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CASE REPORT

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Spontaneous multilevel lumbar pediculolysis associated with spondylolysis: a rare case and review of the literature

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Abstract

Background Pediculolysis is bone hypertrophy and pseudoarthrosis caused by pedicle fracture and has often been combined with contralateral spondylolysis in previous reports. Multilevel pediculolysis with spondylolysis is extremely rare, and we report a case who underwent surgery. Cases of multisegment pediculolysis were reviewed to inspire the diagnosis and treatment of similar pathological phenomena.

Case presentation A 55-year-old man suffering from low back pain and sciatica was admitted to hospital after failing conservative treatment. The imaging studies revealed bilateral pediculolysis at L3 and L4 and right spondylolysis at L5. When L2-5 internal fixation and fusion surgery were performed, the symptoms improved immediately after surgery. At the 2-year postoperative follow-up, proximal junctional failure appeared and progressively worsened.

Conclusions Multilevel pediculolysis often requires surgical intervention, and segment instability is an important consideration in the development of surgical fusion strategies. The etiology of pediculolysis is still complex and unknown, and the spondylolysis protocol can be used as a reference for treatment. Surgeons should be cautious in surgical planning to minimize the likelihood of postoperative instrumentation failure.

Keywords Pediculolysis, Spondylolysis, Proximal junctional kyphosis, Surgical intervention, Global spinopelvic balance

Background

The site of posterior arch injury can be divided into the isthmus, pedicle, and lamina [1]. Among posterior arch injuries, pedicle injuries, as reported by Ekin et al. [2], were more common in males and L5 vertebrae, 70% were isolated pathologies, and 30% were combined with spondylolysis. This chronic injury leads to pedicle fractures, and continuous stress acts on the unhealed fracture site, resulting in local bone hypertrophy, osteosclerosis, and pseudoarthrosis, which is called "pediculolysis". The concept was proposed in 1991 by Gunzburg et al. [3] and previously was often misdiagnosed as osteoblastoma or infectious disease [4, 5]. Pediculolysis has been reported by scholars in recent years. Nontraumatic multilevel pedicle injuries are rare. We reported a case of multilevel bilateral pediculolysis combined with spondylolysis, and postoperative complications occurred proximal to the fused segment.

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Case presentation

Initial visit

A 55-year-old man with low back pain and sciatica, accompanied by intermittent neurogenic claudication for 2 years, visited the outpatient clinic. The visual analog scale (VAS) score for low back pain was 4, and the VAS score for leg pain was 5. CT was performed at the initial visit and revealed L3-4 and L4-5 spinal stenosis, L5 right spondylolysis, and an intact pedicle (Fig. 1). The patient received exercise therapy and nonsteroidal anti-inflammatory drugs (NSAIDs), and the symptoms of leg pain were relieved for two years.

Preoperative

Sciatica progressively worsened over 2 months, and rest was required after intermittent claudication of 50 m (low back pain VAS score of 7, leg pain VAS score of 8). There was no history of trauma or heavy physical labor. Computed tomography (CT) revealed bilateral pediculolysis at L3 and L4; magnetic resonance imaging (MRI)

