Bilateral L5 pedicle fracture with L5–S1 spondylolisthesis after single-level L4–5 posterior lumbar interbody fusion: illustrative case

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BACKGROUND Single-level posterior lumbar interbody fusion (PLIF) or transforaminal lumbar interbody fusion (TLIF) is a commonly performed surgical procedure for L4–5 isthmic spondylolisthesis. Postoperative L5 pedicle fracture with rapidly progressive spondylolisthesis at L5–S1 segment after L4–5 PLIF/TLIF is quite rare, and the etiology remains unclear. This report describes this rare complication and proposes a possible etiology focusing on the lumbosacral sagittal imbalance characterized by an anteriorly shifted lumbar loading axis.

OBSERVATIONS The authors report a case complicated by L5 bilateral pedicle fractures and rapidly progressive spondylolisthesis at the L5–S1 segment very early after a single-level PLIF for L4–5 isthmic spondylolisthesis. Meyerding grade III anterolisthesis was observed at L5–S1 segment by 3 months after the initial surgery. Additional surgery was performed, and the fixation was extended to L4–ilium. Fracture healing was observed at 6 months postoperatively.

LESSONS This complication may have been caused by abnormal local shear forces on the posterior neural arch of L5 vertebra and L5–S1 intervertebral disc, which were triggered by the fusion surgery for L4 shear-type spondylolisthesis. L4 sagittal vertical axis is considered a reasonable parameter representing lumbosacral sagittal imbalance with an anteriorly shifted loading axis and may be a candidate for the predictive parameters of this rare complication.

Illustrative Case

A 69-year-old female with left lower leg pain for more than 6 months was referred to our office. Clinical examination revealed no neurological deficit. Radiographs demonstrated Meyerding grade II isthmic spondylolisthesis at L4–5 (Fig. 1). Magnetic resonance imaging (MRI) demonstrated disc degeneration at the L4–5 and L5–S1 segments and bilateral L4–5 foraminal stenosis. Conservative treatment with medication was not successful, and the patient underwent PLIF at L4–5 segment. The immediate postoperative radiograph demonstrated satisfactory implantation with the restoration of L5–S1 lordosis. Neurological symptoms improved significantly. One week after the surgery, however, routinely performed computed tomography (CT) revealed bilateral L5 pedicle fractures and worsening instability of the L5–S1 segment (Fig. 2). L5–S1

ABBREVIATIONS ASD = adjacent segment disease; CT = computed tomography; HU = Hounsfield unit; LL = lumbar lordosis; LLIF = lateral lumbar interbody fusion; MRI = magnetic resonance imaging; PI = pelvic incidence; PLC = posterior lumbar column; PLF = posterolateral fusion; PLIF = posterior lumbar interbody fusion; SS = sacral slope; SVA = sagittal vertical axis; TLIF = transforaminal lumbar interbody fusion.

INCLUDE WHEN CITING Published August 7, 2023; DOI: 10.3171/CASE23279.


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spondylolisthesis and local kyphotic change progressed rapidly, and by 3 months postoperatively, Meyerding grade III spondylolisthesis was observed. The patient then reported right lower leg pain. CT revealed non-union of an L5 pedicle fracture. Additional surgery was performed, and the fixation was extended to L4–ilium. At 6 months postoperatively, CT demonstrated the fracture healing. Finally, her right leg pain improved (Fig. 3).

For preoperative radiological parameters, lumbar lordosis (LL), pelvic incidence (PI), and sacral slope (SS) were defined as described previously and were 33°, 61°, and 38°, respectively.3 For this case, given the lack of preoperative full-length radiographs of the whole spine, those parameters were measured using standing lateral lumbar radiographs or CT images, as described previously.4,5 L4-sagittal vertical axis (SVA) was defined as the distance between the L4 plumb line and the posteriorsuperior corner of S1, as previously described.3 The preoperative L4-SVA was 58 mm and increased to 64 mm after the initial surgery. These parameters are indicated in Fig. 1. For bone quality of the lumbar spine, the Hounsfield unit (HU) was measured, as previously reported.6 Preoperative HU values at the L2, L3, L4, and L5 vertebral bodies were 164, 140, 229, 173, respectively.
have been reported in other articles investigating L5–S1 adjacent segment disease (ASD) after L4–5 fusion surgery. Therefore, it is still inconclusive whether the frequency is as high as previously reported.

