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Percutaneous pedicle screw fixation in the surgical treatment of monosegmental pyogenic spondylodiscitis

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Abstract

Objective The study assessed the efficacy of percutaneous pedicle screw fixation (PPSF) as a treatment approach for monosegmental pyogenic spondylodiscitis (PS), particularly in patients with compromised health conditions that reduce their ability to endure extensive surgical procedures.

Methods From January 2019 and December 2021, a total of 38 patients with PS who underwent PPSF at our hospital were included in the study. Clinical outcomes were assessed using physical examinations, serological tests, Visual Analog Scale (VAS) scores, Oswestry Disability Index (ODI) scores, and imaging assessments.

Results The mean duration of PPSF among all patients was 73.9 ± 13.9 min, with an average intraoperative blood loss of 52.4 ± 18.4 mL. Pathogenic bacteria were identified in 17 out of 38 cases, representing a detection rate of 44.7%. The mean follow-up period was 21.3 ± 8.3 months. Postoperative assessment of inflammatory markers indicated that infections were effectively controlled in 33 patients, resulting in symptomatic improvement. However, within 2 to 4 weeks postoperatively, 5 patients required a two-stage anterior debridement-fusion following the initial internal fixation. Compared to those who underwent posterior internal fixation alone, these patients had significantly higher Spinal Instability Spondylodiscitis Scores (12.000 ± 1.000 vs. 9.030 ± 2.114, $p < 0.05$) and a significantly greater prevalence of preoperative epidural abscesses (80% vs. 12.1%, $p < 0.01$).

Conclusions PPSF may serve as a viable option for patients with monosegmental PS, providing a minimally invasive surgical approach for patients who are unable to tolerate traditional open surgery due to compromised health or advanced age. For patients with significant spinal instability or abscess formation, a two-stage anterior debridement-fusion may be required. However, single-stage posterior internal fixation can effectively relieve pain and improve the overall condition of patients, thereby enhancing their ability to tolerate subsequent anterior surgical interventions.

Keywords Minimally invasive surgical procedures, Spinal diseases, Spinal fusion, Spondylitis

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Introduction

Pyogenic spondylodiscitis (PS) is a bacterial infection of the spine that can involve vertebral bodies, intervertebral discs, adjacent vertebral structures, paravertebral tissues, psoas major muscles, and the spinal canal [1]. If not promptly diagnosed and treated, PS can result in severe complications, including fever, pain, chronic neurological deficits, and, in some cases, death [2]. The incidence of PS has risen in recent decades, particularly among older patients with multiple comorbidities or compromised immune systems [3].

Conservative management involving the use of appropriate antibiotics combined with bed rest is an effective treatment option for PS; however, failure rates for this approach have been reported to range from 12 to 18% [4]. Indications for surgical intervention in PS include neurological deficits, sepsis, intraspinal abscess formation, failure of conservative treatment, and spinal instability, among others [5]. The primary advantages of surgical management include facilitating early mobilization, reducing the length of hospital stay, minimizing the duration of antibiotic treatment, and preventing spinal deformities [6].

Anterior debridement-fusion combined with posterior internal fixation is a commonly used surgical approach for PS [7]. However, this method is highly invasive, and many patients with PS have compromised health conditions and may have endured prolonged bed rest due to pain or conservative management prior to surgery. These factors can limit their ability to tolerate extensive surgical procedures and increase the associated surgical risks [8].

Single-stage posterior internal fixation offers an alternative by stabilizing the affected spinal segment, thereby alleviating pain and associated symptoms. This approach enables early mobilization and supports the improvement of the overall condition of the patient. Once the patient has stabilized, a two-stage anterior debridement-fusion can be considered. However, evidence from clinical outcomes and literature indicates that posterior internal fixation, combined with antibiotic therapy, not only provides significant relief from pain and neurological symptoms but also leads to a reduction in inflammatory markers. In many cases, the therapeutic objectives can be achieved without the need for a two-stage anterior surgery [9, 10].

This study aims to assess the efficacy of posterior internal fixation in the surgical treatment of PS. For patients who do not achieve satisfactory outcomes, two-stage anterior debridement-fusion will be conducted.

Materials and methods

Patients

The study was conducted after acquiring written informed consent from all patients and approval from the ethics committee of the hospital.