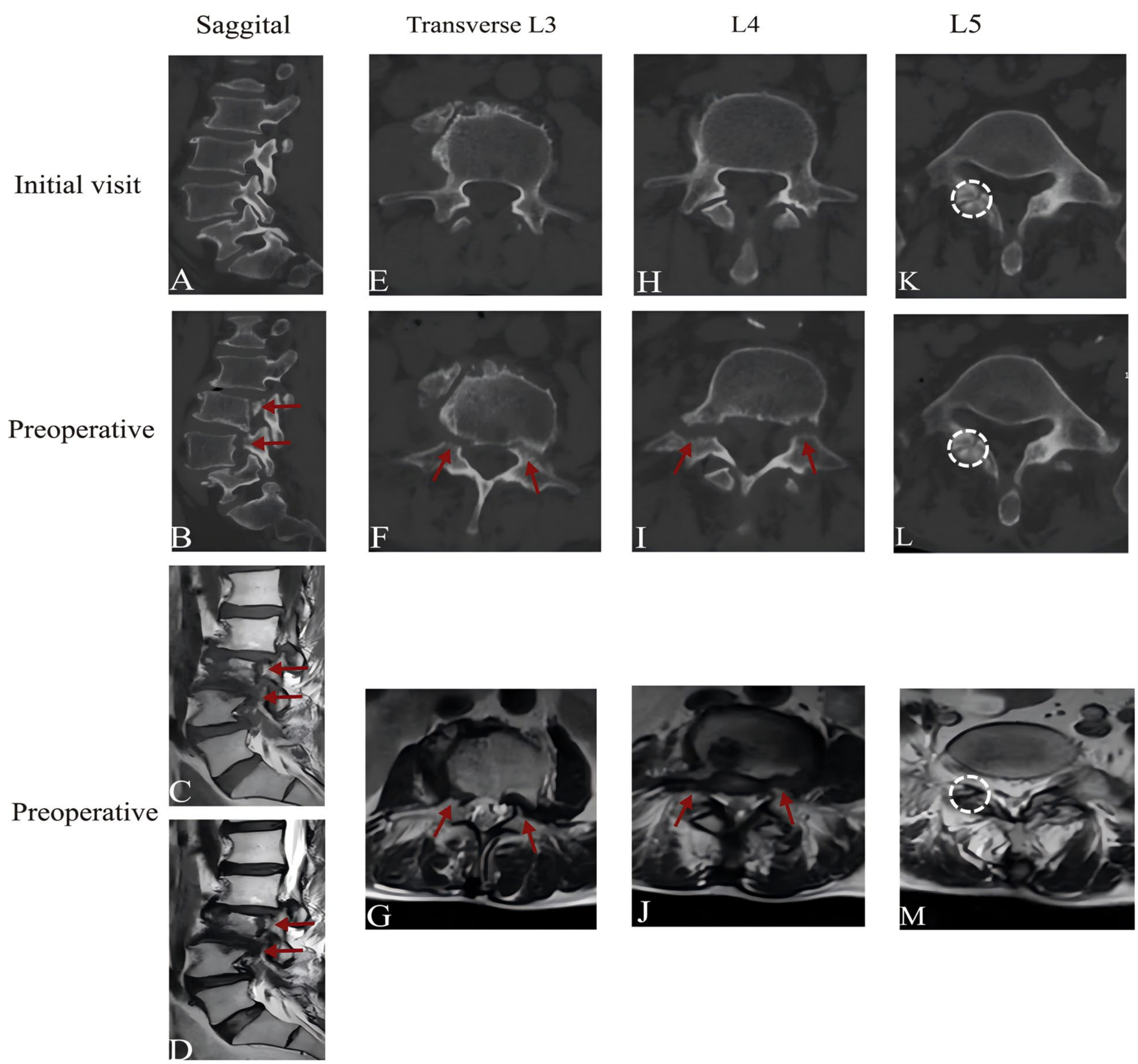

Fig. 1 CT scan at the initial visit confirmed intact pedicles at L3 and L4 (**A**/**E**/**H**) and defects in the right isthmus at L5 (**K**, white circle). The preoperative CT revealed bilateral pediculolysis of L3 and L4, hyperplasia and sclerosis around the defect (**B**/**F**/**I**, red arrow), and hyperplasia and sclerosis at the right isthmus end of L5 (**L**, white circle). On preoperative MRI, sagittal T1- and T2-weighted images revealed hypointensity at the pedicle cleft (**C**/**D**, red arrow), cross-sections with hypointensity at the defect (**G**/**J**, red arrow), and a right isthmus with hypointensity (**M**, white circle)

revealed bilateral pedicle defects at L3 and L4; and T1- and T2-weighted images were hypointense (Fig. 1). L3-4, L4-5 spinal stenosis (Fig. 2); radiographs indicate instability of the L3 and L4 segments (Fig. 3). The patient was previously diagnosed with rheumatoid arthritis and bronchitis and was regularly treated with medication. Preoperative quantitative computed tomography (QCT) was conducted, revealing a bone mineral density of 83.0 mg/cm³ in the L1–L4 vertebral bodies, which indicates the presence of osteopenia.

Patients present with lumbar instability, scoliosis, and significant neurological deficits. Surgical intervention is recommended as an effective treatment modality. The curve was determined to be L2–5 in the coronal plane. L5-S1 shows no segmental instability or severe disc degeneration. The range of motion of the L5-S1 segment is preserved, and the right L5 isthmus defect is not treated. L2-5 fusion surgery, specifically a combination of PLIF and TLIF techniques, was conducted (Fig. 3).

Postoperative recovery was smooth, lower extremity neurological function was intact, and leg pain was significantly improved. He was discharged from the hospital on the 6th day after the operation. Lumbar alignment was restored after the operation, and the stability improved immediately. A brace was given for protection while performing the prescribed functional exercises. The patient was requested to return for outpatient follow-up every three months.

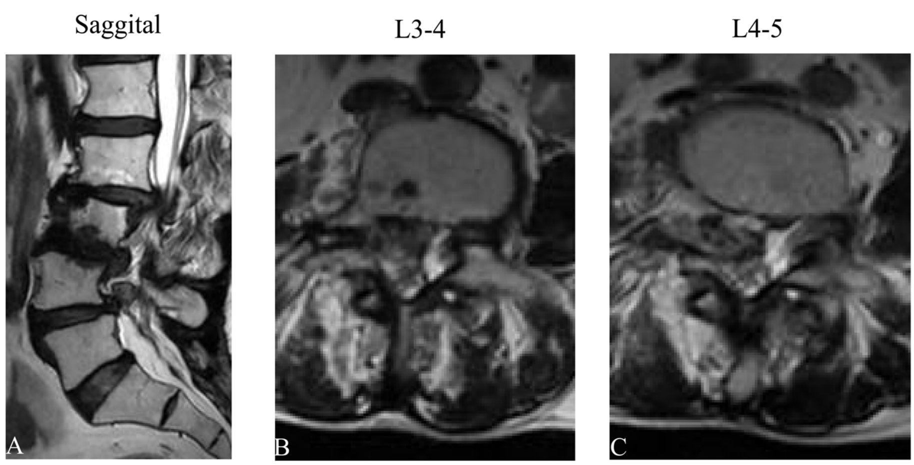

Fig. 2 MRI median sagittal and cross-sectional scans (**A**/**B**/**C**) revealed L3–4 and L4–5 spinal stenosis, dural sac compression, redundant nerve roots, and nerve root sedimentation signs (+); in the sagittal view (**A**), the L3-4 disc indicates downward prolapsed, and the L4-5 disc indicates upward prolapsed; transverse scans reveal the upper endplate layer of L4 (**B**) and the lower endplate layer of L4 (**C**)

