Risk Factors for Cage Subsidence in Minimally Invasive Lateral Corpectomy for Osteoporotic Vertebral Fractures

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Abstract:

Introduction: This study aims to investigate risk factors for cage subsidence following minimally invasive lateral corpectomy for osteoporotic vertebral fractures.

Methods: Eight males and 13 females (77.2±6.0 years old) with osteoporotic vertebral fractures who underwent single corpectomy using a wide-footprint expandable cage with at least a 1-year follow-up were retrospectively included. The endplate cage (EC) angle was defined as the angle between the vertebral body's endplate and the cage's base on the cranial and caudal sides. A sagittal computed tomography scan was performed immediately after surgery and at the final follow-up, with cage subsidence defined as subsidence of ≥2 mm on the cranial or caudal side. Risk factors were analyzed by dividing cases into groups with (n=6) and without (n=15) cage subsidence.

Results: No significant differences were noted in age, bone mineral density, number of fixed vertebrae, sagittal parameters, preoperative and final kyphosis angle, amount of kyphosis angle correction, bone union, screw loosening, and number of other vertebral fractures preoperatively and 1-year postoperatively between the two groups. No difference was noted in cranial EC angle, but a significant difference was noted in caudal EC angle in the group with (10.7±4.1°) and without (4.7±4.2°) subsidence (P=0.008). Logistic regression analysis with the dependent variable as presence or absence of subsidence showed that caudal EC angle (>7.5°) was a significant factor (odds ratio: 20, 95% confidence interval: 1.655-241.7, P=0.018).

Conclusions: In minimally invasive lateral corpectomy for osteoporotic vertebral fractures, a cage tilted more than 7.5° to the caudal vertebral endplate is a risk factor for cage subsidence. The cage should be placed as perpendicular to the endplate as possible, especially to the caudal vertebral body, to avoid cage subsidence.

Keywords:
minimally invasive lateral corpectomy, osteoporotic vertebral fractures, cage subsidence

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Introduction

Surgical treatment of osteoporotic vertebral fracture (OVF) with severe vertebral collapse and instability requires reconstruction of the anterior vertebral body, which can be difficult because of the fragile bone. The placement of an anterior cage reduces the load on the posterior fixation device and can prevent screw loosening and stress fractures[1)]. Maintaining the height of the anterior column can prevent secondary kyphotic deformities. A minimally invasive lateral corpectomy approach with a wide-footprint rectangular cage has become a common surgical procedure for spinal trauma[2,3)]. Cage subsidence reduces primary stability and overloads the posterior fixation device, causing a correction loss[4)]. A wide-footprint rectangular cage has been shown to have less subsidence than the conventional circular footplate cage.

Recently, a minimally invasive lateral corpectomy ap-

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proach with a wide-footprint rectangular cage has also been used for vertebral fractures caused by osteoporosis. While cage subsidence in younger patients following high-energy trauma has been investigated[5-7], the results in vulnerable osteoporotic patients are limited[8-11].

This study aims to investigate the prevalence and risk factors for cage subsidence following minimally invasive lateral corpectomy caused by OVFs using a wide-footprint rectangular cage.

Material and Methods

Between May 2015 and April 2020, 32 consecutive OVF patients treated with minimally invasive lateral corpectomies at our institution were identified. Eleven patients were excluded; six were transferred to other hospitals for rehabilitation but were not seen in our hospital due to other diseases; five were followed up at our hospital but were excluded because of a lack of postoperative CT images. Of the 32 patients, 21 patients (61-87 years old) were included. The cause of injury in all subjects was due to low-energy trauma, such as a fall from a standing height, which often occurs in osteoporotic patients. Fracture cases associated with high-energy trauma, such as traffic injuries and falls from heights, in patients younger than 60 years old were excluded because they were not osteoporotic fractures. Patients with more than two fresh vertebral body fractures and patients with secondary osteoporosis such as dialysis or steroid use were also excluded. Cases in which cage subsidence was observed immediately after surgery due to intraoperative iatrogenic endplate injury were excluded. The days from fracture to surgery were counted. Bone mineral density (BMD) of the lumbar spine or proximal femur compared to the young adult mean value was measured with dual-energy X-ray absorptiometry. Twenty of 21 patients started osteoporosis treatment using teriparatide preoperatively, and the duration of osteoporosis treatment was measured. The indications for surgery were the presence of neurological symptoms, disruption of the posterior ligamentous complex, and a progressive decrease in vertebral height or increase in vertebral kyphosis, or both, noted on standing radiographs with the patient wearing a thoracolumbosacral brace[12]. The review board of our institution approved the study protocol, and all patients provided informed consent.

