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RESEARCH

# Challenges and limitations of the existing scoring systems for postoperative outcomes in thoracolumbar pyogenic spondylitis: a multicenter retrospective cohort study

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## Abstract

**Purpose** This study aimed to evaluate the predictive ability of existing scoring systems for postoperative outcomes in patients with thoracolumbar pyogenic spondylitis treated with minimally invasive posterior fixation.

**Methods** We conducted a multicenter retrospective cohort study of 90 patients with thoracolumbar pyogenic spondylitis treated with minimally invasive posterior fixation between January 2014 and June 2024. We assessed the Brighton spondylodiscitis score (BSDS), spinal instability spondylodiscitis score (SISS), and spinal infection treatment evaluation (SITE) score. Patients were divided into success and failure groups based on infection control or implant failure. The predictive ability of each scoring system for treatment failure was evaluated using receiver operating characteristic (ROC) curves and area under the curve (AUC).

**Results** The success and failure groups consisted of 78 (87%) and 12 patients (13%), respectively, with the failure group including seven and five patients due to infection control or implant failure. The failure group had higher BSDS, SISS, and SITE scores, but the ROC analysis showed low predictive accuracy (AUC: BSDS = 0.65, SISS = 0.64, SITE score = 0.56). Grading the BSDS into three categories revealed no failure in the low-risk patients, whereas 22% of the high-risk patients required unplanned additional surgeries for infection control or implant failure.

**Conclusions** Existing scoring systems showed limited ability to predict postoperative outcomes in patients with thoracolumbar pyogenic spondylitis treated with minimally invasive posterior fixation. BSDS grading demonstrated some utility, with 22% of high-risk patients experiencing postoperative infection control failure and implant failure, highlighting the need for careful treatment planning.

**Keywords** Pyogenic spondylitis · Posterior fixation · Scoring · Multicenter study

## Introduction

The incidence of pyogenic spondylitis, an infectious disease, has been increasing annually [1, 2]. Recent studies indicate that surgical treatment improves prognosis and reduces treatment failure compared with conservative treatment focused on antibiotics and bed rest, reflecting a shift in treatment strategies [3, 4]. Minimally invasive posterior fixation using percutaneous pedicle screws (PPSs) without debridement or bone grafting has been effective, which had fewer complications and improved safety [5]. In particular, in areas with an aging population [6, 7], minimally invasive posterior fixation, which is safe with few complications, has significant benefits. We have adopted this procedure for thoracolumbar pyogenic spondylitis resistant to conservative treatment for achieving early infection control and shortening the treatment duration through spinal stabilization [5, 8].

Determining whether surgical intervention or conservative treatment is appropriate can be challenging. Scoring systems for assessing surgical indications in pyogenic

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spondylitis have been developed recently and proven useful [9–11]. However, infection control may sometimes fail with minimally invasive posterior fixation alone. Factors contributing to the need for additional surgery include severe bone destruction, abscess formation, and identification of causative organisms, but predicting treatment failure at initial presentation remains challenging [12–14]. Thus, determining which patients can achieve infection control with posterior fixation alone is unclear.

We hypothesized that patients with higher scores on existing scoring systems for assessing surgical indications during the initial evaluation have more severe infections and are less likely to achieve infection control with posterior fixation alone. This study aimed to evaluate the predictive ability of various existing scoring systems for postoperative clinical outcomes in patients with thoracolumbar pyogenic spondylitis resistant to conservative treatment who underwent minimally invasive posterior fixation.

## Materials and methods

The institutional review boards of all participating facilities approved this multicenter retrospective cohort study. We included 124 consecutive patients with thoracolumbar (T1/2–L5/S1) pyogenic spondylitis treated with minimally invasive posterior fixation between January 2014 and June 2024 at 10 affiliated facilities.

The inclusion criteria were patients with pyogenic spondylitis resistant to conservative treatment with intravenous antibiotics primarily who subsequently underwent minimally invasive posterior fixation mainly with PPS [5, 12, 15, 16] and those with a minimum follow-up of 6 months postoperatively [12, 15, 16]. The exclusion criteria were patients with short follow-up period, patients with planned direct manipulation of the infection site, such as debridement or bone grafting, and those with tuberculous spondylitis [12, 16].

