Journal of Orthopaedic Surgery and Research

SYSTEMATIC REVIEW

Open Access

Effectiveness and safety of percutaneous endoscopic debridement and drainage for spinal infections: a systematic review and meta-analysis

Guozhong Zhou[1,2†], Xiaorong Liu[1†], Zhi Liang[1], Xuesong Chen[1*] and Chao Song[1*]

Abstract

Background Spinal infections (SI) typically manifest with and pose a growing medical challenge. However, current evidence for treating SI is limited and inconclusive. Our aim was to assess the effectiveness and safety of percutaneous endoscopic disc decompression (PEDD) for SI.

Methods On 20 October 2023, we searched the EMBASE, PubMed, Cochrane Library, China Biology Medicine Disc, China National Knowledge Infrastructure, and Wanfang databases for eligible studies. Cohort studies on SI treated with PEDD, reporting relevant effectiveness or safety outcomes. We assessed study quality using a modified Newcastle–Ottawa Scale and conducted a random-effects meta-analysis to calculate pooled results.

Results Overall, 36 studies involving 925 patients were included. Erythrocyte sedimentation rate levels decreased significantly at 1-week postoperatively compared with preoperative levels (mean difference [MD] = − 13.48 [95% CI − 15.65 to − 11.31]) and continued to decrease over 3 months. Similarly, the c-reactive protein (CRP), visual analogue scale, and oswestry disability index scores significantly reduced postoperatively. The rates of excellent or good MacNab classification were 92.6% (95% CI 84.1–98.1%). Microbiological diagnostics revealed a 71.7% (95% CI 65.5–77.6%) positive rate in tissue cultures, surpassing blood cultures (odds ratio [OR] 2.72 [95% CI 1.01–7.30]). The rates of complication, reoperation, and mortality were 4.1% (95% CI 1.5–8.0%), 8.6% (95% CI 4.3–14.3%), and 1.7% (95% CI 0.4–4.1%), respectively. Subgroup analyses demonstrated a significantly lower reoperation rate in the group that discontinued antibiotics based on a normal CRP than in the fixed-duration group (2.7% [95% CI 0.3–7.7%] vs 20.1% [95% CI 14.5–26.3%], $p = 0.0002$). Conversely, ambulation 1 day postoperatively was associated with a higher reoperation rate than ambulation within 5–14 days (16.2% [95% CI 9.3–24.6%] vs 1.1% [95% CI 0.0–6.0%], $p = 0.0060$).

Conclusion Our meta-analysis suggests that PEDD is a potentially effective and safe intervention for SI. Optimizing antibiotic discontinuation and postoperative care strategies may contribute to reducing reoperation rate. However, these findings require further validation from controlled studies.

Keywords Spinal infection, Percutaneous endoscopic, Minimally invasion, Effectiveness, Safety

†Guozhong Zhou and Xiaorong Liu have contributed equally to this work.

*Correspondence:
Xuesong Chen
jinhou0420@163.com
Chao Song
chaoge6870@163.com
Full list of author information is available at the end of the article

Introduction

Spinal infection (SI) is an inflammatory condition, mainly caused by bacteria or other pathogens, with symptoms that may include persistent back pain, fever, malaise, localized swelling, and stiffness [1]. These infections are classified into primary infections, which are caused by blood or tissue transmission, and secondary infections, which are caused by surgical contamination [2]. The rising incidence of SI globally has been attributed to factors such as an aging population, increasing comorbidities, and higher rates of immunosuppression [3]. Untreated SI leads to debilitating complications including damage to spinal structures, neurological problems, sepsis, and death [4].

The management of SI primarily involves two strategies: conservative antibiotic therapy and surgical interventions. However, successful antibiotic treatment may extend over several weeks or even months to effectively combat the infection [5]. Surgical procedures for SI are known for their invasiveness and often require intricate postoperative care regimens [6–8]. Expanding upon the groundwork laid by percutaneous endoscopic lumbar discectomy (PELD), a pioneering technique known as percutaneous endoscopic debridement and drainage (PEDD) has emerged. PEDD employs percutaneous endoscopy to eliminate infectious materials, encompassing diseased tissues and purulent fluids. This less invasive approach shows promise, especially for patients contending with the complexities associated with SI [9, 10].

Mao et al. conducted meta-analyses in 2019 and 2024 to evaluate the effectiveness and safety of PEDD, incorporating 9 and 26 studies, respectively [6, 11]. However, both analyses were limited to three specific outcome measures: pain control satisfaction, microbiological positivity rate, and reoperation rate. Pain control satisfaction was defined as a Visual Analog Scale (VAS) score of ≤ 3 or an Oswestry Disability Index (ODI) score of ≤ 50 at the final follow-up. These outcomes, however, may be influenced by baseline preoperative pain levels and the duration of follow-up, which introduces potential biases. Consequently, there remains a need for more comprehensive and reliable outcome measures for a thorough evaluation. This study seeks to address these limitations by providing a more robust assessment of the efficacy and safety of PEDD in the treatment of SI.

Methods

Methods adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and the Assessing the Methodological Quality of Systematic Reviews (AMSTAR) guidelines [12, 13]. The study was registered in PROSPERO (CRD42023428502).

Search strategy

On 20 October 2023, we conducted a comprehensive search of the EMBASE, PubMed, Cochrane Library, China Biology Medicine disk, China National Knowledge Infrastructure, and Wanfang databases for eligible studies, without restrictions on the start date. Studies in all languages were included, and for non-English articles, translation was performed using professional translation services and/or institutional resources when necessary. The keyword combinations used for the search are detailed in Table 1. In addition, we manually checked the reference lists of all included studies and relevant review articles to identify any potentially missed studies.

Study selection criteria

The inclusion criteria were: (1) cohort studies involving SI, including both primary and secondary infections, such as vertebral osteomyelitis, discitis, and epidural abscesses; (2) studies on the use of PEDD to treat SI, including unilateral or bilateral percutaneous endoscopic debridement; and (3) studies reporting of outcomes related to efficacy and/or safety. Primary infections were defined as those caused by blood or tissue transmission of pathogens, whereas secondary infections were defined as those resulting from surgical contamination during procedures. The diagnosis of SI primarily relies on microbiological evidence, including blood and tissue cultures or molecular diagnostics, as well as imaging studies such as X-ray, computed tomography (CT), and magnetic resonance imaging (MRI).

The exclusion criteria were: (1) studies with percutaneous endoscopic debridement without intraoperative irrigation or postoperative drainage; (2) studies with fewer than five participants; (3) studies involving vertebral fusion or fixation in conjunction with PEDD; (4) instances of duplicate publications; and (5) review articles, comments, case reports, letters, animal trials, or cadaveric studies.

Two investigators (GZZ and ZL) independently screened article titles and abstracts from the literature search. Full texts of potentially eligible studies were then assessed for final inclusion. Discrepancies, such as differing interpretations of the inclusion and exclusion criteria, were resolved through structured discussions. A third investigator (XSC) mediated by consulting the original study data and standardized scoring guidelines to ensure consensus.

Data extraction and quality assessment

In a preconceived and standardised data extraction form, information was collected regarding the name of the first author, year of publication, title, journal, study

Table 1 Search strategy

Search strategy in PubMed		
#1	(((((((spinal infection) OR (spondylodiscitis)) OR (spondylitis)) OR (diskitis)) OR (vertebral osteomyelitis)) OR (spondylodiskitis)) OR (epidural abscess)) OR (paravertebral infection)	84 207
#2	Endoscopic OR Endoscopy	557 880
#3	#1 AND #2	1225
Search strategy in Embase		
#1	'spinal infection'/exp OR 'spinal infection' OR (spinal AND ('infection'/exp OR infection)) OR spondylodiscitis OR spondylitis OR diskitis OR (vertebral AND osteomyelitis) OR spondylodiskitis OR (epidural AND abscess) OR (paravertebral AND infection)	124 681
#2	Endoscopic OR Endoscopy	591 517
#3	#1 AND #2	1934
Search strategy in Web-of-science		
#1	(((((((spinal infection) OR (spondylodiscitis)) OR (spondylitis)) OR (diskitis)) OR (vertebral osteomyelitis)) OR (spondylodiskitis)) OR (epidural abscess)) OR (paravertebral infection)	121 651
#2	Endoscopic OR Endoscopy	472 608
#3	#1 AND #2	914
Search strategy in Cochrane Library		
#1	(((((((spinal infection) OR (spondylodiscitis)) OR (spondylitis)) OR (diskitis)) OR (vertebral osteomyelitis)) OR (spondylodiskitis)) OR (epidural abscess)) OR (paravertebral infection)	4800
#2	Endoscopic OR Endoscopy	32 710
#3	#1 AND #2	57
Search strategy in China National Knowledge Infrastructure		
#1	脊柱感染 OR 椎间隙感染 OR 椎间盘感染 OR 脊柱炎 OR 脊柱骨髓炎 OR 椎旁脓肿	18 376
#2	内镜	126 300
#3	#1 AND #2	33
Search strategy in China Biology Medicine disk		
#1	(U = 脊柱感染 OR 椎间隙感染 OR 椎间盘感染 OR 脊柱炎 OR 脊柱骨髓炎 OR 椎旁脓肿)	12 895
#2	内镜	110 664
#3	#1 AND #2	14
Search strategy in Wanfang databases		
#1	(脊柱感染 OR 椎间隙感染 OR 椎间盘感染 OR 脊柱炎 OR 脊柱骨髓炎 OR 椎旁脓肿)	31 915
#2	内镜	697 479
#3	#1 AND #2	1055