A retrospective analysis was conducted on 38 patients (24 males and 14 females) diagnosed with PS who underwent posterior pedicle screw fixation at the hospital between January 2019 and December 2021 (Fig. 1). To evaluate the statistical power of the current sample size (38 cases), we used the G*Power software to conduct a post hoc power analysis. In this process, we set the significance level α at 0.05 (that is, allowing a 5% error rate) and expected to achieve a statistical test power of 80% (1-β = 0.8). Through the calculation of the G*Power software, the results showed that under the conditions of a two-tailed test, a significance level α of 0.05, and a statistical test power of 1-β of 0.8, at least 26 cases were required for each group, that is, the total sample size should be at least 52 cases to achieve the expected statistical power. In this study, the selection of the sample size was mainly limited by the disease characteristics of single-segment suppurative spondylitis and the available patients [11].

The patients had a mean age of 69.5 years (range: 48–87 years) at the time of surgery, with a mean follow-up duration of 21.3 ± 8.3 months. All patients were diagnosed with monosegmental PS, with the primary lesions located in the thoracic segments in 12 cases and lumbar segments in 26 cases. Persistent back pain, exacerbated by positional changes, was reported by all patients, along with fever and other nonspecific signs of infection. Seven patients experienced radicular pain and numbness in the lower extremities, although none had cauda equina syndrome or associated complications such as bowel or bladder dysfunction.

Comorbidities were noted in some patients, including diabetes mellitus (10 cases), chronic renal failure requiring dialysis (5 cases), cancer (2 cases), and liver cirrhosis (6 cases). Two patients were on steroid therapy. Additionally, epidural abscesses were observed in eight cases, and six patients had psoas abscesses.

Serologic testing, including white blood cell count (WBC), C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), and procalcitonin (PCT) levels, along with blood cultures, was used to confirm the diagnosis of lumbar pyogenic spondylodiscitis. Imaging assessments included X-rays, computed tomography (CT), and magnetic resonance imaging (MRI). The Spinal Instability Spondylodiscitis Score (SISS) was used to assess the stability of the affected spinal segments [12].