Pedicle fracture after PLIF has rarely been reported, and the etiology remains unclear. Cryon et al. demonstrated that pars interarticularis is most susceptible to injury, followed by the pedicle, which has relatively greater strength and shorter moment arm from the vertebral body. Therefore, under normal mechanical loading, pedicle fractures are very unlikely to occur. However, several reports have offered speculation as to the cause of pedicle fractures. Jorge and Carvalho and Parvataneni et al. have noted that, in cases of posterolateral fusion without anterior fixation, load distribution to the posterior neural arch is unusual and pedicle fracture can occur due to abnormal repetitive shear forces. Macdessi et al. mentioned the involvement of devascularization and cortical weakening of the pedicle after pedicle screw insertion.

In the present case, L5–S1 lumbar spondylolisthesis occurred secondary to L5 pedicle fracture after surgical fixation of L4–5 isthmic spondylolisthesis. Wang et al. and Ferrero et al. reported that, while single-level spondylolisthesis whose sagittal imbalance was not severe can be treated with local fixation, double-level spondylolisthesis presents severe sagittal imbalance with higher PI and higher PI–LL and requires adequate alignment correction when surgery is performed. Du et al. noted a high L4-SVA, a parameter representing the anterior shift of the loading axis of the lower lumbar spine, as one of the indicators of local sagittal imbalance in double-level spondylolisthesis. The present case had single-level spondylolisthesis, but the preoperative lumbosacral sagittal alignment was extremely antverted with a high L4-SVA, and the imbalance was equivalent to or greater than that of double-level spondylolisthesis. Single-level L4–5 fixation for such cases, in turn, may have further increased the mechanical load on the posterior neural arch of the L5 vertebrae and led to L5 pedicle fracture and L5–S1 spondylolisthesis.

Roussouly described two types of mechanical conditions for spondylolisthesis: the shear type (patients with high PI and SS have increased shear stress at the lumbosacral junction, causing more load on the posterior neural arch) and the nutcracker type (patients with low PI and smaller SS would have impingement of the posterior elements of L5 between L4 and S1 during extension). Applying their theory to the present case, the reasonable etiology of this complication may be that, after surgical fixation of L4 shear-type spondylolisthesis, equivalent shear forces were concentrated on the L5 pedicle and L5–S1 intervertebral disc, which led to L5 shear-type spondylolisthesis. This case report is the first to describe the etiology of this rare complication in relation to the pathogenesis of L5 isthmic spondylolisthesis.

L5–S1 disc degeneration was observed preoperatively in our case. Thus, from a different point of view, this complication can be considered as a very acute and severe type of L5–S1 ASD rather than a simple fracture. Although ASD after lumbar fusion has been extensively studied, because of the lower frequency of caudal ASD, quite a few studies have focused on the L5–S1 disorder after L4–5 lumbar fusion. Postoperative pedicle fracture was not described in these articles. Additionally, none of the articles demonstrated a causal relationship between preoperative L5–S1 degeneration and L5–S1 ASD, nor did they investigate the association between L5–S1 ASD and lumbar alignment. Miyakoshi et al. reported 45 cases of L4–5

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**Patient Informed Consent**

The necessary patient informed consent was obtained in this study.

**Discussion**

**Observations**

This is the first case report of L5 bilateral pedicle fractures complicated by L5–S1 spondylolisthesis, which occurred very early after single-level PLIF for L4–5 isthmic spondylolisthesis without traumatic episode. To the best of our knowledge, there have been seven case reports of pedicle fracture associated with posterior instrumentation surgery of the lumbar spine. However, in three cases, the fracture occurred at the adjacent vertebrae, and another case was associated with implant removal. The remaining three cases had pedicle fractures within the fusion range without implant removal, but all of them had experienced middle to long posterolateral fusion (PLF) using a hook-and-rod system without use of pedicle screws.

Chiang et al. reported a case of L5 vertebral fracture and L5–S1 spondylolisthesis at 3 months after L3–5 transfemorallumbar interbody fusion (TLIF). Their case was similar to ours in terms of fracture type and the complication of L5–S1 spondylolisthesis. However, their patient had undergone TLIF for two intervertebral segments. Moreover, their case had an episode of fall trauma at 2 months postoperatively, which was strongly suspected to be involved in the fracture. In our case, on the other hand, the fracture occurred with no traumatic episode at only 1 week after the initial PLIF surgery for the L4–5 single segment. Thus, we believe the clinical impact of the present case is more significant.

