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Efficacy of Additional Surgical Decompression on Functional Outcome in Pyogenic Spinal Epidural Abscess With No Neurological Deficit

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ABSTRACT

Objective: The aim of this study was to investigate the efficacy of additional surgical decompression with antibiotics to treat pyogenic spinal epidural abscess (SEA) with no neurological deficits.
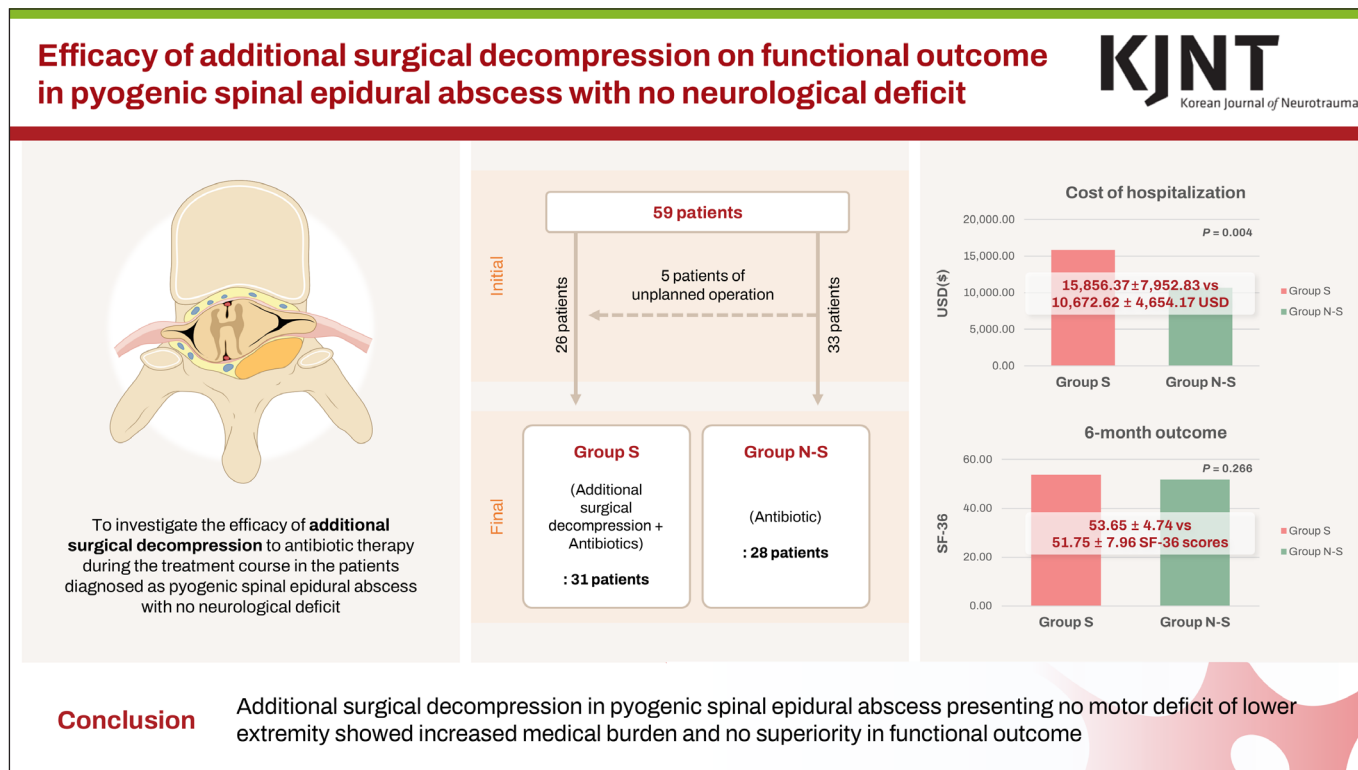**Methods:** We retrospectively reviewed the data of patients diagnosed with spontaneous pyogenic SEA in the thoracolumbosacral area who presented with sciatica and no motor deficits in the lower extremities. The treatment took place in a single tertiary hospital. The effects of additional surgical decompression (decompressive laminectomy) and other clinical variables on functional outcome were assessed using the short form 36 (SF-36).
Results: Fifty-nine patients (49 men and 10 women, mean age 65.73±12.29 [41–89] years) were included in the analysis. Surgical decompression had been performed in 31 patients (Group S, treated with additional surgical decompression and antibiotics). There were five (15.2%, 5/33) unplanned operations to control leg sciatica among the patients with initially non-surgical plans, and 28 patients were finally treated with only antibiotics (group N-S). Group S showed a statistically significant increased cost of hospitalization compared to group N-S (15,856.37±7,952.83 vs. 10,672.62±4,654.17 US dollars, p=0.004) with no superiority of 6-month functional outcome after the completion of antibiotic treatment (53.65±4.74 vs. 51.75±7.96 SF-36 scores, p=0.266).
Conclusion: Although there is a possibility of requiring an unplanned operation to control leg sciatica during conservative antibiotic treatment, overall, additional surgical decompression in pyogenic SEA presenting with no motor deficit of the lower extremity showed increased medical burden and no greater benefit in terms of functional outcomes.