### Collected data

1. Patient background at admission [9–12, 15, 17]: age, sex, infection location (thoracic and thoracolumbar, T1/2–T12/L1; lumbar and lumbosacral, L1/2–L5/S1), comorbidity and immunocompromised (intravenous drug abuse, diabetes mellitus, cancer, and dialysis), presence and type of distant site infection (urinary tract infection, pneumonia, endocarditis, and sepsis), Pola classification, and identification and type of causative organisms.
2. Imaging evaluation:
   X-ray: Presence of subluxation, translation, kyphosis, and scoliosis, including de novo deformity.
   Magnetic resonance imaging (MRI): nonspecific fluid collection, edema, epidural abscess, iliopsoas abscess, empyema, disc and facet joint involvement, and spinal canal stenosis due to abscesses or deformities.
   Computed tomography (CT): degree of bone destruction (≥50%, <50%) and endplate involvement.
3. Neurological symptoms and pain: Presence of pain, ability to ambulate, pain relief at rest, acute paralysis, bladder or bowel dysfunction, motor dysfunction (manual muscle test≥2, 0–1), and sensory dysfunction.
4. Surgical and postoperative outcomes: range of fixation, blood loss, operative time, postoperative follow-up period, pre- and post-operative intravenous antibiotic duration, postoperative complications, unplanned additional surgeries, indications for additional surgeries, numerical rating scale (NRS) for low back pain (preoperative, 1 week postoperative, and at discharge), and infection recurrence.

The Pola classification categorizes patients into three types based on preoperative imaging and neurological symptoms: type A, no bone destruction, segmental instability, epidural abscess, or neurological impairment; type B, bone destruction or segmental instability without epidural abscess or neurological impairment; type C, presence of an epidural abscess or neurological impairment [17]. In this study, "unplanned additional surgery" was defined as any additional surgery performed after posterior fixation to address unexpected postoperative complications [12, 15, 16]. Three spine surgeons, with 20, 12, and 10 years of experience, performed imaging evaluations. Discrepancies were resolved through consensus.

### Brighton spondylodiscitis score (BSDS), spinal instability spondylodiscitis score (SISS), and spinal infection treatment evaluation (SITE) score

We evaluated three scoring systems related to the surgical indications for pyogenic spondylitis: BSDS, SISS, and SITE score [9–11, 18, 19]. Each score was graded into three categories (Table 1).

1. BSDS: Evaluates surgical risk based on six factors: distant site infection, comorbidities, immunocompromised, MRI findings, anatomical location, and presenting neurology. Low risk: ≤14, moderate risk: 15–20, high risk: ≥21 [9].
2. SISS: Assesses spinal stability using four factors: location, bone lesions, spinal alignment, and mechanical pain. Stable: ≤4 (conservative treatment recommended),

**Table 1** BSDS, SISS, and SITE scores

| BSDS | | SISS | | SITE Score | |
|---|---|---|---|---|---|
| Factor | Score | Factor | Score | Factor | Score |
| **Presenting neurology** | | **Mechanical pain** | | **Neurology** | |
| None | 1 | Yes | 3 | Acute plegia or bladder/bowel dysfunction | Surgery/0 |
| Motor/sensory | 2 | Occasional pain but not mechanical | 1 | Motor dysfunction | 1 |
| Complete | 3 | Pain-free lesion | 0 | Sensory dysfunction | 2 |
| | | | | Neurologically intact | 3 |
| **Anatomical location** | | **Location** | | | |
| Cervical | 1 | Junctional (O–C2, C7–T2, T11–L1, L5–S1) | 3 | **Location** | |
| Lumbosacral | 3 | Mobile spine (C3–6, L2–4) | 2 | Junctional (O–C2, C7–T2, T11–L1, L5–S1) | 1 |
| Thoracolumbar | 5 | Semirigid (T3–10) | 1 | Mobile spine (C3–6, L2–4) | 2 |
| | | Rigid (S2–5) | 0 | Semirigid (T3–10) | 3 |
| | | | | Rigid (S2–5) | 4 |
| **MRI findings** | | **Spinal alignment** | | | |
| None | 1 | Subluxation/translation | 4 | **Radiology** | |
| Nonspecific fluid collection | 2 | De novo deformity (kyphosis/scoliosis) | 2 | Spinal canal stenosis with impingement of the central neural elements with or without de novo deformity | 1 |
| Vertebral collapse | 4 | Normal alignment | 0 | | |
| Abscess formation | 5 | | | Segmental angulation or translation with de novo deformity/foraminal stenosis or erosion of the vertebral body on CT > 50% or posterolateral involvement on both sides | 2 |
| | | **Bone lesion** | | | |
| **Distant site infection** | | ≥ 50% vertebral body involvement | 4 | | |
| None | 1 | < 50% vertebral body involvement | 2 | | |
| Urinary tract infection/ pneumonia | 3 | Endplate involvement | 1 | Visible endplate erosion on CT or edema of the vertebral body > 50% on MRI or intervertebral disc involvement on MRI or posterolateral involvement on one side | 3 |
| Endocarditis | 5 | Intact endplates | 0 | | |
| Sepsis | 6 | | | | |
| **Comorbidities** | | | | None of these radiological findings | 5 |
| None | 1 | | | | |
| Intravenous drug abuse | 3 | | | **Pain** | |
| Diabetes mellitus | 5 | | | Standing axial pain or inability to ambulate | 0 |
| | | | | Other pain with the ability to ambulate | 1 |
| **Immunocompromised** | | | | No pain | 2 |
| None | 1 | | | | |
| Metastatic cancers | 4 | | | **Host comorbidities** | |
| Dialysis | 6 | | | Intravenous drug abuse or diabetes mellitus | 0 |
| | | | | Other comorbidities or no comorbidities | 1 |
| Low risk | ≤ 14 | Stable lesion | ≤ 4 | Severe spinal infection | ≤ 8 |
| Moderate risk | 15–20 | Potentially unstable lesion | 5–9 | Moderate spinal infection | 9–12 |
| High risk | ≥ 21 | Unstable lesion | ≥ 10 | Mild spinal infection | ≥ 13 |