country, study design, study period, segment of surgery, proportion of tuberculosis (TB) cases, patient demographics, antibiotic usage strategy, type of intraoperative irrigation solution, postoperative continuation of irrigation, time to initiate postoperative ambulation, number of participants, outcomes of microbiological diagnostics, outcomes related to surgical effectiveness, and safety. Instances of reoperation or mortality attributed to antibiotic discontinuation were excluded from the analysis. Two investigators (GZZ and ZL) independently extracted the data from individual studies. Discrepancies were resolved through structured discussions. A third investigator (XSC) checked the extracted data, and disagreements were unanimously resolved.

We utilized a modified version of the Newcastle–Ottawa Scale (NOS) tailored to the characteristics of single-arm cohort studies. The revised scale includes six items, retaining key elements from the original, such as the representativeness of the study population and follow-up duration, while removing items specific to comparative studies (e.g., selection of the non-exposed cohort, ascertainment of exposure, and absence of outcomes at the start of the study). Additionally, new items were introduced to address the specific needs

of single-arm studies, including clear inclusion and exclusion criteria, detailed descriptions of the surgical procedures and postoperative care, comprehensive documentation of patient demographic information, and explicit follow-up processes. Studies with NOS scores of 1–2, 3–4, and 5–6 were considered of low, moderate, and high quality, respectively. Two investigators (GZZ and ZL) independently assessed the methodological quality of the included studies using the modified NOS. Discrepancies, such as differences in scoring follow-up duration or the representativeness of the population, were resolved through structured discussions. A third investigator (XSC) acted as a mediator, referring to the original study data and standardized scoring guidelines to ensure a unanimous resolution.

Outcomes

Our primary outcomes comprised three domains: clinical parameters (erythrocyte sedimentation rate [ESR] and C-reactive protein [CRP]), patient-reported outcomes (Visual Analog Scale [VAS] for pain and Oswestry Disability Index [ODI] for functional impairment), and safety outcomes (complication rates, MacNab satisfaction scores, and reoperation rates). We pooled the mean values of ESR, CRP, VAS, and ODI at 1 day before surgery and at 1 day, 1 week, 1 month, 3 months, and 6 months after surgery. Only time points with data from more than three studies were included, using MD for comparison. We pooled the rates of culture-positive, MacNab (excellent or good), reoperation, mortality, and complications, with odds ratio (OR) employed for comparing the rates between the two groups. Furthermore, we conducted a subgroup analysis of reoperation rates based on several factors, including the type of infection, duration of antibiotic use, intraoperative irrigation, postoperative continuation of irrigation, and time to initiate ambulation. Using univariate meta-regression, we calculated the p values for each subgroup to determine whether the observed differences were significant.

Statistical analysis

Due to the high heterogeneity ($I^2 > 50\%$) and clinical diversity among the included studies, we opted to use a random-effects model to calculate the pooled results and their 95% confidence intervals (CI). Egger's test was used to detect publication bias, and the trim-and-fill method was applied to adjust for it. Zero-event studies were included with continuity corrections to stabilize variance estimates, and sensitivity analyses were performed to assess the impact of outliers. For studies with missing data, only complete cases were analyzed. All p values were two-sided, with significance set at $p < 0.05$. Statistical analysis was performed using the "meta" package in R (version 3.4.3).

Results

Study selection and characteristics

Of the 8529 potentially eligible studies, 5425 were screened for titles and abstracts after removing duplicates, and 152 full-text articles were reviewed (Fig. 1). After a full-text review, 36 studies involving 925 individuals were included in the meta-analysis [10, 15–49].

Among the 36 studies, 19 (52.8%), 11 (30.6%), and 3 (8.36%) originated from mainland China, Taiwan, and Japan, respectively, and the remaining three were from South Korea, India, and the United States. Twenty-eight studies (77.8%) were conducted in English, and eight (22.2%) were conducted in Chinese. Furthermore, among the interventions, 3 studies (8.3%) explored bilateral percutaneous endoscopic debridement, whereas 33 (91.7%) focused on unilateral percutaneous endoscopic debridement (Table 2).

Regarding intraoperative irrigation strategies, 21 (58.3%), eight (22.2%), and four studies (11.1%) employed physiological saline, antibiotic, and iodine solutions, respectively; whereas information on irrigation was not provided in three studies (8.36%). Concerning postoperative irrigation strategies, 5 studies (13.9%) used antibiotic solutions and 4 studies (11.1%) employed physiological saline; whereas postoperative irrigation was not conducted in 27 studies (75.0%). All nine studies reporting postoperative irrigation strategies were conducted in mainland China. Regarding postoperative ambulation strategies, 7 studies (19.4%) indicated that patients began ambulation one day after surgery, 7 studies (19.4%) recommended ambulation within 5–14 days, and 3 studies (8.36%) reported patients initiating ambulation between 21 and 60 days post surgery; whereas information on ambulation was not provided in 19 studies (52.8%).

Of the 36 studies, 22 (61.1%) were rated as high quality, whereas 14 (38.9%) were considered moderate quality. Fifteen studies (41.7%) lacked detailed information regarding the inclusion or exclusion criteria, and fifteen studies (41.7%) did not provide comprehensive follow-up information. Additionally, five studies (13.9%) had a follow-up duration of < 1 year and one study did not report the follow-up period (Supplementary Figs. S1, S2).

Primary outcomes

Assessment of the effectiveness of PEDD for SI

The 1-week postoperative ESR was significantly lower than the preoperative score (pooled MD = −13.48 [95% CI −15.65 to −11.31, $I^2 = 33\%$]) (Supplementary