Recently, Wanivenhaus et al. reported a case-control study of L5 pedicle fracture after L4–5 PLIF/TLIF and stated that the frequency of this complication is 3.2%. However, their study is currently the only report from a single institute, and no similar cases

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**FIG. 3.** Sagittal (A) and axial (B) CT 6 months after the additional surgery. Arrowheads indicate healing of the pedicle fracture.
PLIF surgery and demonstrated that the presence or absence of preoperative L5–S1 degeneration did not affect the postoperative clinical outcome. Ghistelli et al. reported 32 cases of isolated fixation surgery at the L4–5 segment, and none of them required extended fixation over L5–S1 with an average follow-up of 7.3 years. Spino pelvic or lumbosacral alignment was not assessed in either of these reports. Choi et al. performed single-level L4–5 fixation in 58 cases of L4 spondylolisthesis and evaluated radiography, CT, and MRI studies in detail at 5 years postoperatively. They found that preexisting L5–S1 degeneration did not affect the clinical and radiographic outcomes after L4–5 floating fixation. Then, they concluded that, when fusion surgery is indicated for patients with L4 spondylolisthesis concomitant with L5–S1 degeneration, prophylactic L5–S1 fusion surgery is not routinely necessary unless the preoperative symptoms are attributed to the L5–S1 level. Unfortunately, although 7 of 58 patients had radiographic ASD and 3 had clinical ASD in their study, the authors missed the comparison of preoperative lumbar alignment between the patients with and without L5–S1 ASD.

The following is a discussion about the surgical strategy for the present case. At our institution, in principle, TLIF/PLIF is performed for single-level intervertebral fusion surgery, whereas lateral lumbar interbody fusion (LLIF) with posterior fusion is performed for multilevel fusion. Therefore, PLIF surgery was chosen only routinely for the initial surgery. Retrospectively, however, there is concern that the disruption of the posterior lumbar column (PLC) in the PLIF/TLIF technique may have contributed to pedicle fracture. So, can ASD be avoided with LLIF with the percutaneous posterior fusion technique, which is less disruptive to the PLC? Ouchida et al. reported the impact of surgical disruption of the PLC on ASD after one- or two-level LLIF surgery. They concluded that whether posterior fixation was open or percutaneous, or whether the facet joint was violated or not, did not affect the risk of ASD occurrence, indicating that the avoidance of PLC disruption by the LLIF technique unfortunately does not lead to the avoidance of ASD. When it comes to PLF surgery, there are several case reports of pedicle fractures, albeit in adjacent vertebrae. Thus, the risk of pedicle fracture and ASD seems to be higher in PLF than in PLIF or TLIF. Therefore, when considering surgical treatment for the present case, sufficient alignment correction should have been performed regardless of the surgical procedure, or if it was too difficult, long fusion should have been indicated.

Bone quality was evaluated by HU value assessment. HU value measurement using CT is considered a viable alternative to dual-energy X-ray absorptiometry scanning, and the consensus is that an HU value greater than 160 demonstrates a significant reduction in the risk of osteoporosis, whereas HU values less than 110 are significantly correlated with osteoporosis. In our case, the preoperative HU values at the L4 and L5 vertebral bodies were 229 and 173, respectively, indicating normal bone quality.

Additional surgery with extended fixation is inevitable in the treatment of this complication. Therefore, it would be quite helpful to elucidate the etiology and explore the predictive parameters. The present case showed high PI, PI-LL mismatch, and high L4-SVA, meaning that the patient had both abnormal spino pelvic alignment and abnormal lumbosacral alignment. Which is more directly related to the pathogenesis of this complication: whole spinopelvic alignment or local lumbosacral alignment? A previous study has demonstrated that patients with high PI, high LL, and high SS may be at risk of developing pedicle fractures. Interestingly, however, the study demonstrated no significant difference in PI-LL mismatch between fracture and nonfracture groups, suggesting that spinopelvic imbalance may not successfully predict this fracture. We believe that the anterior shift of the loading axis in the lumbosacral region is associated with excessive shear force on the pedicle. Based on this theory, we suppose that local sagittal imbalance is rather important in the formation of this complication and that the L4-SVA can be a reasonable candidate for the predictive parameters of this rare complication.

Lessons
We presented a case of single-level PLIF for L4–5 isthmic spondylolisthesis that required additional surgery because of early postoperative L5 pedicle fracture and rapidly progressive L5–S1 spondylolisthesis. This complication may have been caused by abnormal shear forces concentrated on the posterior neural arch of L5 pedicle and L5–S1 intervertebral disc due to severe lumbosacral sagittal imbalance with an anteriorly shifted loading axis. The L4-SVA may be a good candidate for the predictive parameters of this rare complication.

Spine surgeons should be aware of such complications, and careful consideration should be given to the treatment strategy when performing surgery in patients with such sagittal imbalance. Further analysis of a larger number of cases will be needed to prove this etiology.

References


Disclosures
The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions
Conception and design: all authors. Acquisition of data: Kitaori. Analysis and interpretation of data: Kitaori. Drafting of the article: Kitaori. Critically revising the article: Kitaori. Reviewed submitted version of the manuscript: Kitaori. Approved the final version of the manuscript on behalf of all authors: Kitaori. Study supervision: Ota.

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