BSDS: Brighton spondylodiscitis score, SISS: Spinal instability spondylodiscitis score, SITE: Spinal infection treatment evaluation, MRI: Magnetic resonance imaging, CT: Computed tomography

potentially unstable: 5–9 (conservative treatment or surgery), unstable: ≥10 (surgery recommended) [10].

3. SITE score: Evaluates severity based on five factors: neurology, location, radiology, pain, and host comorbidities. Severe spinal infection: ≤8 (surgery recommended), moderate spinal infection: 9–12 (medical treatment recommended; surgery optional), mild spinal infection: ≥13 (medical treatment recommended) [11]. Acute plegia or bladder/bowel dysfunction strongly indicates surgery (assigned 0 point).

### Surgical procedures and antibiotic protocol

The surgical indications were neurological deficits, progressive bone destruction, persistent or enlarging abscesses, instability, or failure of conservative treatment [3, 5, 12, 15, 16]. All surgeries were performed under general anesthesia with the patient in the prone position [12, 15, 16]. PPS was inserted two or three levels above and below the infected vertebrae. Each facility decided whether pedicle screws should be inserted into the infected vertebrae [16]. No bone grafting or debridement was performed, and the rods were placed in situ to complete the procedure.

Intravenous antibiotics were generally administered for 6 weeks pre- and post-operatively [2, 3, 12, 15]. The criteria for antibiotic discontinuation were reduction of abscess size on imaging and normalization or near-normalization of C-reactive protein (CRP) levels. The treating physician made the final decision based on the clinical progress.

### Clinical outcomes

Postoperative clinical outcomes were assessed based on infection control failure and implant failure [18, 19]. We defined infection control failure as patients requiring unplanned additional surgeries due to unresolved infection following posterior fixation and implant failure as patients requiring unplanned additional surgery due to screw backout or loosening.

Patients were classified into the failure group if they had infection control failure or implant failure, and the success group if they had a good outcome without either of these problems. We analyzed the predictive ability of each scoring system to identify postoperative failures [12, 15, 16, 18–20].

### Statistical analysis

Patient backgrounds were compared using Welch's t-test and Fisher's exact test for continuous and categorical variables, respectively. We calculated the receiver operating characteristic (ROC) curves and area under the curve (AUC) values to evaluate the predictive ability of the BSDS, SISS, and SITE scores for treatment failure. Each scoring system was graded and further analyzed using ROC curves, AUC values, sensitivity, specificity, and positive likelihood ratios [18–20].

Statistical significance was determined at $p=0.05$. All analyses were performed using JMP 10 software (SAS Inc., Cary, NC, USA). Continuous variables are expressed as means ± standard deviations (SDs).

## Results

### Patient background

We excluded 24 patients with short follow-up, seven patients with planned direct manipulation of the infection site, and three patients with tuberculous spondylitis. The final analysis included 90 patients (mean age: 72.3 ± 10.5 years, range: 44–89, male: 61 patients, female: 29 patients) (Fig. 1).

The success and failure groups consisted of 78 (87%) and 12 patients (13%), respectively. The failure group included seven patients with infection control failure and five patients with implant failure. Eleven patients underwent one unplanned additional surgery, including anterior debridement with autologous bone grafting in four patients, posterior fixation extension in three patients, anterior debridement and corpectomy with metal implants in two patients, and drainage of residual abscesses in two patients. One patient required two unplanned additional surgeries: corpectomy with a metal implant, followed by posterior fixation extension.