All surgeries were performed under general anesthesia, with intraoperative neuromonitoring, which continuously searches for stimulus thresholds triggering electromyogram responses and provides a status report of those thresholds in both sound and vision. Patients were placed in a right lateral position, and the fracture level was premarked using fluoroscopy. An 8- to 10-cm incision was made at the premarked fracture site. The surgeon reached the retroperitoneal cavity manually. The rib was first resected in the thoracic cases to provide retropleural access. A blunt dilator was then used to penetrate the psoas major muscle under fluoroscopy. An expandable retractor (MaXcess®, NuVasive, Inc., San Diego, CA, USA) was placed in line with the posterior wall of the vertebral body. The fractured vertebral body and adjacent discs were exposed, and cephalad and caudal discectomies were performed. After coagulation of the segmental artery, a corpectomy was performed with osteotomes. To reduce the risk of subsidence, a wide-footprint expandable cage (X-CORE2®, NuVasive, Inc.) was used. The cage was filled with autogenous bone taken from the vertebral body beforehand and hydroxyapatite/collagen composite. Then, the cage was inserted as perpendicular to both the cranial and caudal endplates as possible, with appropriately angled endcaps on both sides. To prevent intraoperative endplate injury, cage expansion was completed when the cage adhered to the endplate on fluoroscopic images, and light resistance was felt. To prevent cage subsidence, the kyphosis was corrected gradually while pushing the kyphosis forward manually during the correction. The same spine team performed all surgeries. Percutaneous pedicle screw techniques were not used in all cases but performed open conventional posterior fixation with local bone grafting in the prone position. Pedicle screws were not used for the fractured vertebrae. Posterior open decompression was added for patients with canal stenosis (<50%) and associated neurological deficits. In three of 21 cases, corpectomy was performed after posterior fixation as preferred by the surgeon.

The medical records and images of patients who underwent this surgery were analyzed. Radiographs were taken immediately before surgery; immediately after surgery; and at 1, 3, 6, and 12 months postoperatively. Lumbar lordosis, pelvic incidence, pelvic tilt, thoracic kyphosis, and coronal Cobb angle were measured. In addition, CT images were taken immediately before surgery, immediately after surgery, and 1 year later. Images were evaluated using PACS software (Synapse Vincent; Fujifilm Holdings Corporation, Tokyo, Japan), and the following parameters were measured: (1) local kyphosis angle (the angle between the upper endplate of the intact cranial vertebra and the lower endplate of the caudal intact vertebra on the lateral view of plain radiographs); (2) subsidence (the sinking distance measured from the endplate to the endcap surface of the cage on CT sagittal images); (3) endplate cage (EC) angle (the angle between the endplate and the endcap surface of the cage measured on CT sagittal images immediately after surgery; Fig. 1). Patients with cranial or caudal subsidence (or both) of ≥2 mm at 1 year postoperatively were classified into the subsidence group[13,14], and those without subsidence were classified into the nonsubsidence group. If the sagittal or coronal CT images obtained 1 year postoperatively showed bridging trabeculae between vertebral body or facet joints, radiographic evidence of fusion was determined. Alternatively, flexion and extension radiographs obtained 1 year postoperatively without more than 3° of motion or radiolucency around the cage or hardware failure also were considered radiographic evidence of fusion. The patients' low back and leg pain were evaluated using a visual analog scale (VAS) before surgery and at 1-year follow-up.