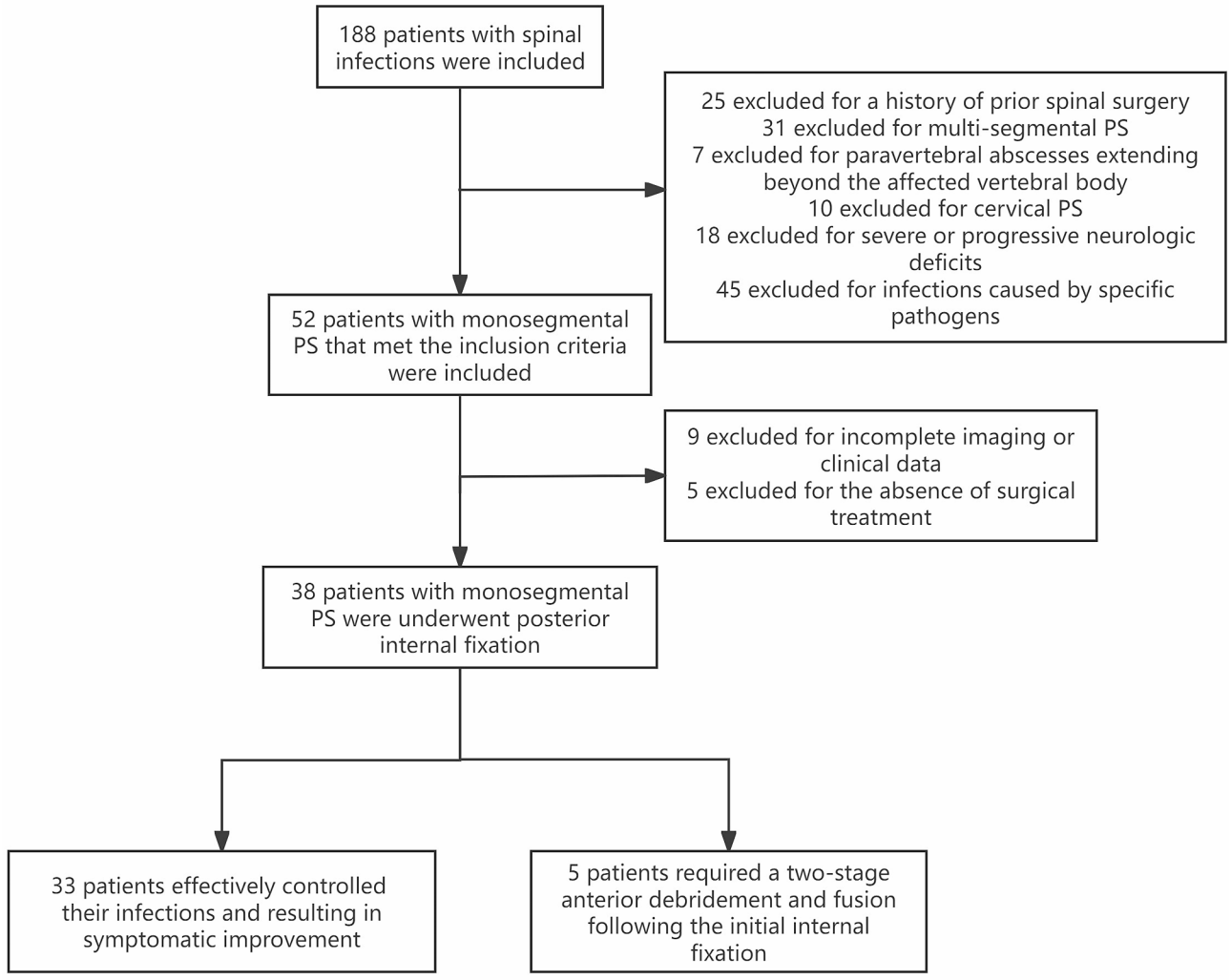

Fig. 1 Flowchart of patient inclusion

Inclusion and exclusion criteria

PS is characterized by specific imaging findings of the intervertebral disc and vertebral bodies, as seen on MRI and/or CT, in conjunction with clinical features such as elevated CRP levels, increased white blood cell count, back pain, and fever.

Indications for posterior pedicle screw fixation included monosegmental PS in the thoracic or lumbar regions, severe pain unresponsive to antibiotic therapy, radicular pain or numbness in the lower extremities due to PS, existing or impending spinal instability, epidural abscess, and focal kyphotic deformity.

Patients were excluded if they had a history of prior spinal surgery, multi-segmental PS, paravertebral abscesses extending beyond the affected vertebral body, cervical PS, incomplete imaging or clinical data, severe or progressive neurologic deficits, or infections caused by specific pathogens such as *Mycobacterium tuberculosis* or *Brucella*.

Operative technique

A preoperative plan for pedicle screw placement was developed based on imaging data. When MRI indicated that the infection did not extend to the screw placement area, standard or shortened pedicle screws were inserted into the affected spinal segment. Additionally, 1–2 vertebral segments proximal and distal to the infected area were selected for screw placement, depending on the stability of the affected region and factors such as the degree of osteoporosis.

General anesthesia was induced, and the patient was positioned prone. Endotracheal intubation was performed. Using a specialized metal frame as a body surface locator, the pedicle projection of the spinal segment targeted for screw placement was marked preoperatively on the skin. Following sterilization and placement of a sterile drape, a vertical skin incision approximately 1.5 cm in length was made at each marked location.

Pedicle screws were inserted percutaneously under C-arm fluoroscopic guidance, and a pre-bent longitudinal connecting rod was passed through the U-groove of the screws beneath the paravertebral muscles. In cases where vertebral body collapse was significant, resulting in kyphotic deformity, or when lower limb pain and numbness due to nerve compression were present, indirect decompression and reduction of the infected vertebral body were performed. This was achieved by elongating the connecting rod along its longitudinal axis using a specialized stretching and compression device compatible with the percutaneous pedicle screw fixation system. After vertebral reduction, the screws were securely tightened to stabilize the affected area.

Lesion puncture biopsy was conducted during the same anesthesia period following minimally invasive internal fixation. The target intervertebral disc was precisely located under fluoroscopic guidance, and the location was marked on the skin. In all cases, the biopsy was performed using an intervertebral foraminal approach.

A puncture needle was inserted into the target intervertebral disc through Kambin's triangle under fluoroscopic guidance. Once positioned, the core was withdrawn to aspirate any abscess material. Biopsy forceps were then introduced to obtain tissue samples from the target disc. The collected specimens were sent for pathological analysis and bacterial cultivation.

Postoperative management

Postoperatively, patients were administered intravenous antibiotics for 2 to 3 weeks. Once substantial improvements were observed in clinical symptoms and laboratory parameters, antibiotic therapy was switched to oral administration for 6 to 8 weeks. If bacterial cultures from blood or lesion tissue were positive, an antibiotic sensitive to the identified pathogen was selected for treatment. In cases where cultures were negative, a broad-spectrum antibiotic effective against both Gram-negative and Gram-positive bacteria was used.

A CT scan was performed three days after surgery to assess the position of the fixation screws. If screw placement was deemed satisfactory, patients were allowed to mobilize with the support of a brace and resume physical activity. The brace was recommended to be worn for three months following the surgery.