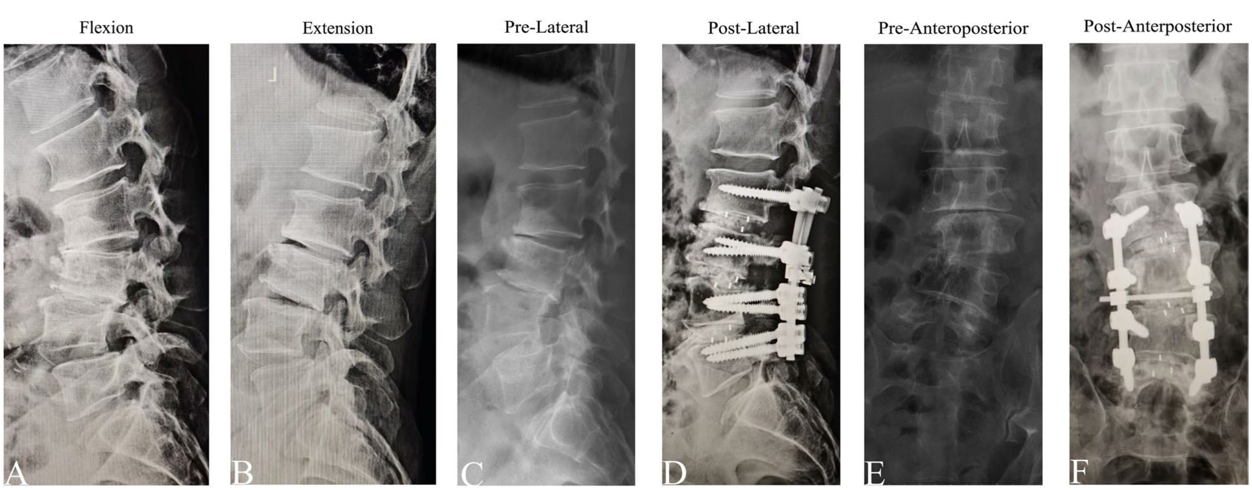

Fig. 3 Preoperative dynamic plain (**A**, **B**) indicates instability of L3 and L4 with spondylolisthesis, showing pediculolysis (**C**), and the anteroposterior plain (**E**) indicates the formation of scoliosis and lateral slip of L3 and L4; status immediately after L2-5 PLIF combined with TLIF surgery (**D**, **F**)

Postoperative

Postoperative follow-up CT confirmed satisfactory interbody fusion (Fig. 4), but progressive proximal junctional kyphosis (PJK) occurred above the fusion level. At follow-up, the Cobb angle of the endplate on the upper instrumented vertebra (UIV) and the endplate on the 2 vertebral bodies above the UIV (UIV + 2) was recorded, which is the proximal junctional angle (PJA) [6], Fig. 5. The PJA had increased significantly at the 1-year follow-up. The UIV and intervertebral space gradually collapsed

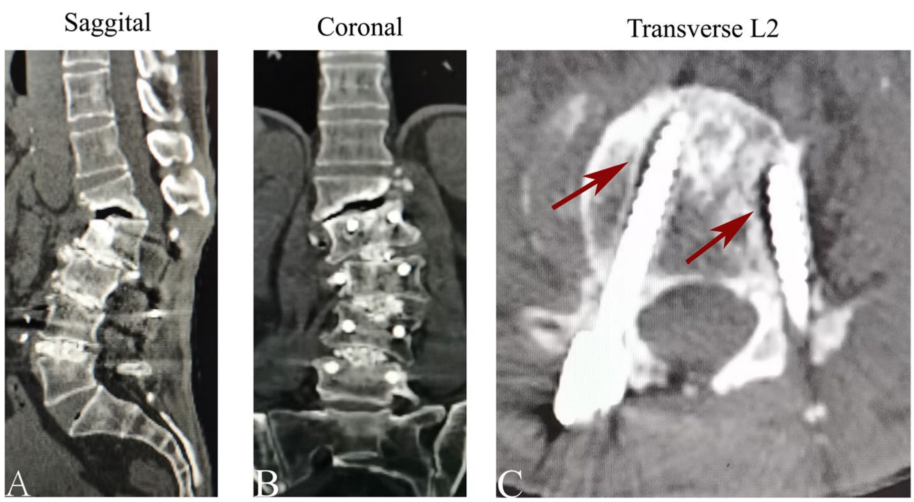

Fig. 4 At the 24-month postoperative follow-up, the sagittal and coronal CT scans (**A**, **B**) confirmed L2-3, L3-4, and L4-5 bony fusion; the sagittal image (**A**) showed severe degeneration of the L1-2 segment, intervertebral space and vertebral collapse, and the formation of proximal junctional kyphosis; the coronal image (**B**) suggested proximal degeneration and collapse; the L2 transverse scan (**C**, red arrow) revealed radiolucent zones around the bilateral screw tips