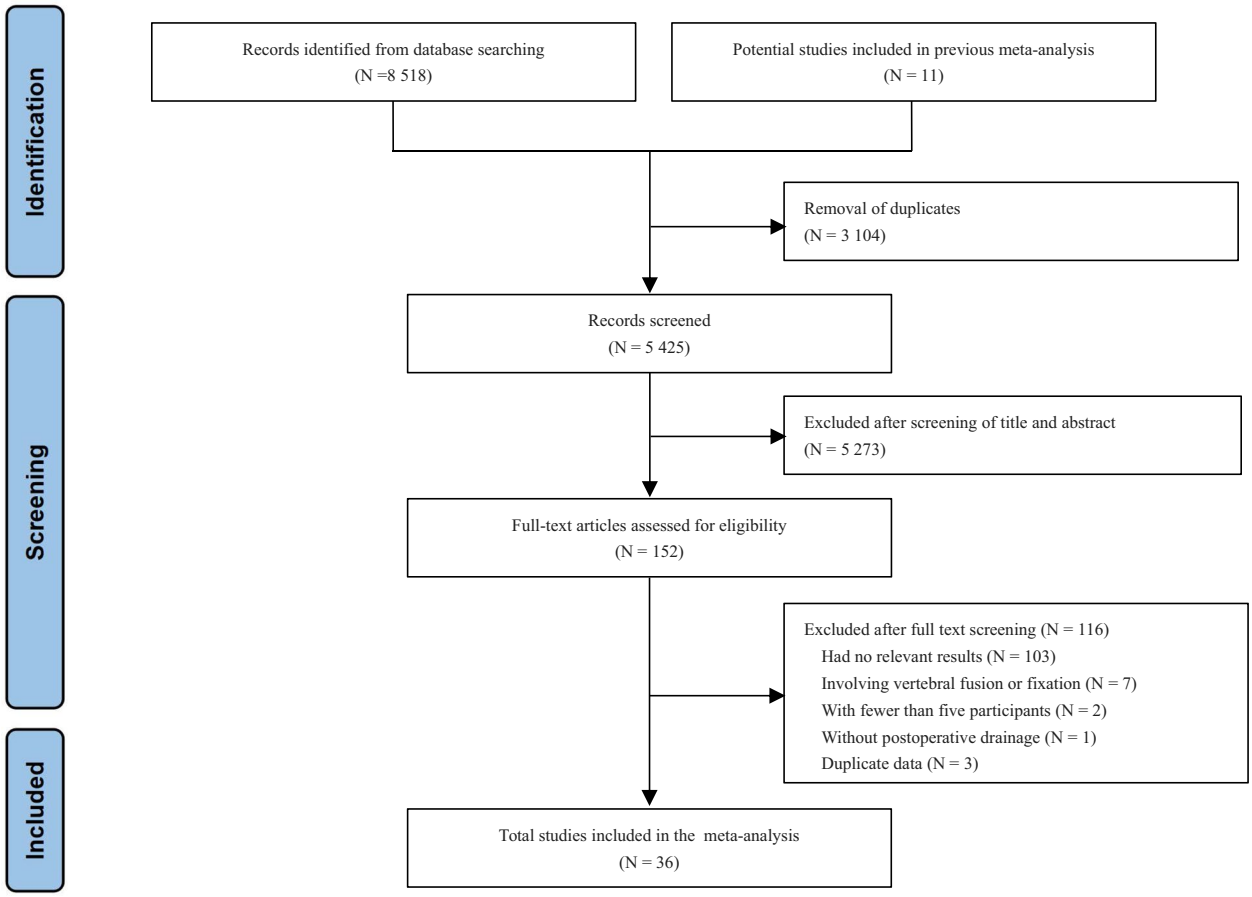

Fig. 1 Study selection

Fig. S3), and ESR continued to decline within 3 months postoperation (See Table 3 and Fig. 2 for details). Similarly, the 1-week postoperative CRP was significantly lower than the preoperative score (pooled MD = −26.77 [95% CI −37.63 to −15.91, I^2 = 94%]) (Supplementary Fig. S4), and CRP continued to decline within 3 months postoperation.

The 1-day postoperative VAS score was significantly lower than the preoperative score (pooled MD = −3.70 [95% CI −4.70 to −2.70, I^2 = 98%]) (Supplementary Fig. S5), and the VAS scores continued to decline within 3 months postoperation. Similarly, the 1-week postoperative ODI score was significantly lower than the preoperative score (pooled MD = −30.18 [95% CI −38.94 to −21.43, I^2 = 93%]) (Supplementary Fig. S6), and the ODI scores continued to decline within 3 months postoperation (See Table 3 and Fig. 2 for details).

Further, 8 cohorts of 164 individuals were eligible for calculating excellent or good rates in the MacNab classification. The pooled excellent or good rate in the MacNab classification was 92.6% (95% CI 84.1–98.1%; I^2 = 70%) (Table 4 and Supplementary Fig. S7).

Although the Japanese Orthopaedic Association (JOA) score and other similar clinical outcome measures were collected, they were not reported in detail due to the limited number of studies that included these measures.

Assessment of PEDD safety for SI

Overall, 25 cohorts of 633 individuals were eligible for the complication rate analysis. The pooled complication rate was 4.1% (95% CI 1.5–8.0%; I^2 = 74%) (Table 4 and Supplementary Fig. S8). A total of 36 complications were reported, of which 26 (72.2%) were mild and 7 (19.4%) were serious. The rate of mild complications was higher than that of serious complications (2.9% [95% CI 0.9–6.1%] vs 0.2% [95% CI 0.0–0.8%]). Additionally, 28 cohorts comprising 651 individuals were eligible for reoperation. The pooled reoperation rate was 8.6% (95% CI 4.3–14.3%; I^2 = 80%) (Table 4 and Supplementary Fig. S9). Further, 26 cohorts of 625 individuals were eligible for reoperation stratified by the cause of uncontrolled infection or intractable pain due to kyphosis. The pooled reoperation rate caused by uncontrolled infection was

Table 2 Detailed characteristics of individual study

	Area	Age (year)	Male (%)	Multi-segment (n)	TB cases (n)	Follow-up (month)	Intraoperative irrigation[¥]	Postoperative irrigation[¥]	Antibiotic strategy[&]	Ambulate (day)	Participants (n)	NOS score
Cao et al. 2021 [13]	China	66.9 ± 9.4	64.7	0	0	20.9 ± 5.8	S	N	Time	NS	17	6
Chen HC et al. 2015 [14]	Taiwan, China	65.6 ± 9.7	38.5	2	0	42.5	S + A	N	CRP	14	13	5
Chen ZH et al. 2022 [15]	China	63.1 ± 9.1	67.4	2	4	29.3 ± 4.0	S + D	N	CRP	NS	43	6
Chen ZW et al. 2022 [16]	China	Mean: 55.5	63.6	0	NS	24.0	S	N	Time	NS	22	3
Choi et al. 2017 [17]	Shouth Korea	70.4 ± 11.1	64.7	5	0	3.0	NS	N	NS	NS	17	3
Fu et al. 2019 [18]	Taiwan, China	56.5 ± 14.4	45.9	0	4	24.0	S	N	Time	1	37	5
Hadjipavlou et al. 2004 [9]	USA	Mean: 49.0	70.6	NS	0	18.0	S + A	N	Time	NS	34	4
Hsu et al. 2015 [19]	Taiwan, China	Mean: 57.8	72.7	0	0	24.0	S + D	N	Time	NS	22	6
Huang JH et al. 2022 [20]*	China	53.5 ± 11.9	35.3	0	0	NS	S + A	N	CRP	NS	17	3
Huang JH et al. 2022 [20]*	China	53.7 ± 11.7	47.1	0	0	NS	S + A	S + A	CRP	NS	17	3
Huang Q et al. 2022 [21]	China	58.3 ± 7.8	38.5	0	1	13.7 ± 2.6	S	S + A	CRP	14	13	6
Ito et al. 2007 [22]	Japan	Mean: 60	66.7	0	0	24.6	S + A	N	CRP	1	15	5
Kang et al. 2019 [23]	China	29.0–69.0	53.8	2	0	24.0	S	N	CRP	NS	13	5
Kono et al. 2019 [24]	Japan	69.2 ± 13.3	62.5	NS	0	7.2 ± 5.4	NS	N	NS	NS	24	3
Lai et al. 2021 [25]	Taiwan, China	63.1 ± 15.0	80.0	0	0	12.0	S	N	CRP	NS	15	6
Liang et al. 2016 [26]	China	Mean: 47.0	27.3	0	0	Mean: 28.7	S + A	N	CRP	21–28	11	4
Lin CY et al. 2019 [27]	Taiwan, China	Mean: 60.0	65.0	0	1	Mean: 42.0	S + A	N	CRP	14	60	5
Lin GX et al. 2019 [28]	Taiwan, China	69.3 ± 8.2	64.3	0	0	20.9 ± 6.7	S + A	N	Time	NS	14	4
Lin IH et al. 2022 [29]	Taiwan, China	61.0 ± 11.7	50.0	NS	0	18.0	NS	N	CRP	14	24	4
Liu et al. 2023 [30]	China	Mean: 51.3	64.3	NS	0	Mean: 7.0	S	S + A	NS	NS	14	3
Pawar et al. 2018 [31]	India	Mean: 46	33.3	0	14	Mean: 17.0	S	N	CRP	NS	18	5

Table 2 (continued)