For patients with insufficient infection control during the postoperative observation period, a two-stage anterior lesion removal and bone graft fusion surgery was required. The primary indications for this procedure included the following:

(1) A lack of a significant decline in inflammatory markers, with a gradual increase observed instead.
(2) Persistent or worsening symptoms, such as fever, low back pain, or pain and numbness in the lower limbs.
(3) Imaging findings indicating an expansion of the infection or an increase in abscess formation.
(4) For patients with unidentified pathogens, the observation period was set at four weeks. This timeline was based on the current recommendation for intravenous antibiotic therapy lasting over four weeks and evidence from the literature indicating that CRP levels may normalize approximately 20 days after treatment.

Outcome assessment

The operation time and the amount of bleeding were recorded. Preoperative status and postoperative clinical outcomes were assessed using the Visual Analogue Scale (VAS) and the Oswestry Disability Index (ODI). Infection control was monitored through changes in WBC count, CRP, ESR, and PCT levels. Follow-up imaging, including plain radiographs, CT, or MRI, was conducted at 1, 3, 6, and 12 months postoperatively.

Statistical analysis

Demographic and clinical data were collected and presented as mean ± standard deviation (SD) for descriptive analysis. Differences between the two groups were analyzed using the Student's t-test or nonparametric tests, as appropriate. Radiological characteristics between the groups were compared using the chi-squared (χ^2) test. A p-value of < 0.05 was considered statistically significant. Statistical analyses were conducted using SPSS version 17.0 (SPSS, Chicago, IL).

Results

All 38 patients successfully underwent posterior minimally invasive pedicle screw fixation, with incisions healing without complications. The average operative time was 73.9 ± 13.9 min, and the average intraoperative blood loss was 52.4 ± 18.4 ml. Among these patients, 33 reported satisfactory outcomes, with significant relief of postoperative low back pain and radiating lower limb pain. As shown in Table 1, the WBC, CRP, and ESR levels at 1 week, 1 month, 3 months postoperatively, as well as at the end of follow-up, were significantly lower than preoperative values ($p < 0.05$). Additionally, significant improvements were observed in preoperative versus postoperative VAS and ODI scores ($p < 0.05$).

Pathological analysis of lesion biopsy specimens revealed tissue degeneration and necrosis, with marked acute and chronic inflammatory cell infiltration, fibrous tissue proliferation, and granulomatous hyperplasia, without evidence of caseous necrosis. Bacterial culture results were positive in five cases using blood samples, three from psoas abscess samples, and nine rom lesion

Table 1 Clinical outcomes and serological detections before and after surgery in successfully treated patients ($N = 38$, mean ± SD)

Parameter	Pre-OP	1 month post-OP	3 months post-OP	Follow-up
White blood cell (WBC) (×10%/L)	11.975 ± 1.825	8.999 ± 1.809*	5.839 ± 0.810*	5.400 ± 0.690*
C-reactive protein (CRP) (mg/L)	101.547 ± 16.741	74.353 ± 10.606*	45.593 ± 6.565*	5.642 ± 1.280*
Erythrocyte sedimentation rate (ESR) (mm/h)	78.781 ± 11.711	52.388 ± 8.397*	38.143 ± 4.925*	11.172 ± 4.088*
Visual analogue scale (VAS)	7.816 ± 0.865	2.316 ± 0.809*	1.413 ± 0.501*	0.579 ± 0.599*
Oswestry Disability Index (ODI)	70.052 ± 5.083	24.921 ± 2.330*	16.842 ± 1.838*	4.816 ± 1.943*

Note: * $P < 0.05$, compared with pre-operation

Table 2 Cultured pathogens detected (n patients)

Cultured pathogens	Number
Staphylococcus aureus	9
Streptococcus spp.	3
MRSA	2
Enterococcus spp.	2
Staphylococcus epidermidis	1
None identified	21

Table 3 Comparison of patient characteristics among the one-stage group and two-stage group

Variables	One-stage group	Two-stage group	*p*-Value
Number of patients	33	5	
Age	68.121 ± 9.519	72.000 ± 6.892	> 0.05
Epidural abscess	4(12.1%)	4(80%)	< 0.01
Spinal Instability Spondylodiscitis Score (SISS)			
Score	9.030 ± 2.114	12.000 ± 1.000	< 0.01
Potentially unstable lesion	19(57.6%)	0	< 0.05
Unstable lesion	14(42.4%)	5(100%)	

biopsy specimens. *Staphylococcus aureus* was the most frequently identified pathogen ($n = 9$), followed by *Streptococcus* ($n = 3$) (Table 2).