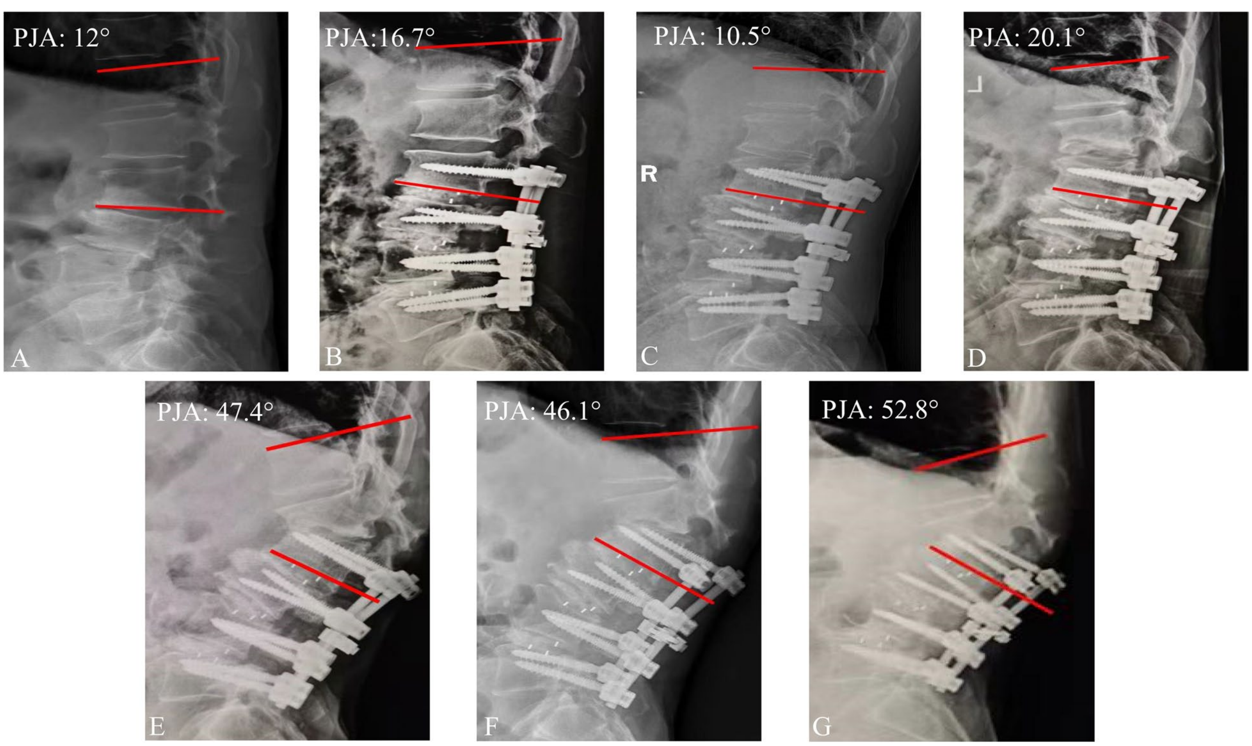

Fig. 5 During the follow-up period, PJA was recorded on the lateral plain preoperatively (**A**), immediately postoperative (**B**), at the 3-month follow-up (**C**), at the 6-month follow-up (**D**), at the 12-month follow-up (**E**), at the 18-month follow-up (**F**), and at the 24-month follow-up (**G**)

and there were signs of loosening of the L2 screw. Kyphosis centered at L1-2 appeared (Fig. 4). Lab results and postoperative MRI showed no signs of infection (Fig. 6). Spino-pelvic parameters [lumbar lordosis (LL), pelvic tilt (PT), pelvic incidence (PI), and sacral slope (SS)] fluctuated greatly during the two-year follow-up (Table 1). The LL was gradually lost after surgery, PT increased compensatorily, and the PI-LL mismatch increased.

At the last follow-up, a full-length radiograph revealed that the global balance was within the normal range. The PJK had increased significantly to 52.8°, the thoracic kyphosis (TK) and decreased, and the degree of PI-LL mismatch reached 44° (Fig. 7). In the postoperative follow-up QCT, the recorded bone density value at T11-L1 was 100.6 mg/cm³, which still indicates osteopenia. The patient was able to walk normally with a brace in the first year following surgery. In the second year following surgery, he suffered from low back pain, which worsened when walking upright. The VAS score for low back pain was 4, and there were no symptoms of neurological damage to the lower extremities. Moreover, we recommended a conservative strategy of continuing to wear a brace and avoid strenuous activities. At the 24-month follow-up, we recommended surgical correction due to postoperative junctional failure (PJF), but the patient refused surgical treatment because of tolerable low back pain. The patient is still undergoing follow-up.

Table 1 Changes of spinopelvic parameters

PI (°) 74.4				
	PT (°)	**SS (°)**	**LL (°)**	**PJK (°)**
Preoperative	18.6	55.8	25.7	12
Postoperative-immediate	20.6	53.8	60.2	16.7
Follow-up				
3 months	17.5	56.9	54.3	10.5
6 months	19.2	55.2	46.2	20.1
12 months	32.3	42.1	31.2	47.4
18 months	26.9	47.5	34.1	46.1
24 months	31.1	43.3	30.4	52.8

Discussion

Pediculolysis is one of the uncommon causes of low back pain [2, 7, 8]. The etiology remains unclear, but local biomechanical deterioration, advanced age, immune diseases, metabolic abnormalities, and neural arch defects are risk factors for its occurrence [9–11]. Several articles have reported unilateral spondylolysis combined with contralateral pediculolysis [3, 9, 12–14]. Sairy et al. [15] confirmed via mechanical simulations that the contralateral pedicle and isthmus can increase stress to 12.6 times greater than normal in unilateral isthmus defects. Unilateral isthmus defects are a predictable cause of contralateral posterior arch injury.

Due to their strong structure, injuries associated with pedicles are often caused by severe violent trauma. Compared with those of the isthmus, fatigue injuries are less likely to occur. According to a previous literature review, unlike failure of formation, cracks, and other deformities can occur. Pediculolysis does not appear congenitally but is caused by “abnormally high stress” on the pedicle structure [2, 16–18]. Gradual failure of the neural arch results in bone discontinuity accompanied by a stress reaction.