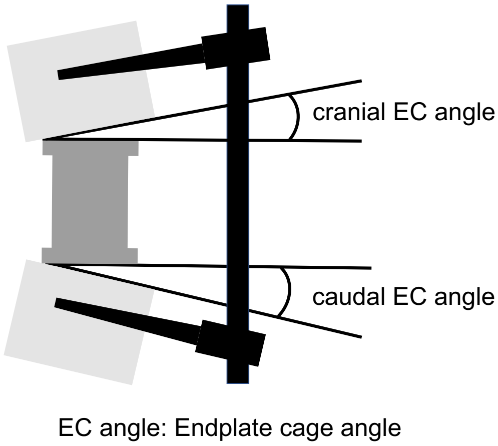

Figure 1. Endplate cage (EC) angle.
The angle between the endplate and the end cap surface of the cage was defined as the EC angle.

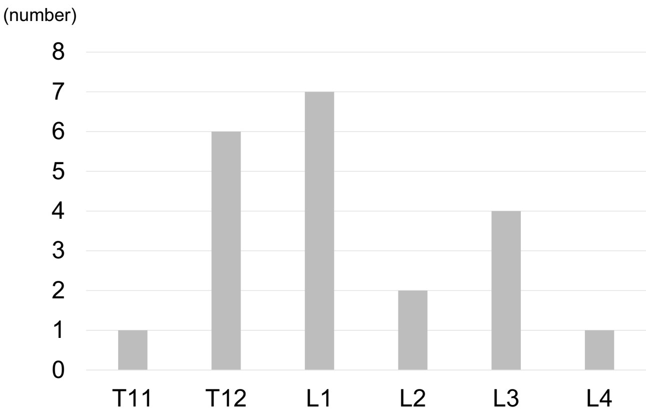

Figure 2. Distribution and number of vertebral fractures by level.

All statistical analyses were conducted using SPSS Statistics (version 25, IBM Corp, Armonk, NY, USA). A *t*-test was used to compare the means of continuous variables such as age and a χ^2 test to compare the proportions of categorical variables such as gender between the subsidence and nonsubsidence groups. A univariate logistic regression analysis was performed to identify the risk factors for the subsidence group as dependent variables. A receiver operating characteristic (ROC) analysis was applied to calculate the cutoff value of the caudal EC angle within the subsidence and nonsubsidence groups; the point with the smallest distance from the upper left corner of the ROC curve was used as the cutoff point. The threshold for significance was set at $P<0.05$. A post hoc power analysis was used for the statistical analysis results because the number of patients involved was small.

Results

The level of the fractured vertebra is shown in Fig. 2. Six of the 21 (28.6%) patients had subsidence (Fig. 3). Four of the six patients with subsidence had cranial and caudal subsidence, one cranial and one caudal. Patients were divided into the subsidence (n=6) and the nonsubsidence (n=15) groups. No significant differences were noted in the age or sex ratio, choice of anterior or posterior surgery first, days from fracture to surgery, BMD, duration of osteoporosis treatment, or cranial and caudal numbers of the fused segments between the two groups (Table 1). No significant differences in sagittal parameters were also noted (Table 2). One year postsurgery, the correction loss of the local kyphotic angle was 3.3±1.7° and 17.0±15.9° in the nonsubsidence and subsidence groups, respectively, but the differ-