During long-term follow-up, CT scans demonstrated solid fusion of reactive hyperplastic bone around the intervertebral disc space in the affected segments. Two of the 33 patients treated with single posterior internal fixation exhibited loose internal fixation. MRI indicated resorption of lesions and resolution of epidural and psoas abscesses, with no signs of recurrence.

Five patients underwent two-stage anterior debridement-fusion following minimally invasive internal fixation. This decision was made during the postoperative observation period 10–25 days) due to a lack of improvement or worsening of the lesion scope and inflammatory markers in three patients, and unresolved symptoms of nerve injury in two patients. Following the two-stage procedure, these patients experienced symptomatic relief, and the infection was effectively controlled.

The proportion of preoperative epidural abscesses was significantly higher among patients requiring two-stage surgery compared to those treated with posterior internal fixation alone (80% vs. 12.1%, $p < 0.01$). Additionally, the instability score was significantly higher in the two-stage surgery group compared to the posterior fixation group (12.000 ± 1.000 vs. 9.030 ± 2.114, $p < 0.05$). Vertebral instability was identified in all five patients in the two-stage surgery group, while 14 patients in the posterior pedicle screw fixation group were classified as unstable and 19 as potentially unstable (Table 3).

Discussion

PS, also referred to as discitis, vertebral osteomyelitis, or bacterial spondylitis, is the most common spinal infection, primarily affecting the intervertebral discs, adjacent vertebral bodies, and occasionally the posterior parts of the spine [13]. Prior studies have identified high-risk populations for PS, including patients with immunosuppression, diabetes mellitus, advanced age, prolonged corticosteroid use, renal failure, prior spinal surgery, endocarditis, or a history of intravenous substance use [1]. The mortality rate associated with PS ranges from 1.8 to 15%.

In vulnerable populations, the disease can lead to significant morbidity due to pre-existing health conditions, with 35–40% of cases revealing indications of nerve injury [14–17]. Although uncomplicated cases of PS often respond favorably to conservative management, including antibiotic therapy and immobilization, failure rates for conservative treatment ranges between 12 and 18% [18–20].

Currently, widely accepted surgical indications for PS include neurological deficits, sepsis, intraspinal abscess formation, failure of conservative therapy, and spinal instability, though there are no standardized criteria [5]. In this study, the surgical indication criteria were broadened to include some patients with milder forms of PS who also underwent surgical treatment.

This approach was based on several considerations. First, surgical intervention effectively alleviates pain. Some authors have proposed that persistent pain alone, irrespective of spinal instability, empyema, or neurological deficits, is a valid indication for surgery [14]. Second, while infection control outcomes are comparable between conservative and surgical management, early surgical intervention combined with antibiotics has been associated with shorter hospital stays and reduced

antibiotic requirements compared to conservative treatment alone [6]. Third, surgical intervention facilitates earlier ambulation, which is significant, as evidence indicates that prolonged preoperative immobility increases the risk of mortality in older patients [1].

In this study, all patients underwent single-stage posterior minimally invasive internal fixation. Among these, 33 patients (86.8%) demonstrated significant pain relief, reductions in inflammatory markers, and a decreased extent of lesions on imaging studies, indicating effective infection management (Fig. 2).

Currently, common surgical approaches for PS include anterior, posterior, or combined methods involving lesion removal, intervertebral fusion, and internal fixation. Minimally invasive posterior pedicle screw fixation has gained prominence in the management of thoracolumbar fractures due to its minimally invasive nature and shorter operative time. In our study, the mean duration of PPSF among all patients was 73.9 ± 13.9 min, with an average intraoperative blood loss of 52.4 ± 18.4 ml. Both of these parameters were notably more favorable compared to those reported in a previous study involving posterior fixation with debridement, decompression, and reconstruction, which demonstrated a surgical duration of 95.3 ± 22.9 min and intraoperative blood loss of 350.5 ± 88.0 ml [21]. However, there are relatively few