The most common surgical indication was conservative treatment failure, with 47 (52%) patients, comprising 40 and 7 patients in the success group and failure groups, respectively. This was followed by progressive bone destruction in 25 (28%) patients and persistent or enlarging abscesses in 10 (11%). No significant difference was noted in the reasons for surgery between the success and failure groups. The failure group had a higher incidence of empyema than the success group (3 vs. 1 patient, $p=0.0069$). The proportion of patients with type B in the Pola classification was higher in the failure group than in the success group (7/12 patients, 58% vs. 17/78 patients, 22%, $p=0.014$). During the follow-up period, no patient in either group had recurrent infection. No difference was noted in the NRS for low back pain between the two groups preoperatively and postoperatively.

Additionally, the failure group also had a longer duration of pre- and post-operative intravenous antibiotics (11.5 vs. 6.6 weeks, $p=0.016$) (Table 2).

### Relationship between clinical outcomes and each scoring system

The total scores for each scoring system in the success and failure groups were BSDS (17.4 vs. 19.4), SISS (8.7 vs. 9.8), and SITE score (6.6 vs. 6.8).

The ROC curves for predicting failure based on total scores showed low predictive ability, with AUC values of BSDS: 0.65 ($p=0.057$), SISS: 0.64 ($p=0.11$), and SITE score: 0.56 ($p=0.72$) (Table 3).

After grading, no patients were classified as stable lesions by SISS or mild spinal infection by SITE score (Table 4).