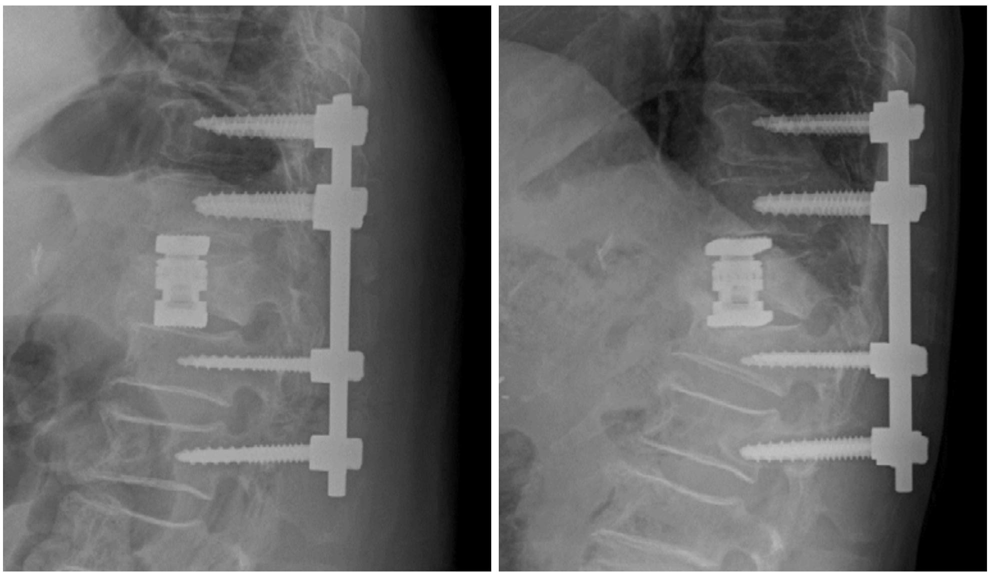

Figure 3. Radiographs of patients.
An 80-year-old woman with a Th12 burst fracture. A No subsidence was present immediately after surgery, but the caudal endplate cage (EC) angle was 15°. B Six months after the surgery, caudal subsidence was observed.

Table 1. Characteristic of Patients with Subsidence and Nonsubsidence.

	Non-subsidence group (n=15)	Subsidence group (n=6)	P value
Age at operation (years)	77.3±7.2	76.8±2.9	0.889
Sex (male vs. female)	6:9	2:4	0.776
First procedure (anterior vs. posterior)	13:2	5:1	0.844
Time from fracture to surgery (days)	46.7±92.9	120.6±47.9	0.112
BMD YAM (%)	76.5±20.1	69.3±21.1	0.48
Duration of osteoporosis treatment (days)	25.5±75.9	81.6±35.5	0.134
Number of cranial fused segments	2.0±0.0	1.8±0.4	0.363
Number of caudal fused segments	2.0±0.0	1.8±0.4	0.363

Data are expressed as means±standard deviation.
BMD, bone mineral density; YAM, young adult mean

Table 2. Radiologic and Surgical Factors in Patients with Subsidence and Nonsubsidence.

	Non-subsidence group (n=15)	Subsidence group (n=6)	P value
Lumbar lordosis (°)	30.5±13.3	23.5±15.1	0.304
Pelvic incidence (°)	47.3±7.9	46.2±13.4	0.818
Pelvic tilt (°)	23.1±8.5	27.2±11.5	0.416
Thoracic kyphosis (°)	26.6±12.5	32.2±8.1	0.401
Coronal Cobb angle (°)	4.4±3.9	5.8±3.3	0.424
Local kyphosis angle (°)			
Preop	17.5±16.4	20.3±22.9	0.755
Postop	2.7±10.5	5.3±13.1	0.63
1 year Postop	5.5±10.6	21.7±26.1	0.052
Operative correction (°)	15.9±6.3	15.7±9.6	0.941
Correction loss of kyphosis angle (°)	3.3±1.7	17.0±15.9	0.089
EC angle (°)			
Cranial	4.5±3.3	7.8±7.5	0.333
Caudal	4.7±4.2	10.7±4.1	0.008*
Fusion			
No	3 (20.0%)	3 (50.0%)	0.198
Yes	12 (80.0%)	3 (50.0%)	
PS loosening			
No	8 (53.3%)	3 (50.0%)	0.633
Yes	7 (46.7%)	3 (50.0%)	
Number of other vertebral fractures			
Preop.	1 (6.7%)	0 (0%)	0.714
1 year Postop	6 (40%)	1 (16.7%)	0.314

Data are expressed as means±standard deviation.
EC angle, endplate cage angle; PS, pedicle screw * Statistically significant

ence was not significant. A significant difference was noted between the groups in caudal EC angle (Table 2). Bone fusion was achieved in 80.0% and 50.0% of the nonsubsidence and subsidence groups, respectively, without a significant difference. Screw loosening was observed in half of the patients in both groups, but no patient required revision surgery (Table 2). The position of pedicle screw loosening was 38.1%, 4.8%, 4.8%, and 47.6% for the two vertebral cranial, one cranial, one caudal, and two caudal levels to the fracture level, respectively. Analysis of low back pain and leg pain using the VAS showed no significant difference between the groups either preoperatively or 1 year postoperatively (Table 3). Univariate logistic regression analysis (Table 4) and ROC curve (Fig. 4) showed that the only significant risk factor for subsidence was caudal EC angle (odds ratio: 20, 95% confidence interval: 1.655-241.7, P=0.018), with a cutoff value of 7.5° (area under the curve [AUC]: 0.844, sensitivity=83.3%, specificity=80.0%). A post hoc power analysis showed that this study was powered to detect differences.