	Area	Age (year)	Male (%)	Multi-segment (n)	TB cases (n)	Follow-up (month)	Intraoperative irrigation[¥]	Postoperative irrigation[¥]	Antibiotic strategy[&]	Ambulate (day)	Participants (n)	NOS score
Qiu et al. 2019 [32]	China	58.0 ± 17.6	55.0	3	20	Mean: 16.4	S	N	NS	30–60	20	6
Tang et al. 2020 [33]	China	39.7 ± 3.5	62.1	NS	NS	NS	S	S + A	NS	NS	87	3
Wang XP et al. 2018 [34]	China	Mean: 59.5	64.7	0	2	NS	S	N	Time	1	17	5
Wang YC et al. 2016 [35]#	Taiwan, China	51.4 ± 16.4	62.5	0	0	24.0	S	N	NS	1	24	5
Wang YC et al. 2016 [35]#	Taiwan, China	60.5 ± 11.4	82.4	0	0	24.0	S	N	NS	1	17	5
Wu et al. 2020 [36]$	China	Mean: 48.4	45.0	0	9	18.0	S	S	NS	NS	20	4
Wu et al. 2020 [36]$	China	Mean: 48.4	50.0	0	8	18.0	S	S	NS	NS	20	4
Xu et al. 2018 [37]	China	66.7 ± 9.5	55.6	NS	6	1.0	S + A	N	NS	NS	9	2
Yamada et al. 2023 [38]	Japan	61.5 ± 14.7	71.9	12	0	Mean: 63.8	S	N	CRP	5	64	5
Yang SC et al. 2008 [39]	Taiwan, China	62.9 ± 14.9	60.0	NS	3	36.8	S	N	Time	1	20	6
Yang SC et al. 2014 [40]	Taiwan, China	Mean: 57.4	71.9	4	1	Mean: 38.5	S + D	N	Time	1	32	6
Yang Y et al. 2022 [41]	China	49.3 ± 17.4	62.5	NS	1	28.1 ± 10.2	S	S	CRP	NS	16	6
Yang Y et al. 2023 [42]	China	54.5 ± 15.3	100.0	0	2	28.1 ± 10.2	S	N	CRP	NS	4	4
Yu et al. 2020 [43]	Taiwan, China	Mean: 62.3	35.3	0	0	12.0	S + D	N	NS	1	34	4
Zhang et al. 2020 [44]	China	27.3 ± 4.9	58.1	0	31	Mean: 46.0	S	S	NS	7	31	5
Zheng JW et al. 2018 [45]	China	60.7 ± 8.7	33.3	0	7	Mean: 18.0	S	S + A	CRP	7	15	5
Zheng Q et al. 2021 [46]	China	58.1 ± 7.5	57.1	0	0	15.5 ± 3.5	S	S + A	CRP	30	21	6
Zhuang et al. 2022 [47]	China	50.5 ± 16.0	60.0	NS	1	11.6 ± 2.3	S	S	NS	NS	10	6

N number; *TB* tuberculosis; *CRP* c-reactive protein; *NS* not specified; *NOS* Newcastle–Ottawa scale

[*] This study compared the postoperative continuous negative pressure drainage with conventional irrigation drainage outcomes

[#] This study compared the clinical outcomes of using empirical antibiotics before histological examination

[$] This study compared the clinical efficiency of unilateral or bilateral percutaneous endoscopic debridement

[¥] S represents physiological saline, D represents iodine solution, and A represents antibiotics

[&] CRP stands for using CRP and other inflammatory markers as the criterion for antibiotic discontinuation, while Time indicates a fixed antibiotic treatment duration

Table 3 The outcomes of mean value

	Studies (n)	Participants (n)	Mean value (95% CI)	I^2 (%)	MD* (95% CI)	I^2 (%)
ESR data (mm/h)						
Preoperative	18	354	56.79 (46.59–69.24)	99	–	–
1-week	11	199	48.02 (40.55–56.86)	97	−13.48 (−15.65 to −11.31)	33
1-month	13	218	24.67 (19.83–30.70)	98	−28.60 (−37.88 to −19.32)	98
3-month	11	243	14.29 (11.36–17.97)	100	−37.42 (−49.07 to −25.78)	99
CRP data (mg/l)						
Preoperative	23	488	69.60 (58.08–83.41)	99	–	–
1-week	15	309	35.68 (28.92–44.02)	97	−26.77 (−37.63 to −15.91)	94
1-month	16	321	9.02 (6.51–12.50)	99	−60.75 (−74.81 to −46.69)	99
3-month	11	243	5.51 (3.66–8.30)	100	−76.27 (−93.36 to −59.18)	99
VAS data						
Preoperative	24	576	7.60 (7.32–7.90)	94	–	–
1-day	8	141	3.80 (3.26–4.44)	99	−3.70 (−4.70 to −2.70)	98
1-week	10	196	2.84 (2.45–3.28)	88	−4.72 (−5.48 to −3.96)	91
1-month	15	355	2.75 (2.38–3.18)	98	−4.77 (−5.42 to −4.11)	97
3-month	11	279	1.67 (1.18–2.36)	99	−6.00 (−6.89 to −5.11)	98
ODI data						
Preoperative	13	310	60.43 (51.85–70.43)	99	–	–
1-week	4	55	37.71 (27.06–52.56)	98	−30.18 (−38.94 to −21.43)	93
1-month	8	213	26.45 (22.93–30.55)	94	−29.53 (−42.97 to −16.08)	99
3-month	8	218	24.05 (18.59–31.11)	99	−45.80 (−57.32 to −34.29)	99
6-month	6	119	14.81 (8.68–25.26)	99	−40.17 (−52.81 to −27.53)	99

ESR erythrocyte sedimentation rate; *CRP* C-reactive protein; *VAS* visual analog scale; and *ODI* oswestry disability index

*MD (Mean Differences) represent the changes compared with preoperative data

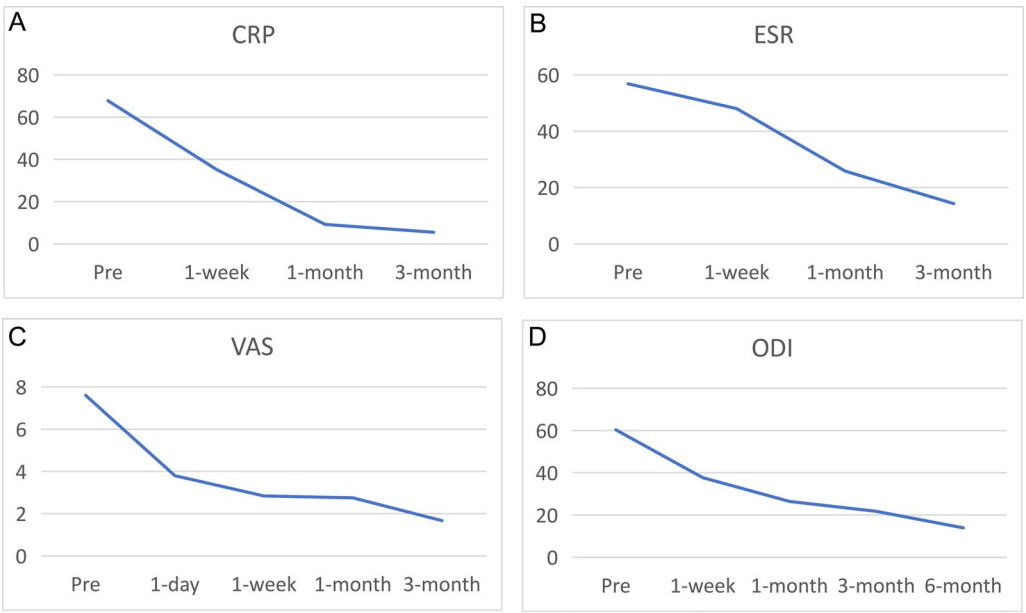

Fig. 2 Postoperative trends of the mean values of ESR, CRP, VAS, and ODI

Table 4 The outcomes of rate

	Studies (n)	Participants (n)	Rate (95% CI)	I^2 (%)
Excellent or good rate of MacNab classification	8	164	92.6% (84.1–98.1%)	70
Complication rate	25	633	4.1% (1.5–8.0%)	74
Mild complications*	23	588	2.9% (0.9–6.1%)	68
Serious complications*	23	588	0.2% (0.0–0.8%)	3
Reoperation rate	28	651	8.6% (4.3–14.3%)	80
Caused by uncontrolled infection	26	625	3.3% (1.1–6.8%)	75
Caused by kyphotic deformity[§]	26	625	3.4% (1.0–7.3%)	79
Mortality rate	15	359	1.7% (0.4–4.1%)	41
Caused by uncontrolled infection	15	359	0.4% (0.0–1.3%)	6
Caused by comorbidities[&]	15	359	0.6% (0.0–2.0%)	35
Tissue culture positive rate (all studies)	30	683	71.7% (65.5–77.6%)	67
Tissue culture positive[#]	6	172	59.6% (40.3–77.5%)	83
Blood culture positive[#]	6	172	35.5% (25.5–46.3%)	46

* Twenty-nine mild complications were observed, including 20 cases of transient lower limb paresthesia, 8 cases of radicular pain in the lower limb, and 1 case of local pain. Seven serious complications were reported, including 1 case of hematoma, 2 cases of fever, 1 case of instrument breakage 2 cases of superficial wound infection, and 1 case of cerebrospinal fluid leakage

§ Kyphotic deformity represents a group of patients, with studies reporting it as a potential outcome related to kyphotic deformity, including spinal instability or persistent intractable back pain

& Comorbidities include cancer, heart failure or kidney failure

In six studies, head-to-head comparisons were conducted between tissue culture and blood culture

3.3% (95% CI 1.1–6.8%; $I^2=75\%$), and the pooled reoperation rate caused by kyphotic deformity was 3.4% (95% CI 1.0–7.3%; $I^2=79\%$).