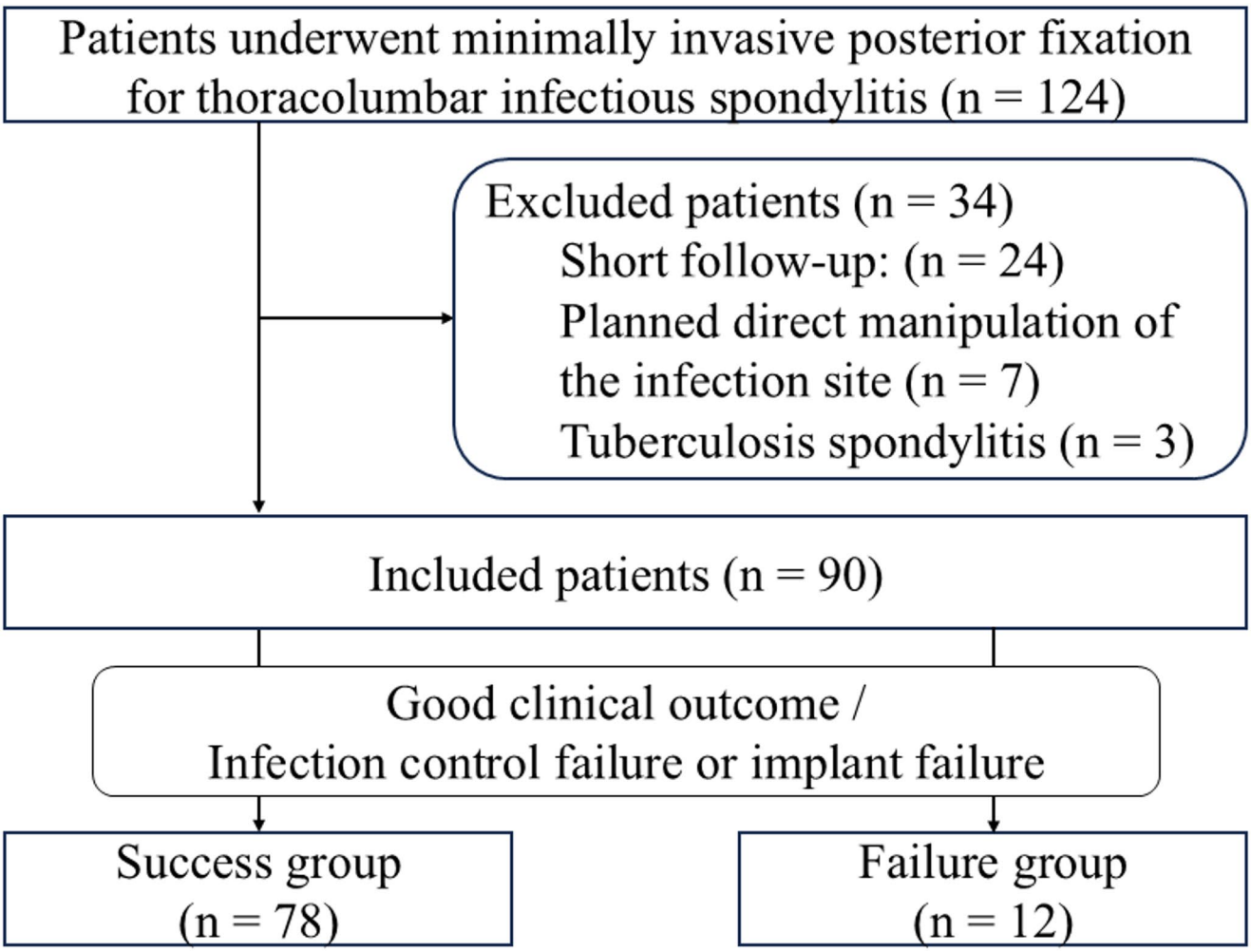



**Fig. 1** Inclusion and exclusion of patients

The AUC was the highest in BSDS and was statistically significant (AUC, 0.66; $p=0.041$). In BSDS, no failures were observed in the low-risk patients (Fig. 2). The failure group had 14% and 22% moderate- and high-risk patients in BSDS, respectively (Fig. 3). The sensitivity, specificity, and positive likelihood ratio of the high-risk patients in BSDS were 42%, 79%, and 2.00, respectively.

## Discussion

The key results of this study are as follows.

1. The predictive ability of the BSDS, SISS, and SITE scores for postoperative outcomes after posterior fixation in pyogenic spondylitis was low (AUC, 0.51–0.66).
2. Grading the BSDS into three categories showed that low-risk patients achieved favorable outcomes with posterior fixation alone, whereas 22% of high-risk patients required unplanned additional surgeries due to infection control failure or implant failure.

Several scoring systems for pyogenic spondylitis have been reported, including BSDS, SITE score, and Pola classification, for assessing surgical indications, the SISS for evaluating fixation requirements, and the mortality in spinal infection score to predict patient mortality [9–11, 17, 21].

The SITE score shows high sensitivity and specificity for assessing surgical indications, whereas the effectiveness of BSDS may vary based on regional characteristics [19, 20]. The optimal scoring system for predicting postoperative clinical outcomes remains unclear, as most studies primarily focus on surgical indications rather than treatment failure, highlighting the need for further research [22].

Factors associated with poor postoperative outcomes include severe bone destruction, skip screw insertion into infected vertebrae, abscess formation, high CRP levels, identification of causative organisms—particularly Gram-negative rods—and multiple comorbidities [12–16, 23].

**Table 2** Patient background of the success and failure groups

| | Success group ($n=78$) | Failure group ($n=12$) | $p$ |
|---|---|---|---|
| Age (years) | 71.9 ± 10.9 | 75.1 ± 6.2 | 0.16[a] |
| Sex | | | |
| Male | 52 | 9 | 0.74[b] |
| Female | 26 | 3 | |
| Postoperative period of follow-up (month) | 27.5 ± 18.4 | 21.8 ± 15.1 | 0.26[a] |
| Causative organisms | | | |
| Identified | 53 | 10 | 0.50[a] |
| Unidentified | 25 | 2 | |
| Location | | | |
| Lumbar and lumbosacral (L1/2–L5/S) | 47 | 5 | 0.37[b] |
| Thoracic and thoracolumbar (T1/2–T12/L1) | 31 | 7 | |
| Comorbidity and immunocompromised (including duplicate) | | | |
| Diabetes mellitus | 27 | 3 | 0.74[b] |
| Cancer | 15 | 5 | 0.13[b] |
| Dialysis | 4 | 0 | 1.00[b] |
| Intravenous drug abuse | 0 | 0 | 1.00[b] |
| Distant site infection (including duplicated) | | | |
| With | 44 | 10 | 0.11[b] |
| Urinary tract infection/pneumonia | 6 | 1 | 1.00[b] |
| Endocarditis | 2 | 1 | 0.35[b] |
| Sepsis | 38 | 9 | 0.12[b] |
| Extravertebral abscess (including duplicated) | 56 | 9 | 1.00[b] |
| Epidural abscess | 46 | 5 | 0.35[b] |
| Iliopsoas abscess | 32 | 5 | 1.00[b] |
| Empyema | 1 | 3 | 0.0069[b] |
| Neurology | | | |
| Acute plegia or bladder/bowel dysfunction | 4 | 1 | 0.52[b] |
| Motor dysfunction | 11 | 1 | 1.00[b] |
| Sensory dysfunction | 11 | 0 | 0.35[b] |
| Neurologically intact | 52 | 10 | 0.33[b] |
| Pola classification | | | |
| Type A | 10 | 0 | 0.35[b] |
| Type B | 17 | 7 | 0.014[b] |
| Type C | 51 | 5 | 0.20[b] |
| Surgical indications | | | |
| Failure of conservative treatment | 40 | 7 | 0.76[b] |
| Progressive bone destruction | 22 | 3 | 1.00[b] |
| Persistent or enlarging abscesses | 9 | 1 | 1.00[b] |
| Neurological deficits | 6 | 1 | 1.00[b] |
| Instability | 1 | 0 | 1.00[b] |
| Surgical data | | | |
| Operation time (min) | 147 ± 93 | 179 ± 185 | 0.26[a] |
| Blood loss (g) | 109 ± 125 | 491 ± 667 | 0.073[a] |
| Range of fixation (number of fixed vertebrae) | 5.8 ± 1.8 | 6.7 ± 2.3 | 0.26[a] |
| Numerical rating scale for low back pain | | | |
| Preoperative | 5.9 ± 2.8 | 7.4 ± 2.3 | 0.16[a] |
| 1 week postoperative | 3.4 ± 2.6 | 5.1 ± 2.9 | 0.17[a] |
| At discharge | 1.1 ± 1.4 | 1.3 ± 2.0 | 0.81[a] |
| Infection recurrence | 0 | 0 | 1.00[b] |
| Duration of pre- and post-operative intravenous antibiotics (week) | 6.6 ± 3.1 | 11.5 ± 5.9 | 0.016[a] |