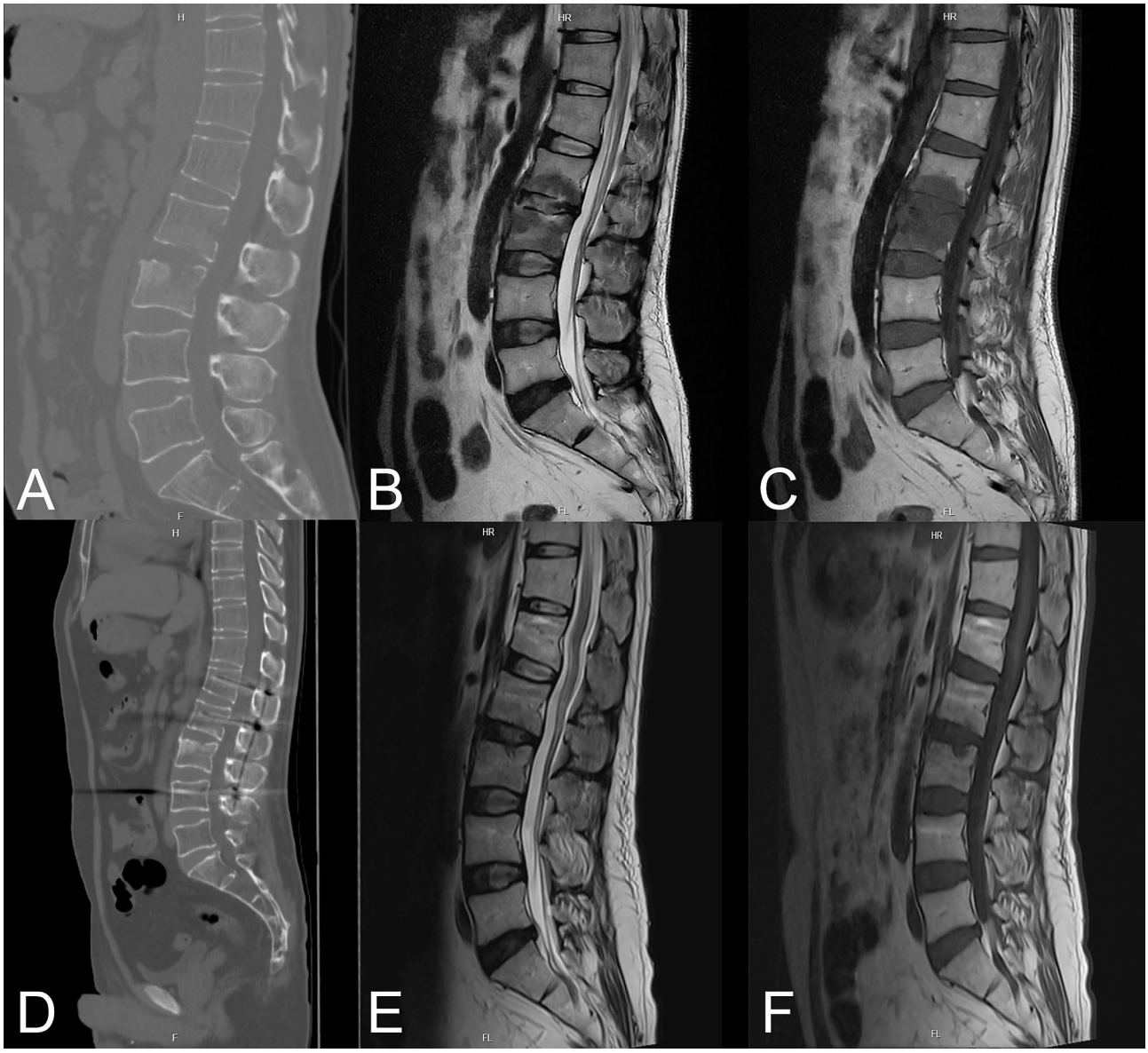

Fig. 2 Exemplary case of a 65-year-old male with PS: CT and MRI demonstrated L2/3 infection (**a**, **b**, and **c**). The SISS was 7, indicating a potentially unstable lesion. Percutaneous pedicle screw fixation was performed. CT imaging at 6 months post-surgery revealed sclerosis at L2/3 and maintained lumbar spine stability without screw loosening (panel **d**). MRI at 6 months revealed complete resolution of the infection (panels **e** and **f**)