Further, 15 cohorts comprising 359 individuals were eligible for evaluating the mortality rate. The pooled mortality rate was 1.7% (95% CI 0.4–4.1%; $I^2=41\%$) (Table 4 and Supplementary Fig. S10). Fifteen cohorts were eligible for assessing the mortality rate stratified by the cause of uncontrolled infection or morbidity. The pooled mortality rate caused by uncontrolled infection was 0.4% (95% CI 0.0–1.3%; $I^2=6\%$), and the pooled mortality rate caused by comorbidities was 0.6% (95% CI 0.0–2.0%; $I^2=35\%$).

Secondary outcomes

Outcomes of microbiological diagnostics

Next, 38 of 683 individuals were eligible for calculating the tissue culture positive rate. The pooled positive rate was 71.7% (95% CI 65.5–77.6%; $I^2=67\%$) (Table 4 and Supplementary Fig. S11). Further, 6 cohorts of 172 individuals were eligible for comparing the culture-positive rates between tissue and blood cultures. The pooled positive rates of tissue and blood cultures were 59.6% (95% CI 40.3–77.5%; $I^2=83\%$) and 35.5% (95% CI 25.5–46.3%; $I^2=46\%$), respectively. The pooled OR for the two positive rates in six studies was 2.72 (95% CI 1.01–7.30; $I^2=74\%$) (Supplementary Fig. S12).

Subgroup analysis of the reoperation rate

We performed a subgroup analysis on the reoperation rate, stratified by the duration of antibiotic usage, time to initiate ambulation, intraoperative irrigation, postoperative continuation of irrigation, type of infection, proportion of males, segment, and quality of study. Notably, significant differences emerged primarily within the subgroups of antibiotic usage duration and time to initiate ambulation (Table 5).

Duration of antibiotic usage: The subgroup analysis revealed a significant difference in reoperation rates between the two antibiotic usage strategies. The group that discontinued antibiotics on the normal of inflammatory markers had a substantially lower reoperation rate than the group with a fixed duration strategy (2.7% [95% CI 0.3–7.7%, $I^2=77\%$] *vs* 20.1% [95% CI 14.5–26.3, $I^2=0\%$], $p=0.0002$). This finding was consistent across the subgroup analyses of reoperation rates caused by uncontrolled infection and kyphotic deformity (Table 5).

Time to initiate postoperative ambulation: The timing of postoperative ambulation had a significant impact on reoperation rates. Patients who began walking 1 day postoperatively had a significantly higher reoperation rate than those who initiated ambulation 5–14 days post operation (16.2% [95% CI 9.3–24.6%, $I^2=53\%$] *vs* 1.1% [95% CI 0.0–6.0, $I^2=71\%$], $p=0.0060$). Furthermore, for reoperation rates caused by kyphotic deformity, the group initiating ambulation 1 day post surgery

Table 5 Subgroup analysis of reoperation rate

	N/n*	Reoperation rate (95% CI)	I^2 (%)	*p* value	N/n	Uncontrolled infection* (95% CI)	I^2 (%)	*p* value	N/n	Kyphotic deformity# (95% CI)	I^2 (%)	*p* value
All studies	28/651	8.6 (4.4–14.2)	80	–	26/625	3.3 (1.1–6.8)	75	–	26/625	3.4 (1.0–7.3)	79	–
Duration of antibiotic usage												
Normalization of CRP	15/349	2.7 (0.3–7.7)	77	Ref.	13/333	0.5 (0.0–2.1)	47	Ref.	13/333	0.5 (0.0–2.9)	66	Ref.
Fixed duration	7/176	20.1 (14.5–26.3)	0	0.0002	7/176	13.6 (5.2–25.1)	74	0.0001	7/176	10.9 (5.0–18.8)	55	0.0030
NS	6/126	18.6 (12.1–26.1)	0	0.0079	5/116	4.8 (0.2–15.1)	73	0.0875	5/116	7.2 (0.2–22.4)	83	0.0484
Time to initiate ambulation												
1-day	8/196	16.2 (9.3–24.6)	53	Ref.	8/196	6.0 (1.1–14.4)	74	Ref.	8/196	13.3 (6.4–22.4)	64	Ref.
5–14 days	6/189	1.1 (0.0–6.0)	71	0.0060	6/189	1.1 (0.0–6.0)	71	0.2042	6/189	0.0 (0.0–0.5)	0	< 0.0001
21–60 days	2/32	1.8 (0.0–17.7)	63	0.1121	2/32	1.8 (0.0–17.7)	63	0.5297	2/32	0.0 (0.1–0.3)	0	0.0115
NS	12/234	11.6 (3.8–22.9)	81	0.5169	10/208	3.5 (0.1–11.3)	79	0.5683	10/208	3.2 (0.1–10.6)	79	0.0221
Intraoperative irrigation												
Antibiotic solution	6/147	5.9 (0.0–22.1)	87	Ref.	6/147	4.5 (0.0–17.1)	86	Ref.	6/147	0.4 (0.0–3.4)	47	Ref.
Iodine solution	4/131	10.3 (0.8–28.5)	87	0.6024	4/131	3.0 (0.0–14.3)	83	0.7957	4/131	7.5 (0.5–21.9)	83	0.1199
Saline	15/308	9.7 (4.1–17.4)	74	0.5564	13/282	2.3 (0.2–6.6)	68	0.5827	13/282	6.6 (1.3–15.5)	83	0.0705
NS	3/65	7.7 (0.0–29.0)	82	0.8329	3/65	7.7 (0.0–29.0)	79	0.6590	3/65	0.0 (0.0–1.5)	0	0.7162
Postoperative continuation of irrigation												
Antibiotic solution	3/50	0.7 (0.0–6.3)	34	Ref.	3/49	0.7 (0.0–6.3)	34	Ref.	3/49	0.0 (0.0–1.9)	0	Ref.
Saline	2/26	7.2 (0.0–49.8)	85	0.3893	–	–	–	–	–	–	–	–
No continuation of irrigation	23/576	10.2 (5.2–16.7)	81	0.1069	20/576	4.0 (1.2–8.4)	78	0.4166	20/576	4.3 (1.3–8.9)	80	0.1407
Type of infection												
Pyogenic infection	16/362	10.9 (4.8–18.9)	79	Ref.	14/362	3.0 (0.5–7.3)	73	Ref.	14/362	3.1 (0.3–8.4)	80	Ref.
Partial of TB	12/289	6.0 (1.3–13.9)	80	0.3287	10/263	3.9 (0.4–11.1)	80	0.7560	10/263	4.0 (0.4–11.1)	79	0.7886
Proportion of males												
Less than 64%	10/199	5.6 (0.6–15.1)	80	Ref.	10/189	5.1 (0.5–13.9)	78	Ref.	10/199	1.7 (0.0–6.5)	67	Ref.
More than 65%	18/452	10.5 (4.8–18.0)	81	0.3468	18/436	2.6 (0.4–6.4)	74	0.4414	18/452	4.7 (1.0–10.8)	83	0.3446
Infection segment												
Single-segment cases	16/341	10.0 (3.8–18.8)	81	Ref.	16/341	1.9 (0.2–5.5)	69	Ref.	16/341	4.9 (1.1–11.2)	79	Ref.
Partial multi-segment cases	6/182	4.3 (0.1–13.9)	80	0.3192	6/182	4.3 (0.1–13.9)	80	0.4737	6/182	0.7 (0.0–5.7)	76	0.1889
NS	6/128	10.6 (2.0–25.0)	79	0.9317	6/102	9.2 (0.9–24.9)	79	0.1344	6/102	4.1 (0.0–18.2)	83	0.8808
Quality of study												
High	20/485	9.8 (2.9–13.9)	81	Ref.	18/459	1.7 (0.2–4.9)	73	Ref.	18/459	5.2 (1.3–11.4)	83	Ref.
Moderate	8/166	12.2 (4.1–23.9)	74	0.4200	8/166	9.0 (2.5–19.0)	71	0.0448	8/166	0.9 (0.0–4.4)	52	0.1489

TB tuberculosis cases; *CRP* C-reactive protein; *NS* not specified

*Reoperation rate caused by uncontrolled infection

Reoperation rate caused by kyphotic deformity

had a significantly higher reoperation rate than the 5–14 day group (13.3% [95% CI 6.4–22.4%, $I^2 = 64\%$] *vs* 0.0% [95% CI 0.0–0.5, $I^2 = 0\%$], $p < 0.0001$). A similar trend was observed for reoperation rates because of uncontrolled infection; however, univariate meta-regression did not yield significant results (Table 5).