a: Welch's t-test, b: Fisher's exact test. Values are presented as mean ± standard deviations

**Table 3** BSDS, SISS, and SITE scores of the success and failure groups

| | Success group ($n=78$) | Failure group ($n=12$) | AUC | $p$ |
|---|---|---|---|---|
| BSDS | 17.4±3.4 | 19.4±3.0 | 0.65 | 0.057 |
| SISS | 8.7±2.2 | 9.8±2.4 | 0.64 | 0.11 |
| SITE score | 6.6±1.5 | 6.8±1.9 | 0.56 | 0.72 |

BSDS: Brighton spondylodiscitis score, SISS: spinal instability spondylodiscitis score, SITE: spinal infection treatment evaluation, AUC: area under the curve

Values are presented as mean±standard deviations

Because of the nature of surgical interventions for infections, most reports are based on limited sample sizes, making the prediction of outcomes for specific surgical techniques challenging.

This is the first study that attempted to predict the clinical outcomes of posterior fixation for pyogenic spondylitis using existing scoring systems. The following two key findings were obtained:

1. The predictive ability of the existing scoring systems was limited, with low AUC values.
BSDS, SISS, and SITE scores were designed to determine surgical indications. However, multiple factors, including CRP levels, identification of the causative organisms, and the time from treatment initiation to surgery, influence surgical outcomes [9–12, 15]. These factors may explain the limited predictive performance of these systems. Both SISS and SITE scores use three grading levels, but no patients were classified as stable lesions of SISS or mild spinal infection of SITE score. In contrast, some patients classified as low risk by BSDS still underwent surgery [20]. An important consideration while interpreting our findings is the discrepancy between the study's objective, which focused on predicting postoperative clinical outcomes, and the primary purpose of existing evaluation systems, which are intended to assess surgical indications. This difference

**Table 4** Grading of the BSDS, SISS, and SITE scores of the success and failure groups

| | Total | Success group ($n=78$) | Failure group ($n=12$) | Failure/Total | Sensitivity | Specificity | PLR | AUC | $p$ |
|---|---|---|---|---|---|---|---|---|---|
| BSDS | | | | | | | | 0.66 | 0.041 |
| Low risk (≤14) | 18 | 18 | 0 | 0% | 100% | 0% | 1.00 | | |
| Moderate risk (15–20) | 49 | 42 | 7 | 14% | 100% | 23% | 1.30 | | |
| High Risk (≥21) | 23 | 18 | 5 | 22% | 42% | 79% | 2.00 | | |
| SISS | | | | | | | | 0.62 | 0.13 |
| Stable lesion (≤4) | 0 | n/a | n/a | n/a | | | | | |
| Potentially unstable lesion (5–9) | 48 | 44 | 4 | 8% | 100% | 0% | 1.00 | | |
| Unstable lesion (≥10) | 42 | 34 | 8 | 19% | 67% | 56% | 1.53 | | |
| SITE score | | | | | | | | 0.51 | 0.81 |
| Severe spinal infection (≤8) | 84 | 73 | 11 | 13% | 100% | 0% | 1.00 | | |
| Moderate spinal infection (9–12) | 6 | 5 | 1 | 17% | 8% | 94% | 1.25 | | |
| Mild spinal infection (≥13) | 0 | n/a | n/a | n/a | | | | | |

BSDS: Brighton spondylodiscitis score, SISS: spinal instability spondylodiscitis score, SITE: spinal infection treatment evaluation, PLR: positive likelihood ratio, AUC: area under the curve, n/a: not applicable