Discussion

The prevalence and risk factors for cage subsidence were analyzed following minimally invasive lateral corpectomy for OVFs. Subsidence occurred in 28.6% of the patients. This study also demonstrated that a bigger caudal EC angle was a significant risk factor for cage subsidence with a cutoff value of 7.5°.

Table 3. Comparison of VAS in Patients with Subsidence and Nonsubsidence.

		Non-subsidence group (n=15)	Subsidence group (n=6)	P value
Preop	VAS (low back pain)	7.8±3.2	5.3±3.8	0.306
	VAS (leg pain)	4.5±4.0	4.0±4.9	0.866
Follow up	VAS (low back pain)	3.7±2.9	3.5±2.4	0.923
	VAS (leg pain)	2.7±2.3	2.5±2.1	0.909

Data are expressed as means±standard deviation.
VAS, visual analogue scale

Table 4. Multivariate Logistic Regression Analysis of Factors for Subsidence.

	P value	Odds ratio	95% confidence interval
Caudal EC angle >7.5	0.018*	20	1.655-241.7

EC, endplate cage
* Statistically significant

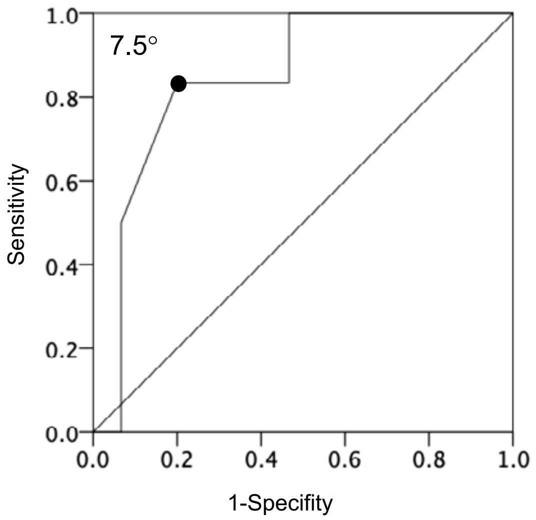

Figure 4. ROC analysis.
From the ROC curve analysis, the cutoff value was 7.5° (AUC=0.844, sensitivity=83.3%, specificity=80.0%).

This study showed that cage subsidence occurred in six of 21 (28.6%) patients, unrelated to clinical outcomes. Previous studies have reported that the frequency of cage subsidence in patients with OVFs was 29-44%[8-11]. Early cage subsidence is expected to decrease tension inside the stabilized structure, reducing primary stability and overloading the remaining posterior fixation devices. Thus, subsidence may lead to postoperative correction loss[4]. The results of this study showed that the loss of kyphosis was 17.0±15.9° and 3.3±1.7° in the subsidence and nonsubsidence groups, respectively, but the difference was not significant.

Clinical outcomes report that subsidence is associated with unfavorable outcomes[14,15], while others report that it does not significantly affect outcomes[16-18]. The results of this study show the presence or absence of subsidence did not affect the bone union, screw loosening, or pain. This may be because the number of cases was small.

Wide-footprint rectangular cages frequently have been used to address bone fragility because osteoporosis has been reported to be a factor in cage subsidence. Previous studies showed that the wide-footprint design resists subsidence better than the circular footplate design[9,14]. The advantages of a wide-footprint cage are that the contact area is larger than that of a circular cage and that the wide-footprint cages are placed on the harder ring apophysis rather than on the vulnerable central portion[19]. Moreover, the expandable cage used in this study has the benefit of adequately adapting to local anatomic conditions in terms of height and lordosis[20]. Thus, using a rectangular footprint cage is an effective treatment for OVF to minimize surgical invasiveness and postoperative correction loss[8,9].

However, this study revealed that an inadequate angle between the cage and the caudal vertebra caused subsidence. A bigger caudal EC angle leads to a smaller contact area between endplates and cages, which induces stress concentrations and results in cage subsidence. Previous studies also found that the superior endplate is mechanically weaker than the inferior endplate. These biomechanical data support the results of this study that show endplate injuries were observed primarily at the superior endplates[6,21]. Therefore, appropriate cage location and EC angle, especially on the caudal side of the cage, should be considered to prevent subsidence.