Comparing the effectiveness and safety of PEDD and open surgery

Four studies [20, 35, 39, 49] compared PEDD with open surgery for treating SI. Among them, three studies (comprising 107 patients) focused on VAS scores. No statistically significant differences were observed in preoperative VAS scores between PEDD and open surgery. However, postoperatively, PEDD showed a significantly lower VAS score at 1-week compared to open surgery (pooled MD = −1.06 [95% CI −1.24 to −0.89, $I^2 = 0\%$]) (Supplementary Fig. S13).

Two studies (involving 86 patients) were eligible for comparing ODI scores. No statistically significant differences were found in preoperative ODI scores between PEDD and open surgery. However, in the postoperative period, PEDD demonstrated a significantly lower ODI score at 1-week compared to open surgery (pooled MD = −7.02 [95% CI −9.00 to −5.04, $I^2 = 0\%$]) (Supplementary Fig. S14).

Three studies (involving 251 patients) were eligible for comparison among complication rates, and PEDD demonstrated a significantly lower complication rate than open surgery (pooled OR = 0.25 [95% CI 0.11–0.55, $I^2 = 0\%$]) (Supplementary Fig. S15). Additionally, three studies (involving 254 patients) were eligible for comparing hospitalisation duration, with PEDD revealing a shorter hospital stay than open surgery; however, this difference was not significant (pooled MD = −19.79 [95% CI −50.63 to 11.04, $I^2 = 100\%$]) (Supplementary Fig. S16).

Sensitivity analysis and publication bias

We performed a sensitivity analysis of the MD of the ESR at one week postoperatively and preoperatively and found no significant change in the pooled MD after excluding any of the studies (point estimates and 95% CIs for MD were less than 0), suggesting that the pooled MD was stable. For example, excluding study conducted by Cao et al. Resulted in an MD of −13.61 (95% CI −16.25 to −10.96), while excluding study conducted by Hsu et al. led to an MD of −13.17 (95% CI −15.37 to −10.97), showing minimal variation across the analyses. Similarly, sensitivity analyses for other primary outcomes also demonstrated stability (Supplementary Figs. S17, S18, S19, S20, S21, S22, S23, S24).

Egger's test for publication bias was not significantly associated with primary outcomes, including complication ($p = 0.4755$), reoperation ($p = 0.5607$), mortality ($p = 0.7730$), and culture-positive rates ($p = 0.5330$). Similarly, publication bias was not significant for the pooled MD of ESR, CRP level and VAS and ODI scores ($p > 0.05$).

Discussion

We conducted a comprehensive systematic review and meta-analysis of 36 studies (925 patients) evaluating PEDD for SI treatment. Four key findings were as follows: First, there were significant postoperative reductions in ESR, CPR, VAS and ODI scores, persisting for 3 months. Second, the microbiological diagnostics rate of tissue culture after PEDD surpassed that of blood cultures. Third, the rates for excellent or good outcomes based on the MacNab classification, as well as complication, reoperation, and mortality rates, were 92.6%, 4.1%, 8.6%, and 1.7%, respectively. Finally, the group discontinuing antibiotics showed a significantly lower reoperation rate compared to CRP normalization, while the group ambulating 1-day postoperatively exhibited a higher reoperation rate compared to ambulation within 5–14 days.

In this study, we observed a significant reduction in inflammatory markers such as ESR and CRP one week postoperatively, with levels gradually approaching normal within the 1–3 month follow-up period. These findings suggest effective control of acute inflammation, which is clinically relevant as it reflects a reduced burden of infection and supports tissue healing. Pain, as measured by VAS scores, decreased significantly, with the average score falling below 4 by the 1-day mark. This rapid pain relief not only highlights the efficacy of PEDD in early symptom management but also facilitates patient mobility and accelerates rehabilitation, which are critical for recovery. Additionally, ODI scores showed significant improvement, dropping below 30 at 1 month. This indicates a marked reduction in disability and suggests that patients can resume normal daily activities, which is a key measure of functional recovery and quality of life [50]. Together, these findings underscore the clinical relevance of PEDD in achieving favorable short- and medium-term outcomes.

These improvements in inflammation, pain, and function resulted in a high rate of excellent or good outcomes (92.6%) based on the MacNab classification. Although no specific meta-analysis on the MacNab satisfaction rate for PEDD or other SI procedures exists, the pooled excellent or good rate for PELD in treating lumbar disc herniation is reported at 82.4% [50]. Patients with SI often experience a significant decline in quality of life due to chronic pain and infection, but symptom relief after

surgery leads to notable improvements in satisfaction. In contrast, while PELD effectively alleviates nerve compression and related pain, its effectiveness may be limited by more complex lesions, such as free disc fragments or calcified foci, which could affect patient satisfaction.

We observed a complication rate of 4.1% for PEDD, with the majority (72.2%) being mild complications, such as limb numbness. When comparing this complication rate with that of similar procedures, it is noteworthy that biportal endoscopic surgery [50] and PELD [51] for treating lumbar disc herniation have reported complication rates of 7.9% and 3.1%, respectively. The complication rate associated with PEDD appears to be relatively acceptable. Overall, during the follow-up period, patients with SI treated with PEDD had a mortality rate of 1.7%, with only 0.4% attributed to uncontrolled infections. Kim et al. [52] investigated a cohort of 10 695 patients with pyogenic SI and reported a mortality rate of up to 1.2% at 12 weeks after onset, which increased to 3.3% when combined with infections at other sites. Additionally, Park et al. assessed 153 patients with hematogenous vertebral osteomyelitis who underwent open surgical treatment for infection, revealing that 10 patients (6.5%) died during hospitalisation, with 2 deaths (1.3%) directly linked to the infection [53]. Considering that the majority of patients undergoing PEDD treatment had previously failed antibiotic therapy or were elderly, and with the follow-up period exceeding 12 months in 15 studies reporting mortality rates, the observed 1.7% mortality rate in our study could be deemed acceptable.

Our study found a reoperation rate of 8.6% (95% CI 4.3–14.3%), which is similar to the results of Mao et al.'s 2024 [11] study (8% [95% CI 3–13%]). Furthermore, we conducted a comprehensive analysis of the underlying reasons for reoperations. Only 3.3% of reoperations were due to uncontrolled infections, while 3.4% were associated with spinal instability or intractable pain. These findings emphasize the importance of prioritizing infection control and considering factors related to spinal instability in order to reduce reoperation rates. Potential deformities and their consequences should also be taken into account postoperatively. For example, some studies have suggested that patients with severe local kyphosis (>30°) or large bony defects (more than half of the vertebral body) may not be suitable candidates for PEDD treatment [20, 31]. Factors such as the location of infection can influence deformities in SI patients [54]. Future research should explore the relationship between the type or severity of deformities and the need for secondary surgery.

We conducted subgroup analyses of the reoperation rate and discovered that using a normal CRP as the criterion for discontinuing antibiotics and implementing antibiotic irrigation during and postoperatively may offer advantages for reducing the reoperation rate. However, early ambulation within 1-day postoperatively is associated with an increased reoperation rate. These findings highlight the potential to optimize clinical outcomes with PEDD by adjusting antibiotic administration and postoperative care strategies. Nonetheless, it is important to acknowledge certain limitations in our study, including the absence of comparative studies and the relatively limited sample sizes of the included studies. Therefore, further validation of these findings is warranted through well-designed randomised controlled trials.

In addition to its effectiveness in treating SI, PEDD offers the added benefit of obtaining tissue samples for bacterial culture. Mao et al. included 26 studies with 565 participants and reported a bacterial culture positivity rate of 73% [11]. Our analysis, which incorporated 30 studies with 683 participants, yielded a similar result of 71.7%. This relatively high positivity rate helps identify the most effective pathogen-specific antibiotics, avoiding unnecessary prolonged use of broad-spectrum antibiotics. This approach not only minimizes the risk of adverse effects but also supports antibiotic stewardship by reducing the development of antimicrobial resistance [34, 55, 56]. Moreover, our results revealed that tissue culture positivity rates were significantly higher than blood culture positivity rates, with an odds ratio of 2.72 (95% CI 1.01–7.30). These results highlight the diagnostic advantage of PEDD, as it allows for direct sampling of infected tissue, reducing the risk of false negatives associated with the lower sensitivity of blood cultures.