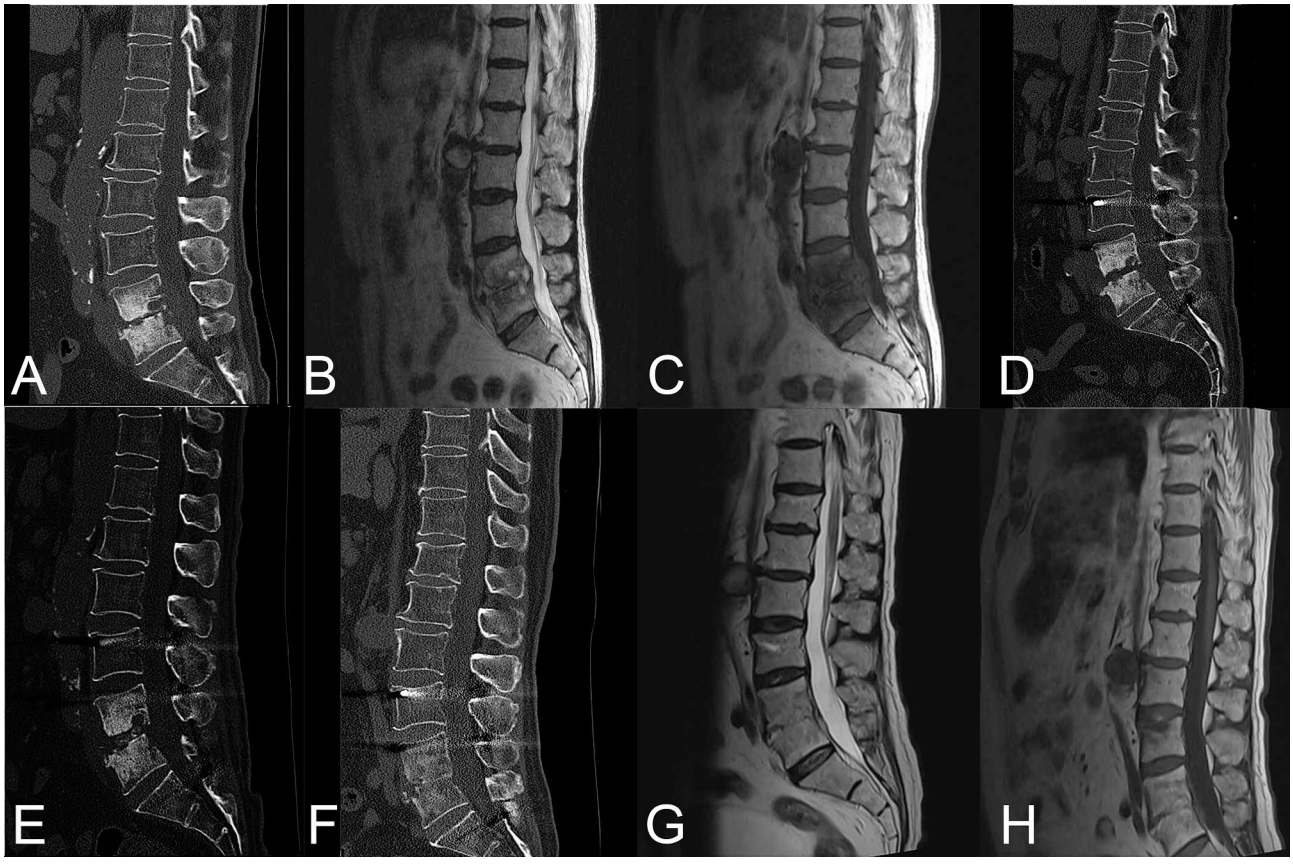

Fig. 3 Exemplary case of a 76-year-old male with L4/5 PS: CT and MRI revealed L4/5 infection with an epidural abscess (panels **a**, **b**, and **c**). The SISS was 10, indicating an unstable lesion. Percutaneous pedicle screw fixation was performed (panel **d**). Due to worsening neurological function, anterior debridement-fusion with iliac bone grafting were conducted one week after the initial surgery (panel **e**). CT imaging at 12 months demonstrated bony fusion on the sagittal view (panel **f**). MRI at 12 months revealed complete resolution of the infection (panels **g** and **h**)

studies examining its use as a standalone treatment for PS. For instance, Chen et al. reported the use of this technique combined with endoscopic debridement and drainage for PS treatment [9].

Posterior internal fixation alone does not directly target the lesion but primarily focuses on restoring spinal stability to achieve therapeutic goals. This approach is supported by several considerations. First, pain and neurological symptoms in PS are closely associated with spinal instability and osteolysis caused by infection. Stabilizing the spine helps alleviate symptoms and facilitates early ambulation, which may prevent complications associated with prolonged immobility, such as venous thromboembolism and dysfunction across multiple organ systems, including the cardiopulmonary, endocrine, neurological, gastrointestinal, and urinary systems [22].

Second, for patients experiencing limited symptom relief, two-stage anterior lesion removal and bone graft fusion can be performed. Staged surgical management also improves patient tolerance for subsequent anterior procedures. Third, mild indirect decompression achieved through pedicle fixation effectively relieves pain and numbness in the lower limbs caused by abscess compression [3]. Finally, stabilization of the infected vertebrae promotes reactive hyperplastic bone fusion and improves the efficacy of antibiotics [6].