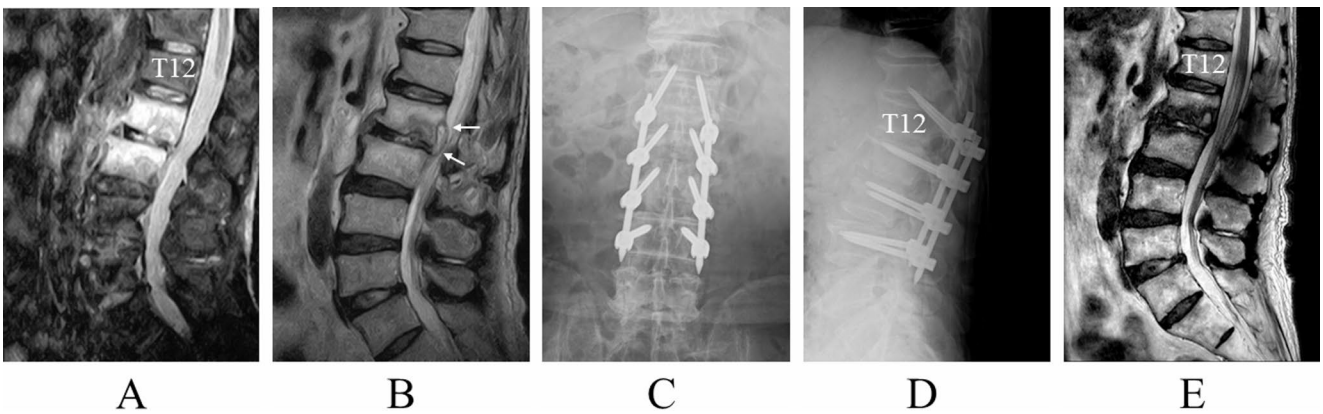



**Fig. 2** Illustration of low-risk patients in BSDS. A 78-year-old male patient with L1/2 pyogenic spondylitis had a BSDS score of 12 (**A**). He had no comorbidities and no distant infection sites. Preoperative symptoms were limited to lower back pain without neurological deficits. After a 4-week conservative treatment, residual abscesses were observed (**B**, arrows). Therefore, minimally invasive posterior fixation from T12 to L3 was performed (**C**, **D**). The abscess disappeared 2 weeks after posterior fixation (**E**), and intravenous antibiotics were discontinued. The patient had no recurrence during follow-up.
BSDS: Brighton spondylodiscitis score