Our comparison of PEDD with open surgery revealed that PEDD offers notable advantages in pain relief (as indicated by VAS scores), functional recovery (ODI scores), and reduced complication rates. As a minimally invasive technique, PEDD also minimizes trauma, blood loss, and recovery time, making it a promising alternative for patients with mild infections or stable spinal conditions. However, it may not be suitable for individuals with complex or extensive infections that necessitate open surgery. Despite these benefits, the steep learning curve associated with PEDD (rooted in its foundation on PELD) highlights the importance of surgeon proficiency for successful outcomes [57]. Consequently, enhancing physician training and providing robust technical support are crucial for the wider adoption of PEDD and the optimization of clinical results.

This study has some limitations. First, most of the included studies were single-arm cohorts with small sample sizes. This could introduce bias and limit the generalisability of our findings. Second, only four studies directly compared PEDD with open surgery. Therefore, further comparative research is required to comprehensively

understand the differences between the two approaches. Third, the predominance of studies originating from Asia (35 out of 36; 91.7%) may restrict the generalizability of these findings to populations in other regions. Fourth, substantial heterogeneity was observed among the included studies, likely stemming from differences in patient populations, surgical techniques, and antibiotic protocols. This heterogeneity poses challenges to drawing definitive conclusions from the available data. Finally, the variability in follow-up durations across studies may have impacted the consistency and interpretation of the reported outcomes.

Conclusions

PEDD is a potentially effective and safe intervention for SI. Optimizing antibiotic discontinuation and postoperative care strategies may contribute to reducing reoperation rate. However, these findings require further validation from controlled studies.

Abbreviations

SI	Spinal infection
PELD	Percutaneous endoscopic lumbar discectomy
PEDD	Percutaneous endoscopic debridement and drainage
ESR	Erythrocyte sedimentation rate
CRP	C-reactive protein
VAS	Visual analogue scale
ODI	Oswestry disability index
NOS	Newcastle–Ottawa scale
OR	Odds ratio
CI	Confidence intervals
MD	Mean difference

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13018-025-05540-6.

Supplementary file 1.

Acknowledgements

Not applicable.

Author contributions

GZZ, XRL, XSC and CS conceived and designed the study, collected the data, performed the formal analysis, curated the data, and wrote and prepared the original draft. GZZ and ZL collected the data and validated the study. All authors contributed to the methodology, interpreted the results, contributed to writing the manuscript, approved the final version, and had final responsibility for the decision to submit for publication.

Funding

Yunnan Fundamental Research Projects, 202301BE070001-036, Medical Joint Special Project of Kunming University of Science and Technology, KUST-AN2023004Z, KUST-AN2023018Y, Yunnan Xingdian Talent Support Project-Famous Doctor Project, XDYC-MY-2022-0071.

Availability of data and materials

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

Declarations

Ethics approval and consent to participate

Not required.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Pain Medicine, The Affiliated Anning First People's Hospital of Kunming University of Science and Technology, Kunming 650302, Yunnan Province, China. [2]School of Basic Medical Sciences, Kunming University of Science and Technology, Kunming 650500, Yunnan Province, China.

Received: 11 September 2024 Accepted: 23 January 2025
Published online: 04 February 2025

References

1. Weissman S, Parker RD, Siddiqui W, Dykema S, Horvath J. Vertebral osteomyelitis: retrospective review of 11 years of experience. Scand J Infect Dis. 2014;46(3):193–9.
2. Lazzeri E, Bozzao A, Cataldo MA, Petrosillo N, Manfrè L, Trampuz A, et al. Joint EANM/ESNR and ESCMID-endorsed consensus document for the diagnosis of spine infection (spondylodiscitis) in adults. Eur J Nucl Med Mol Imaging. 2019;46(12):2464–87.
3. Euba G, Narváez JA, Nolla JM, Murillo O, Narváez J, Gómez-Vaquero C, et al. Long-term clinical and radiological magnetic resonance imaging outcome of abscess-associated spontaneous pyogenic vertebral osteomyelitis under conservative management. Semin Arthritis Rheum. 2008;38(1):28–40.
4. Skaf GS, Domloj NT, Fehlings MG, Bouclaous CH, Sabbagh AS, Kanafani ZA, et al. Pyogenic spondylodiscitis: an overview. J Infect Public Health. 2010;3(1):5–16.
5. Papachristodoulou E, Kakoullis L, Louppides S, Panos G. Granulomatous infective spondylitis in a patient presenting with progressive difficulty in walking: the differential between tuberculosis and brucellosis. BMJ Case Rep. 2019;12(11):e232540.
6. Mao Y, Li Y, Cui X. Percutaneous endoscopic debridement and drainage for spinal infection: systemic review and meta-analysis. Pain Physician. 2019;22(4):323–30.
7. Yue L, Zhang F, Mu G, Shang M, Lin Z, Sun H. Effectiveness and safety of intrathecal morphine for percutaneous endoscopic lumbar discectomy under low-dose ropivacaine: a prospective, randomized, double-blind clinical trial. Spine J. 2023;23(7):954–61.
8. Lener S, Hartmann S, Barbagallo G, Certo F, Thomé C, Tschugg A. Management of spinal infection: a review of the literature. Acta Neurochir. 2018;160(3):487–96.
9. Nagata K, Ohashi T, Ariyoshi M, Sonoda K, Imoto H, Inoue A. Percutaneous suction aspiration and drainage for pyogenic spondylitis. Spine. 1998;23(14):1600–6. https://doi.org/10.1097/00007632-199807150-00018.
10. Hadjipavlou AG, Katonis PK, Gaitanis IN, Muffoletto AJ, Tzermiadianos MN, Crow W. Percutaneous transpedicular discectomy and drainage in pyogenic spondylodiscitis. Eur Spine J. 2004;13(8):707–13.
11. Mao Y, Zhang J, Zhan Y, Ye Z. Unilateral or bilateral percutaneous endoscopic debridement and drainage for thoracolumbar infections: a systemic review and meta-analysis. Pain Physician. 2024;27(3):111–9.
12. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ. 2009;339:b2700.
13. Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J, et al. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. BMJ. 2017;358:j4008.

14. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ. 2003;327(7414):557–60.
15. Cao C, Chen SL, Gao YZ, Ai JW, Zhang K, Wang YB, et al. Percutaneous endoscopic debridement and irrigation for non-specific infection of lumbar intervertebral space. Orthop J China. 2021;29(5):408–12.
16. Chen HC, Huang TL, Chen YJ, Tsou HK, Lin WC, Hung CH, et al. A minimally invasive endoscopic surgery for infectious spondylodiscitis of the thoracic and upper lumbar spine in immunocompromised patients. Biomed Res Int. 2015;2015:780451.
17. Chen Z-H, Wang X, Zhang Yi, Sheng-Ting Wu, Ying-Hao Wu, Shi Q, Zhang B-K, Jian-Guang Xu, Chen X-H, Lian X-F. Percutaneous transforaminal endoscopic debridement and drainage with accurate pathogen detection for infectious spondylitis of the thoracolumbar and lumbar spine. World Neurosurg. 2022;164:e1179–89. https://doi.org/10.1016/j.wneu.2022.05.123.
18. Chen ZW, Ma Y, Li TT, Huang ZZ, Liu H, Lin B, et al. Clinical experience of percutaneous intervertebral foramenoscopic surgery for the treatment of lumbar intervertebral space infection. Chin J Bone Joint Injury. 2022;37(11):1169–70.
19. Kim K-H. Percutaneous endoscopic debridement and drainage with four different approach methods for the treatment of spinal infection. Pain Physician. 2017;20(6):E933–40. https://doi.org/10.36076/ppj.20.5.E933.
20. Fu TS, Wang YC, Lin TY, Chang CW, Wong CB, Su JY. Comparison of percutaneous endoscopic surgery and traditional anterior open surgery for treating lumbar infectious spondylitis. J Clin Med. 2019;8(9):1356.
21. Hsu LC, Tseng TM, Yang SC, Chen HS, Yen CY, Tu YK. Bilateral portal percutaneous endoscopic debridement and lavage for lumbar pyogenic spondylitis. Orthopedics. 2015;38(10):e856–63.
22. Huang JH. Comparison of the effects of continuous negative pressure drainage and conventional flushing drainage after spinal endoscopic treatment of intervertebral space infection. J Med Theory Pract. 2022;35(4):614–6.
23. Huang Q, Gu Q, Song J, Yan F, Lin X. The effectiveness of percutaneous endoscopic lumbar discectomy combined with external lumbar drainage in the treatment of intervertebral infections. Front Surg. 2022;9:975681.
24. Ito M, Abumi K, Kotani Y, Kadoya K, Minami A. Clinical outcome of posterolateral endoscopic surgery for pyogenic spondylodiscitis: results of 15 patients with serious comorbid conditions. Spine. 2007;32(2):200–6. https://doi.org/10.1097/01.brs.0000251645.58076.96.
25. Kang T, Park SY, Lee SH, Park JH, Suh SW. Spinal epidural abscess successfully treated with biportal endoscopic spinal surgery. Medicine. 2019;98(50):e18231.
26. Kono M, Koda M, Abe T, Miura K, Nagashima K, Fujii K, et al. Percutaneous endoscopic discectomy might be effective in selected cases of pyogenic spondylitis. J Orthop Surg. 2019;27(3):2309499019885446.
27. Lai PJ, Wang SF, Tsai TT, Li YD, Chiu PY, Hsieh MK, et al. Percutaneous endoscopic interbody debridement and fusion for pyogenic lumbar spondylodiskitis: surgical technique and the comparison with percutaneous endoscopic drainage and debridement. Neurospine. 2021;18(4):891–902.
28. Liang PZ, Chen XD, Zhao HB, Li QX, Shu G, Zhai MY. Application of percutaneous endoscopy in the treatment of lumbar intervertebral disc infection. World Latest Med Inf. 2016;16(92):190–3.
29. Lin CY, Chang CC, Chen YJ, Tsai CH, Tsou HK, Lin CS, et al. New strategy for minimally invasive endoscopic surgery to treat infectious spondylodiscitis in the thoracolumbar spine. Pain Physician. 2019;22(3):281–93.
30. Lin G-X, Kim J-S, Sharma S, Sun L-W, Hsuan-Han Wu, Chang K-S, Chen Y-C, Chen C-M. Full endoscopic discectomy, debridement, and drainage for high-risk patients with spondylodiscitis. World Neurosurg. 2019;127:e202–11. https://doi.org/10.1016/j.wneu.2019.02.206.
31. Lin IH, Lin CY, Chang CC, Chen YJ, Hsiao PH, Tsou HK, et al. Percutaneous endoscopic surgery alone to treat severe infectious spondylodiscitis in the thoracolumbar spine: a reparative mechanism of spontaneous spinal arthrodesis. Pain Physician. 2022;25(2):E299-299E308.
32. Liu FY, Luo HM, Shi XZ, Zhang C. Treatment of 14 cases of postoperative epidural effusion complicated with infection in thoracic and lumbar spinal surgery with debridement under intervertebral foramen microscopy and self made double lumen drainage tube irrigation. Chin J Bone Joint Injury. 2023;38(7):747–9.
33. Pawar A, Manwani C, Thete R, Bapat M, Peshettiwar V, Gore S. Endoscopic decompression can be effective for diagnosing and treating tubercular spondylodiskitis with early epidural spinal compression: a retrospective study of 18 cases. Asian Spine J. 2018;12(5):803–9.
34. Qiu P. Percutaneous spinal endoscopic debridement and drainage for continuous local chemotherapy in the treatment of spinal tuberculosis (Master's thesis). Nanchang University. 2019.
35. Tang W, Meng L, Han J, Yin X, Feng Z. Effects of percutaneous endoscopic debridement, lavage and drainage intervention on postoperative infection and recovery of patients with pyogenic spondylitis. Int J Clin Exp Med. 2020;13(12):9769.
36. Wang X, Zhou S, Bian Z, Li M, Jiang W, Hou C, et al. Unilateral percutaneous endoscopic debridement and drainage for lumbar infectious spondylitis. J Orthop Surg Res. 2018;13(1):306.
37. Wang YC, Wong CB, Wang IC, Fu TS, Chen LH, Chen WJ. Exposure of prebiopsy antibiotics influence bacteriological diagnosis and clinical outcomes in patients with infectious spondylitis. Medicine. 2016;95(15):e3343.
38. Wu D, Sun J, Fan W, Yuan F. Unilateral or bilateral percutaneous endoscopic debridement and lavage treatment for lumbar spinal tuberculosis. World Neurosurg. 2020;140:e73-73e80.
39. Zhongyang Xu, Zheng Y. Percutaneous endoscopic debridement and irrigation for thoracic infections. Rev Assoc Med Bras. 2018;64(6):518–24. https://doi.org/10.1590/1806-9282.64.06.518.
40. Yamada K, Takahata M, Nagahama K, Iwata A, Endo T, Fujita R, et al. Posterolateral full-endoscopic debridement and irrigation is effective in treating thoraco-lumbar pyogenic spondylodiscitis, except in cases with large abscess cavities. Eur Spine J. 2023;32(3):859–66.
41. Yang S-C, Fu T-S, Chen L-H, Chen W-J, Tu Y-K. Identifying pathogens of spondylodiscitis: percutaneous endoscopy or CT-guided biopsy. Clin Orthop Relat Res. 2008;466(12):3086.
42. Yang SC, Fu TS, Chen HS, Kao YH, Yu SW, Tu YK. Minimally invasive endoscopic treatment for lumbar infectious spondylitis: a retrospective study in a tertiary referral center. BMC Musculoskelet Disord. 2014;15:105.
43. Yang Y, Wang J, Chang Z. The percutaneous endoscopic lumbar debridement and irrigation drainage technique for the first-stage treatment of spontaneous lumbar spondylodiscitis: a clinical retrospective study. Oxid Med Cell Longev. 2022;2022:6241818.
44. Yang Y, Li J, Chang Z. A comprehensive clinical analysis of the use of percutaneous endoscopic debridement for the treatment of early lumbar epidural abscesses. Front Surg. 2023;10:1215240.
45. Yu CH. Full-endoscopic debridement and drainage treating spine infection and psoas muscle abscess. J Spine Surg. 2020;6(2):415–23.
46. Zhang X, Wang K, Xia Y, Gao X, Du Y, Chen L. Treatment of lavage drainage under spinal endoscopy on lumbar spinal tuberculosis with vertebral lesions. Eur J Inflamm. 2020;18:1–8.
47. Zheng JW. Clinical outcomes of percutaneous transforaminal endoscopic debridement followed by continuous irrigation and drainage for lumbar spondylodiscitis were analyzed (Master's thesis). Dalian Medical University. 2021.
48. Zheng Q, Ying X, Jin Y, Zhu B, Shen J, Wang Y, et al. Treatment of single-segment suppurative spondylitis with the transforaminal endoscopic focal cleaning and drainage. J Spinal Cord Med. 2021;44(2):267–75.
49. Zhuang JW. Clinical efficacy of unilateral biportal spinal endoscopy in the management of spinal epidural abscess (Master's thesis). Zhengzhou University. 2022.
50. Park DY, Upfill-Brown A, Curtin N, Hamad CD, Shah A, Kwon B, et al. Clinical outcomes and complications after biportal endoscopic spine surgery: a comprehensive systematic review and meta-analysis of 3673 cases. Eur Spine J. 2023;32(8):2637–46.
51. Li X, Han Y, Di Z, Cui J, Pan J, Yang M, et al. Percutaneous endoscopic lumbar discectomy for lumbar disc herniation. J Clin Neurosci. 2016;33:19–27.
52. Kim J, Oh SH, Kim SW, Kim TH. The epidemiology of concurrent infection in patients with pyogenic spine infection and its association with early mortality: a nationwide cohort study based on 10,695 patients. J Infect Public Health. 2023;16(6):981–8.
53. Park KH, Cho OH, Lee YM, Moon C, Park SY, Moon SM, et al. Therapeutic outcomes of hematogenous vertebral osteomyelitis with instrumented surgery. Clin Infect Dis. 2015;60(9):1330–8.
54. Zhang G, Zhang H, Hu X, Xu D, Tang B, Tang M, et al. Clinical application value of metagenomic next-generation sequencing in the diagnosis of spinal infections and its impact on clinical outcomes. Front Cell Infect Microbiol. 2023;13:1076525.

55. Srinivasan D, Terman SW, Himedan M, Dugo D, La Marca F, Park P. Risk factors for the development of deformity in patients with spinal infection. Neurosurg Focus. 2014;37(2):E2.
56. Di Martino A, Papapietro N, Lanotte A, Russo F, Vadalà G, Denaro V. Spondylodiscitis: standards of current treatment. Curr Med Res Opin. 2012;28(5):689–99.
57. Wu XB, Fan GX, Gu X, Shen TG, Guan XF, Hu AN, et al. Learning curves of percutaneous endoscopic lumbar discectomy in transforaminal approach at the L4/5 and L5/S1 levels: a comparative study. J Zhejiang Univ Sci B. 2016;17(7):553–60.

Publisher's Note