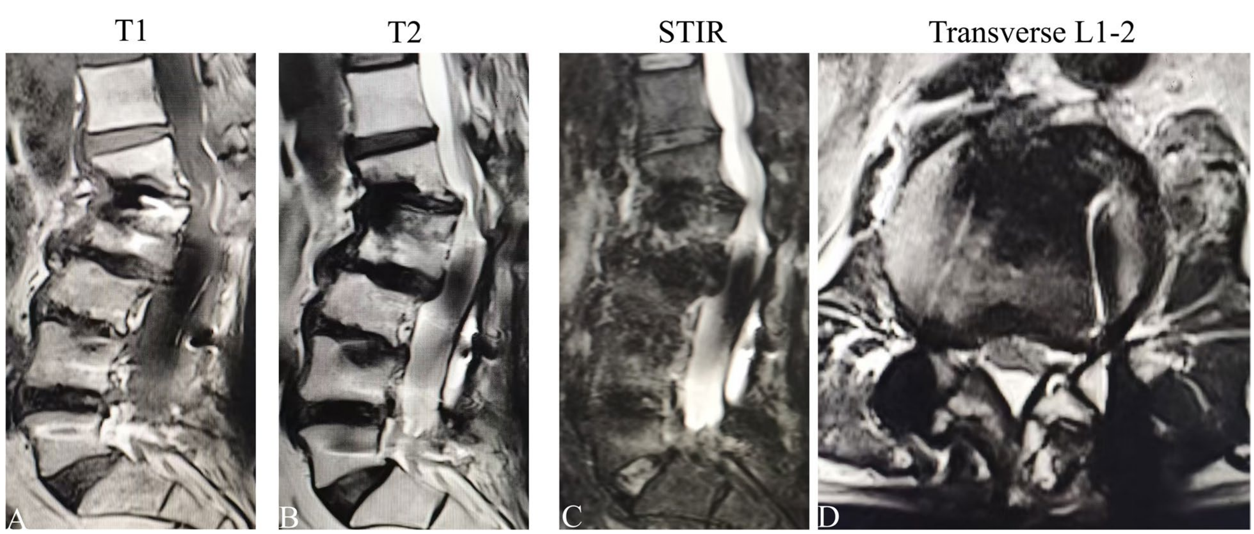

Fig. 6 MRI was performed at the last postoperative follow-up, and there were no signs of infection on sagittal (**A**, **B**, **C**) or transverse (**D**) scans

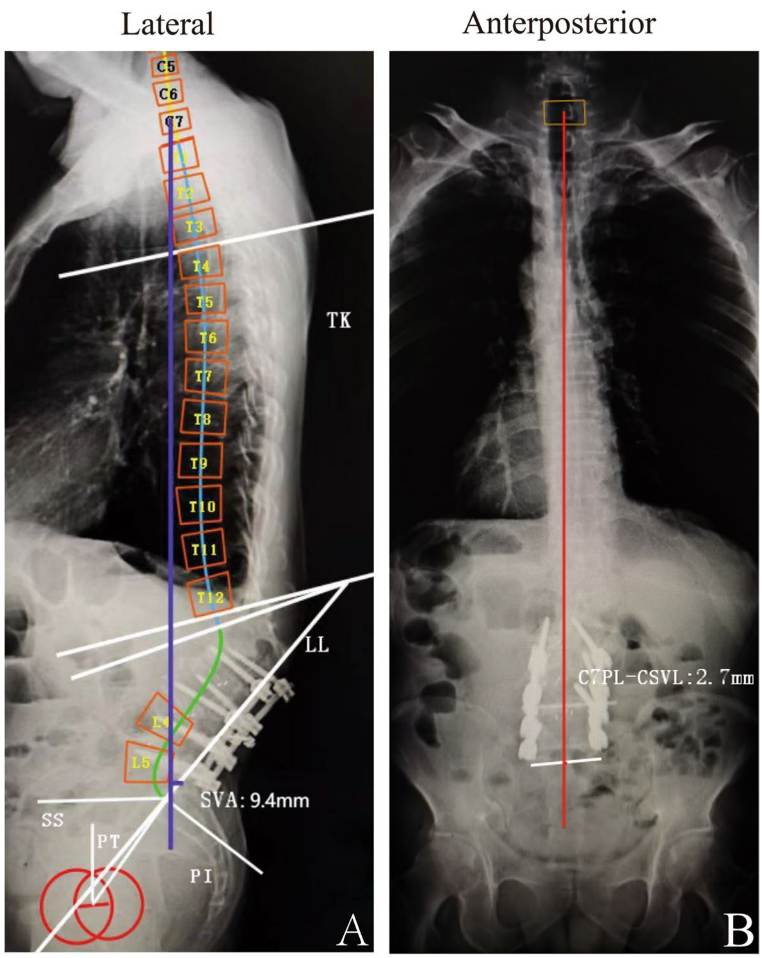

Fig. 7 At the 24-month follow-up, the full-length anteroposterior and lateral radiographs (**A** and **B**) revealed that the sagittal vertical axis (SVA) was 9.4 mm, the coronal C7PL-CSVL was 2.7 mm, and the global alignment was within the normal range. Pelvic parameters: PI: 74.4°, PT31.1°, and SS43.3°; other parameters: TK 2.6°, LL 30.4°, and PJA 52.8°

The relationship between pedicle stress fractures and pediculolysis has not yet been fully distinguished. The two terms may not be considered independent concepts but rather have interactive processes. For pedicle defects, fractures may be more likely to occur under long-term "stress fatigue", and fractures may be a serious consequence. Stress fractures may be a broader concept [16, 17, 19]. For "fatigue injury" caused by healthy bones, the biomechanics and damage characteristics are different from those of pediculolysis. Pediculolysis is a chronic pathological process that is repeatedly stimulated by shear, axial, flexion, and extension stresses, and changes in the pedicle, such as osteosclerosis, pseudoarthrosis, and callus formation, occur [3, 18, 20]. There are differences in the treatment scenarios between the two conditions on the basis of the mechanism and anatomical characteristics.

Imaging provides information about pedicle injuries. In addition to the different pathogeneses of the injury, imaging is the key to identifying the injury. CT and radionuclide scans are often used [5, 21, 22]. Injury characteristics have been described in past studies: Pedicle dysplasia: the cleft produces less hyperplasia and sclerosis [23]; pedicle stress fracture: more prone to transverse injury, resulting in accumulation of the mid-pedicle [18]; and pediculolysis: the cleft tends to be irregular, often located at the junction of the pedicle and vertebral body.