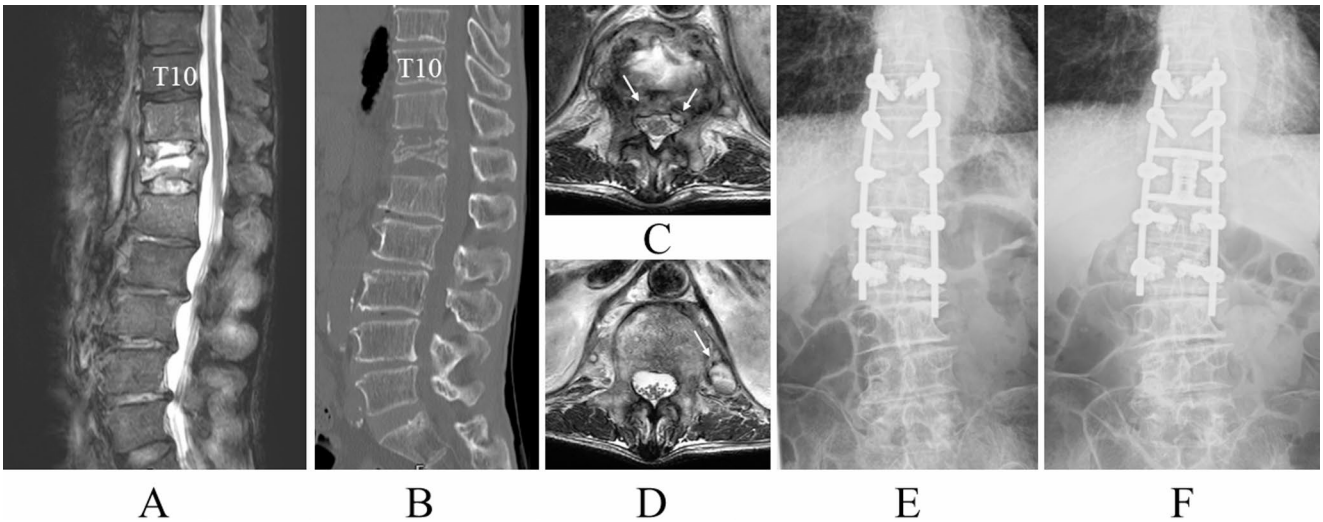



**Fig. 3** Illustration of a high-risk patient in BSDS. A 73-year-old male patient with T11/12 and T12/L1 pyogenic spondylitis had a BSDS score of 22 (**A**). He had bladder cancer and presented with sepsis at the initial evaluation. Blood cultures revealed *Bacteroides fragilis*. Bone destruction progressed after a 6-week conservative treatment (**B**), and epidural (**C**, arrows) and iliopsoas abscesses (**D**, arrow) developed. Due to poor infection control, minimally invasive posterior fixation from T10 to L2 was performed (**E**). Infection control remained insufficient, necessitating anterior debridement and corpectomy with metal implants after 2 weeks (**F**). Intravenous antibiotics were administered 2 weeks after the additional surgery. The patient had no recurrence during follow-up.
BSDS: Brighton spondylodiscitis score

potentially influenced the accuracy of the results.

Furthermore, our patients had distinct characteristics compared with previous studies, including a higher mean age (72.5 years), higher prevalence of cancer, and no intravenous drug abuse than those reported in Western populations [24] These regional differences likely contributed to the difficulty in predicting outcomes using the existing scoring systems.

2. Grading BSDS into three categories showed some utility in risk stratification.

   Grading the BSDS into three categories showed potential for risk stratification. Low-risk patients without comorbidities or sepsis achieved favorable outcomes with simple posterior fixation alone. In contrast, 22% of high-risk patients, often presenting with sepsis, abscess formation, comorbidities, or immunosuppression, required unplanned additional surgeries due to infection control failure or implant failure. In the failure group, prolonged intravenous antibiotic treatment (mean, 11.5 weeks) also posed a significant clinical challenge. Recent systematic reviews and meta-analyses have highlighted that minimally invasive surgery reduces postoperative CRP levels and pain while being less invasive. However, for deformity or instability due to infection, open surgery may be necessary, with up to 25% of cases unsuitable for minimally invasive surgery [25]. To improve outcomes in the failure groups, combining posterior fixation with techniques, such as lateral interbody fusion or percutaneous endoscopic debridement, may be effective [26–28]. However, these additional procedures are more invasive and are generally limited to lumbar lesions [26, 28]. Despite this limitation, such techniques may be viable options for patients at a higher risk of poor outcomes with posterior fixation alone.

This study has several limitations. First, the surgical indications slightly varied despite the standardized criteria as this was a retrospective multicenter study. Second, the sample size of 90 patients was relatively small, and we were unable to evaluate factors outside the existing scoring systems. Variables, such as age and identification of the causative organisms, may have influenced the outcomes [12, 23].

Future research issues include the need to improve the reliability of the results and the accuracy of the predictions by analyzing more patients through prospective studies and more multicenter studies.

To improve the predictive accuracy, increasing the sample size is essential. In addition, factors such as the surgery type (posterior alone, anterior alone, and combined), infection severity (e.g., blood tests, CRP, and WBC levels during initial diagnosis), characteristics of the causative organisms (whether resistant bacteria are present), and the patient's overall condition (e.g., age and nutritional status) should be considered [3, 5, 7, 12, 26, 27].

In terms of generalizability, this study provides valuable insights by reporting surgical outcomes for a single procedure in 90 patients with pyogenic spondylitis. Although

caution is necessary regarding differences in race and region, a certain degree of generalization is considered possible. The multicenter design and a mean follow-up of 2 years further enhance this generalizability.

This study emphasizes the limited utility of existing scoring systems in predicting clinical outcomes following posterior fixation without debridement for pyogenic spondylitis. Our results may contribute to the improvement of existing tools and the development of a new risk stratification system for surgery. Ultimately, we hope this study will serve as a foundation for improving clinical decision-making and optimizing treatment strategies for this challenging condition.

## Conclusions

In patients with thoracolumbar pyogenic spondylitis resistant to conservative treatment who underwent minimally invasive posterior fixation, the existing scoring systems showed limited ability to predict treatment failure and unplanned additional surgeries. BSDS grading showed some utility, with 22% of high-risk patients experiencing postoperative infection control failure and implant failure, highlighting the need for careful treatment planning in this group.

**Author contributions** HG, TF, YO, and MK conceived and designed the study. HG, YO, YS, TN, TS, KS, SO, KO, YS, HK, KN, KF, YT, MT, IS, and MU gathered and analyzed the data for the study. HG, TF, and YO drafted the manuscript which was then significantly revised by MK. All authors approved the current version of the manuscript submitted for publication.

**Data availability** The datasets generated and analyzed during the current study can be obtained from the corresponding author upon reasonable request.

## Declarations

**Competing interests** The authors declare no competing interests.

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