In this study, five patients (13.2%) required two-stage anterior surgery due to persistent pain or inadequate infection control, as revealed by blood test results and imaging examinations (Fig. 3). This rate is comparable to the 17.4% of patients in a study by Ishihara et al., who underwent two-stage anterior lesion removal and bone grafting following single posterior internal fixation [10]. Analysis of the five patients who required two-stage surgery revealed worse vertebral stability compared to those treated successfully with posterior fixation alone.

The PS stability score, proposed by Schömig et al. was used to assess vertebral stability in this study [12]. This scoring system evaluates stability based on the number of affected segments, the extent of bone destruction, spinal alignment, and mechanical pain, with higher scores indicating greater instability. Patients requiring two-stage surgery had significantly higher instability scores (12.000 ± 1.000 vs. 9.030 ± 2.114) and more unstable

lesions compared to the group treated with posterior internal fixation, which included 19 cases of instability and 14 cases of potential instability.

A comprehensive etiological assessment was key to the success of posterior internal fixation alone [23]. Lesion puncture was performed concurrently with posterior fixation, and tissue samples were subjected to bacterial culturing, pathological analysis, and genetic testing. Combined with pathogen identification from other sources, such as blood, lungs, or the urinary tract, the pathogen detection rate in this study was 44.7%, significantly higher than the 22.4% reported in a recent study on purulent discitis [24].

Patients with confirmed pathogens received intravenous antibiotics for 10 days to 6 weeks, followed by oral antibiotics for 6 weeks to 3 months. For those with culture-negative discitis, antibiotic therapy was extended for a minimum of 8 weeks [14].

The potential for internal fixation to contribute to non-healing or recurrence of infection remains a topic of debate [25, 26]. In cases involving a single infected segment, screws were placed in the uninfected vertebral bodies above and below the affected segment. For patients with multiple infected segments, additional fixation segments were included, with screws placed in the uninfected vertebral bodies adjacent to the infected areas. Additionally, short screws were inserted at the pedicles of lesioned vertebrae with minimal infection on one or both sides, aiming to minimize contact with infectious material and reduce the risk of non-healing or recurrence.

There are several limitations to this study. These included a small sample size, its retrospective characteristics, and the lack of controlled comparisons between conservative management and one-stage debridement-fusion surgery. These were due to the strict inclusion criteria, combined with a low incidence of monosegmental PS requiring surgical treatment. Future research should include prospective controlled studies to better assess the efficacy of posterior internal fixation alone for treating PS. Furthermore, some patients required two-stage anterior surgery following single posterior internal fixation. However, multivariate regression analysis of risk factors could not be conducted due to the limited sample size. Future researches could expand the sample size in subsequent studies for more comprehensive analyses, and investigate the long-term outcomes of different surgical approaches for this patient population.

Conclusion

Patients with PS often present with compromised health conditions that limit their ability to tolerate extensive surgical procedures. Posterior percutaneous pedicle screw fixation offers a minimally invasive alternative with a shorter operative duration. Monosegmental PS can be effectively managed through surgical stabilization of the affected vertebral segment combined with appropriate antibiotic therapy. For patients with poor vertebral stability, two-stage anterior surgery may be necessary. However, single-stage posterior internal fixation can improve patient tolerance for subsequent anterior surgery and, in some cases, eliminate the need for more invasive anterior surgery.

Abbreviations

PS	Pyogenic spondylodiscitis
PPSF	Percutaneous pedicle screw fixation
SISS	Spinal Instability Spondylodiscitis Score
WBC	White blood cell count
CRP	C-reactive protein
ESR	Erythrocyte sedimentation rate
VAS	Visual analogue scale
ODI	Oswestry Disability Index
CT	Computed tomography
MRI	Magnetic resonance imaging

Author contributions

Zhen-Zhong Chen: Conceptualization, Funding acquisition. Writing – original draft. Ke-Jun Zhu: Writing – original draft, Writing – review & editing. Bin Pan: Conceptualization, Writing – original draft. Chao Lou: Data curation, Formal Analysis, Software. Wei-Yang Yu: Data curation, Formal Analysis, Software. Deng-Wei He: Conceptualization, Writing – review & editing. All authors read and approved the final draft.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was conducted with approval from the Ethics Committee of Lishui Municipal Central Hospital (Approval Number: 2022-30, Approval Date: March 10th, 2022). This study was conducted in accordance with the declaration of Helsinki. Written informed consent was obtained from all participants.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Conflict of interest

The authors declare that they have no conflict of interests.

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