Literature review on multi-level pediculolysis

We reviewed cases of multilevel pediculolysis. The PubMed English online database was used to search the literature for the relevant keywords of "Pediculoysis". Use descriptors(pedicle stress fracture[Text Word]) OR (pediculolysis[Text Word]) OR (pedicle stress injury[Text Word]) OR (pedicle fractures[Text Word]) OR (pedicle cleft[Text Word]). Articles were retrieved from 1990 to present. The language of the included studies was limited to English. We limited the criteria for inclusion in the cohort: (1) No history of trauma or spontaneous pedicle fracture caused by nonsurgical factors; (2) ≥ 2 consecutive segments; (3) In line with the concept of "pediculolysis". A total of 131 publications were identified, and 5 manuscripts that met the criteria were ultimately included. The characteristics and outcomes of these reports are shown in Table 2.

The literature review revealed that pediculolysis occurred in middle-aged and elderly patients. The vast majority of cases involved women. Except for one patient with minor trauma, none were caused by an acute event. The course of the disease is long, even if there is a recent episode of low back pain, but it tends to have a longer natural history. Most reported cases of involve osteoporosis, and the segments prone to injury are mainly at L3, L4, and L5. Surgery is the choice of most surgeons and has good results.

Treatment strategy

In this case, QCT, a bone quality detection tool with less interference with degeneration and vascular calcification [29], was used for evaluation (according to the guidelines, ≤ 80 is osteoporosis, 80–120 is osteopenia, and ≥120 is normal). The osteopenia level did not significantly decrease, which is not a serious defect in bone strength. There appears to be disagreement with previous reports that multilevel fractures are caused by osteoporosis [18, 20]. In this patient, pediculolysis occurred as a short-term progression within 2 years, without dysplasia, and was a spontaneous and nontraumatic process. We speculate that its occurrence was caused by multiple factors, such as long-term stress on the pedicle defect, immunosuppressive use, and local spinal imbalance. Owing to the rarity of this condition, there are no guidelines for treatment. As a structure of the spinal motor unit, its treatment can be referred to as spondylolysis [22].

There are still differing theories about fracture treatment for defects [16–18, 20, 23]. Conservative treatment is the most recommended treatment, especially for adolescent athlete injuries [16]. For clefts without osteosclerosis, activity restriction, bracing, and physical therapy may be beneficial. If there is no evidence of instability, compression screws are an option for direct repair of the cleft. For the fixed strategy, Viswanathan provided advice [20]. The pedicle is the strongest of the three columns, and posterior fixation is recommended for pedicle injuries [30]. The use of fusion is still controversial. In multilevel pediculolysis, the motor unit is unstable because of separation of the pedicle and body, spinal canal enlargement, scoliosis, and slippage, which requires fusion intervention.

In this case, nerve involvement is also present, and thorough decompression and fusion are inevitable, which increases the operation time and degree of trauma. There is a large dissociative cleft during pediculolysis, and loosening of the UIV screws and junctional kyphosis occur despite strong intervertebral fusion. Nonunion of the pedicle of the cleft results in greater stress on the screw–bone interface. Accurate screw placement is the key to ensuring defect healing, and we believe that autologous bone grafting at the defect site can achieve better healing.

For multilevel cases, we suggest the use of a full-length radiograph to assess global balance, thoracolumbar compensation, and scoliosis flexibility to help formulate surgical strategies to restore alignment. For long-segment correction, pelvic immobilization is not routinely

Table 2 Studies of multilevel pediculolysis

Author, Year	Sex	Age	Involve segment	Symptoms/ Duration	Complication	Treatment	Final outcome
Kim et al. [24] 2012	Female	70	L4,L5	Low back and leg pain/2 years	Osteoporosis	L4-5PLIF	Pain relief
Karabay et al. [25] 2015	Female	61	L1,L2,L3,L4	Low back pain/2 years	Osteoporosis	Physical therapy	-
Schmid et al. [26] 2017	Female	60	L2,L3,L4	Low back and leg radiating pain/-	primary adrenal failure and hypothyreosis	L4-5PLIF + L2-3/ L3-4ALIF	Pain relief, osseous fusion
Carr et al. [27] 2018	Female	79	L2,L3	Neurogenic claudication and back pain/10 years	-	L4-5MID + L2-3 unilateral fixation	Pain relief, bony trabeculation
Yi et al. [28] 2023	Female	60	L3,L4,L5	Mechanical low back pain/3 weeks	Type 2 diabetes, osteoporosis, and obesity	L3-5PPSF	Pain relief, bone healing
Current study 2024	Male	55	L3,L4	Low back pain and sciatica	Rheumatoid arthritis, bronchitis	L2-5PLIF	Pain relief, L2-5 bone healing, proximal junctional kyphosis

PLIF Posterior umbar interbody fusion, *MID* minimally invasive decompression, *ALIF* anterior lumbar interbody fusion, *PPSF* percutaneous pedicle screw fixation recommended. In this case, the L5-S1 had no segmental instability. The L5 isthmic defect was not affected, and fusion was terminated at the L4-5 level. However, the L5–S1 angulation increased significantly after surgery. Although preoperative planning preserves lumbosacral mobility and increases the global compensatory capacity, S1 fixation is still required for the potential instability of spondylolysis.

The center of mass of the lumbar spine caused by high PI and high SS moves forward, TK decreases compensatorily, the overall center of mass of the thoracolumbar segment trends backward, and the stress in the thoracolumbar junction increases significantly [31]. The abnormal stress at the thoracolumbar junction can result in instrumentation failure, frequently presenting as PJK. In this case, PJK progressed during the two-year postoperative follow-up. PJK is considered a common complication after long-segment fusion surgery, with an incidence of 15–40% [32]. PJF is regarded as a progressive manifestation of PJK, characterized by proximal fractures, instrumentation loosening or breakage, and neurological deficits [32].