A few reports exist comparing the outcomes of combined anterior-posterior surgery for vertebral fractures, but it is still unclear whether anterior or posterior surgery should be performed first[2,6,22-25]. A previous study reported that in anterior surgery followed by posterior surgery (A-P surgery), great care should be taken to avoid endplate injury and cage floating, especially in cases with insufficient intervertebral space or long-range posterior fixation[11]. In A-P surgery, even if the appropriate endcaps are selected, the cage is extended to correct kyphosis, resulting in the endplate and cage not being parallel. It is believed that this is the mechanism of a large EC angle, which is the risk of subsidence (Fig. 5). In posterior surgery followed by anterior surgery (P-A surgery), however, the endcap can be selected at an appropriate angle before the cage insertion, resulting in a smaller EC angle, maximizing the contact area of the cage, and lowering the risk of subsidence (Fig. 6). Thus, P-A surgery is considered preferable in patients who can be corrected by posterior fixation in the prone position, such as the acute phase or

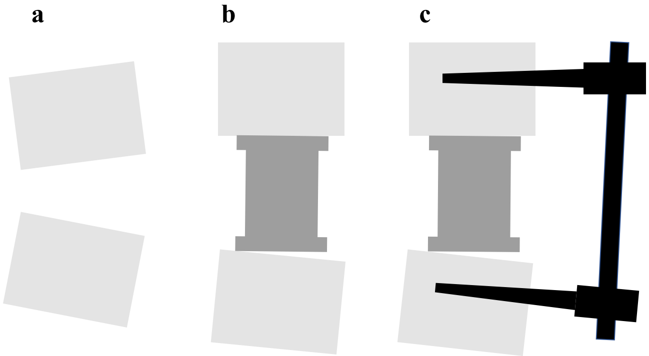

Figure 5. Anterior surgery followed by posterior surgery.
In A-P surgery, cage placement parallel to the endplate is difficult, increasing the risk of subsidence. a Before surgery, b kyphosis correction by cage insertion, and c after posterior fixation.

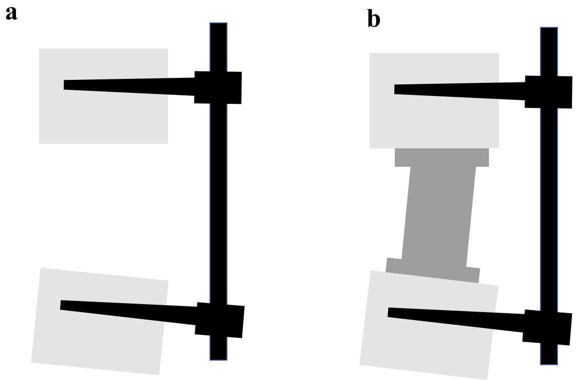

Figure 6. Posterior surgery followed by anterior surgery (P-A surgery).
In P-A surgery, appropriate angled endcaps can be selected, making it easier to place the cage parallel to the endplate. a Posterior correction and fusion and b cage insertion.

pseudoarthrosis, but A-P surgery may also be preferable when sufficient reduction without anterior release cannot be achieved. Therefore, the surgical method depends on the pathology of the OVFs.

This study has several limitations. First, it had a retrospective design, which could have introduced a degree of selection bias. Second, the number of included patients is small because of the low follow-up rate. Third, the follow-up period was short at 1 year. However, a report showed that most of the subsidence and correction loss occurs within 1 year[6]. Further study is required to clarify the long-term outcomes. Nevertheless, this study is the first paper to demonstrate the significance of placing a wide-footprint expandable cage at the proper angle for OVFs.

In conclusion, subsidence occurred in 28.6% of patients following minimally invasive lateral corpectomy for osteoporotic vertebral fractures. A bigger caudal EC angle was a significant risk factor for cage subsidence. The cage should be placed as perpendicular to the endplate as possible, especially to the caudal vertebral body, to avoid cage subsidence.

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Informed Consent: Informed consent was obtained by all participants in this study.

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