Feng-Dong Zhao, Xiang-Qian Fang, Jian-Feng Zhang.

Methodology: Zhi-Jie Zhou, Feng-Dong Zhao, Xiang-Qian Fang, Jian-Feng Zhang.

Supervision: Shun-Wu Fan, Jian-Feng Zhang.

Writing – original draft: Zhi-Jie Zhou, Jian-Feng Zhang.

Writing – review & editing: Zhi-Jie Zhou, Jian-Feng Zhang.

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