PJK may be a compensatory mechanism for rebalancing, and a "new balance" occurs when insufficient correction of thoracic kyphosis occurs [33]. It is not in a "balanced state"; rather, it exists in a compensatory "deterioration state" which is characterized by structural failure of the UIV. Some scholars believe that fixation across the thoracolumbar segment can reduce stress concentration. In a survey of surgeons [34], for the UIV, they preferred T10 in the lower thoracic vertebra and T3 in the upper thoracic vertebra, with the former being the lowest inactive thoracic vertebra and the latter spanning the physiological kyphosis of the thoracic vertebra. In this case, PJF progressed within two years, and the revision strategy should be away from the kyphotic vertex, at least above 2–3 segments; improve the fusion rate; and reduce junction failure caused by physiological activities.

In this report, it is essential to acknowledge that increased soft tissue dissection, disruption of the posterior ligamentous complex, and excessive bone structure destruction may contribute to postoperative instrumentation failure. Postoperative PI-LL mismatch and high PT were significantly related to instrumentation failure in previous studies [31, 35]. There was a significant imbalance in the spino–pelvic relationship during follow-up. The PI–LL relationship should be used to avoid the risk of instrumentation failure caused by overcorrection; if the SVA is imbalanced, the sagittal sequence should be corrected during surgery [36]. Patient acceptance, physical health status, potential functional loss, and surgical efficiency affect the initial surgery decision [34]. There are limitations in this report, and full-spine X-rays were not included as part of the routine evaluation of scoliosis in the perioperative evaluation at our center. Attention should be given to the collection of global balance information during follow-up.

Conclusion

Multilevel pediculolysis is a three-dimensional deformity caused by stress anomalies and degenerative factors. Caution should be exercised in surgical planning to reduce long-term complications. For such patients, UIV selection, recovery alignment, and brace protection are the keys to treatment. The cause of pediculolysis is still unclear. Current reports on pediculolysis are all based on case-by-case pathological diagnosis and treatment, and more complete anatomical and biomechanical observations are needed.

Abbreviations

VAS	Visual analog scale
CT	Computed tomography
MRI	Magnetic resonance imaging
PLIF	Posterior lumbar interbody fusion
PJF	Postoperative junctional failure
UIV	Upper instrumented vertebra
PJK	Proximal junctional kyphosis
PJA	Proximal junctional angle
LL	Lumbar lordosis
PT	Pelvic tilt
PI	Pelvic incidence
SS	Sacral slope
TK	Thoracic kyphosis
QCT	Quantitative computed tomography
ASD	Adjacent segment degeneration
SVA	Sagittal vertical axis
MID	Minimally invasive decompression
ALIF	Anterior lumbar interbody fusion
PPSF	Percutaneous pedicle screw fixation

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Authors' contributions

Conception and design: Zan Chen and Yusheng Bao. Acquisition of data: Zan Chen, Yusheng Bao. Analysis and interpretation of imaging data: Zan Chen, Yusheng Bao. Manuscript Preparation: Daxiong Feng, Peng Yinxiao. Manuscript revision and modification: Fei Lei. All authors critically revised the manuscript.

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Data availability

The data supporting the results of this study are available from the corresponding author [F.L] on reasonable request.

Declarations

Ethics approval and consent to participate

Approval for this study was obtained from the Ethics committee of the Affiliated Hospital of Southwest Medical University(KY2024400).

Consent for publication

Informed consent was obtained from participating researchers to publish information and images. The patient provided written informed consent to release personal and clinical details and all identifying images. This paper has not been published elsewhere in whole or in part, or submitted elsewhere for review. All authors have read and approved the content.

Competing interests
The authors declare no competing interests.

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References

1. Miyagi R, Sairyo K, Sakai T, et al. Two types of laminolysis in adolescent athletes. J Orthop Traumatol. 2012;13(4):225–8.
2. Ekin EE, Altunrende ME. Pedicle Stress Injury in Children and adolescents with Low Back Pain. Spine (Phila Pa 1976). 2019;44(17):E1038–44.
3. Gunzburg R, Fraser RD. Stress fracture of the lumbar pedicle. Case reports of pediculolysis and review of the literature. Spine (Phila Pa 1976). 1991;16(2):185–9.
4. Wiener MD, Martinez S, Forsberg DA. Congenital absence of a cervical spine pedicle: clinical and radiologic findings. AJR Am J Roentgenol. 1990;155(5):1037–41.
5. Wilkinson RH, Hall JE. The sclerotic pedicle: tumor or pseudotumor? Radiology. 1974;111(3):683–8.
6. Ham DW, Kim HJ, Park SM, et al. The importance of thoracolumbar junctional orientation, change in thoracolumbar angle, and overcorrection of lumbar lordosis in development of proximal junctional kyphosis in adult spinal deformity surgery. J Neurosurg Spine. 2022;37(6):874–82.
7. Sakai T, Sairyo K, Takao S, et al. Adolescents with symptomatic laminolysis: report of two cases. J Orthop Traumatol. 2010;11(3):189–93.
8. Turner PG, Green JH, Galasko CS. Back pain in childhood. Spine (Phila Pa 1976). 1989;14(8):812–4.
9. Doita M, Ando Y, Hirata S, et al. Bilateral pedicle stress fracture in a patient with osteoporotic compression fracture. Eur Spine J. 2009;18(Suppl 2Suppl 2):206–9.
10. Han SH, Hyun SJ, Jahng TA, et al. Posterior osteosynthesis of a spontaneous bilateral pedicle fracture of the lumbar spine. J Neurosurg Spine. 2016;24(3):398–401.
11. Hajjioui A, Khazzani H, Sbihi S, et al. Spondylolisthesis on bilateral pedicle stress fracture in the lumbar spine: a case study. Ann Phys Rehabil Med. 2011;54(1):53–8.
12. Dhamija B, Kombogiorgas D, Harland SP. Spontaneous pediculolysis with associated contralateral laminar fracture. A case report. Acta Orthop Belg. 2011;77(6):847–52.
13. Garber JE, Wright AM. Unilateral spondylolysis and contralateral pedicle fracture. Spine (Phila Pa 1976). 1986;11(1):63–6.
14. Kim KS, Kim YW, Kwon HD. Unilateral spondylolysis combined with contralateral lumbar pediculolysis in a military parachutist. J Spinal Disord Tech. 2006;19(1):65–7.
15. Sairyo K, Katoh S, Sasa T, et al. Athletes with unilateral spondylolysis are at risk of stress fracture at the contralateral pedicle and pars interarticularis: a clinical and biomechanical study. Am J Sports Med. 2005;33(4):583–90.
16. Kessous E, Borsinger T, Rahman A, et al. Contralateral spondylolysis and fracture of the lumbar pedicle in a Young Athlete. Spine (Phila Pa 1976). 2017;42(18):E1087–91.
17. Kriz PK, Kobelski GP, Kriz JP, et al. Pars interarticularis and Pedicle Stress Injuries in young athletes with Low Back Pain: a retrospective cohort study of 902 patients evaluated with magnetic resonance imaging. Am J Sports Med. 2024;52(10):2639–45.
18. Viswanathan VK, Shetty AP, Jakkepally S et al. Symptomatic unilateral Pediculolysis Associated with Contralateral spondylolysis and spondylolisthesis in adults-case report and review of literature. World Neurosurg. 2020;143:339–45.
19. Sadiq MZ. Bilateral pedicle stress fracture in the lumbar spine of a sedentary office worker. Eur Spine J. 2006;15(Suppl 5):653–5.
20. Viswanathan VK, Rajaram Manoharan SR, Subramanian S. Symptomatic unilateral Spondylolysis Associated with nonspondylolytic lateral clefts in adults: review of an infrequently reported Pathology. Cureus. 2016;8(12):e928.
21. Traughber PD, Havlina JM. Jr. Bilateral pedicle stress fractures: SPECT and CT features. J Comput Assist Tomogr. 1991;15(2):338–40.
22. Hu SS, Tribus CB, Diab M, et al. Spondylolisthesis and spondylolysis. J Bone Joint Surg Am. 2008;90(3):656–71.
23. Chang S, Wang Y, Liu Y et al. Case Report: lumbar spondylolisthesis with unilateral pedicle cleft and contralateral spondylolysis: a report of two cases and literature review. Front Surg. 2024;11:357282.
24. Kim HS, Kim SW, Lee WT. Spondylolisthesis accompanying bilateral pedicle stress fracture at two vertebrae. J Korean Neurosurg Soc. 2012;51(6):388–90.
25. Karabay N, Ozer E, Ada E. Multi-level, bilateral pedicle fractures: case report. Turk Neurosurg. 2015;25(2):340–3.
26. Schmid T, Heini P, Benneker L. A rare case of non-traumatic, multi-level, bilateral pedicle fractures of the lumbar spine in a 60-year-old patient. Eur Spine J. 2017;26(Suppl 1):197–201.
27. Carr D, Cook RF, Bahoura M, et al. Two-level spontaneous pedicle fracture above a degenerative spondylolisthesis and minimally invasive treatment. Asian J Neurosurg. 2018;13(4):1279–81.
28. Yi J, MacAllister MC, Caruso JP et al. Image-guided Percutaneous Multilevel Pediculosynthesis for treatment of contiguous pedicle stress fractures: Technical Case Report. World Neurosurg. 2023;174132–6.
29. Kulkarni AG, Thonangi Y, Pathan S, et al. Should Q-CT be the Gold Standard for detecting spinal osteoporosis? Spine (Phila Pa 1976). 2022;47(6):E258–64.
30. Hu C, Zhong W, Chen Z, et al. Comparison of the outcomes between AO type B2 Thoracolumbar fracture with and without Disc Injury after posterior surgery. Orthop Surg. 2022;14(9):2119–31.
31. Zhou Q, Hu B, Yang X, et al. Proximal junctional kyphosis in Lenke 5 AIS patients: the important factor of pelvic incidence. BMC Musculoskelet Disord. 2021;22(1):185.
32. Kim HJ, Iyer S. Proximal junctional kyphosis. J Am Acad Orthop Surg. 2016;24(5):318–26.
33. Clément JL, Pesenti S, Ilharreborde B, et al. Proximal junctional kyphosis is a rebalancing spinal phenomenon due to insufficient postoperative thoracic kyphosis after adolescent idiopathic scoliosis surgery. Eur Spine J. 2021;30(7):1988–97.
34. Virk S, Platz U, Bess S, et al. Factors influencing upper-most instrumented vertebrae selection in adult spinal deformity patients: qualitative case-based survey of deformity surgeons. J Spine Surg. 2021;7(1):37–47.
35. Ye J, Gupta S, Farooqi AS, et al. Predictive role of global spinopelvic alignment and upper instrumented vertebra level in symptomatic proximal junctional kyphosis in adult spinal deformity. J Neurosurg Spine. 2023;39(6):774–84.
36. Cerpa M, Sardar Z, Lenke L. Revision surgery in proximal junctional kyphosis. Eur Spine J. 2020;29(Suppl 1):78–85.

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