Keywords: Epidural abscess; Paralysis; Surgery; Economics; Prognosis

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GRAPHICAL ABSTRACT

Efficacy of additional surgical decompression on functional outcome in pyogenic spinal epidural abscess with no neurological deficit

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To investigate the efficacy of **additional surgical decompression** to antibiotic therapy during the treatment course in the patients diagnosed as pyogenic spinal epidural abscess with no neurological deficit

Initial

59 patients

26 patients — 5 patients of unplanned operation — 33 patients

Final

Group S
(Additional surgical decompression + Antibiotics)
: 31 patients

Group N-S
(Antibiotic)
: 28 patients

Cost of hospitalization
$P = 0.004$
15,856.37 ± 7,952.83 vs 10,672.62 ± 4,654.17 USD
■ Group S ■ Group N-S

6-month outcome
$P = 0.266$
53.65 ± 4.74 vs 51.75 ± 7.96 SF-36 scores
■ Group S ■ Group N-S

Conclusion
Additional surgical decompression in pyogenic spinal epidural abscess presenting no motor deficit of lower extremity showed increased medical burden and no superiority in functional outcome

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Conflict of Interest
The authors have no financial conflicts of interest.

Informed Consent
Not applicable.

Ethics Approval
All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study was approved by the Institutional Review Board of Yeungnam University Medical Center (2020-06-091), which waved the requirement for informed consent due to its retrospective design.

INTRODUCTION

The prevalence of pyogenic spine infection (PSI), the most frequent form of spinal infection, has been rising due to the factors such as an aging population with degenerative spinal disorders, chronic immunosuppressive conditions, increased spine-related interventions, and advances in diagnostic techniques. In the United States, the annual rate of hospital admissions for PSI increased from 2.9 to 5.4 per 100,000 people between 1998 and 2013. Among various PSIs, spinal epidural abscess (SEA) is particularly serious, as it involves the epidural space and poses significant risks to life. Current global mortality rates for SEA range from 5% to 16%, and fewer than half of those who survive fully regain their pre-infection function.[42] Although SEA is relatively rare, its incidence has almost doubled over the past five decades. This increase may be attributed to aging populations with degenerative spine conditions, spinal procedures such as epidural injections, nerve root blocks, discography, and spinal surgery, as well as growing intravenous drug use. The widespread adoption of magnetic resonance (MR) imaging, which enhances diagnostic sensitivity, has also contributed to increased detection rates.[1,17,33,38,43,45]

There remains considerable uncertainty regarding the optimal antibiotic regimen for PSI, including the duration and route of administration. Typically, patients receive prolonged intravenous antibiotic therapy followed by oral antibiotics for maintenance.[9,10,20,28,29,48] When an epidural abscess is confirmed as part of PSI, the treatment approach depends on the presence or absence of acute or progressive neurological symptoms.[5] In cases where neurological deficits are evident, emergency surgical decompression is generally

undisputed.[5] However, debate persists regarding the best initial strategy for patients without neurological impairments, even when MR imaging shows epidural abscess and spinal cord compression.[51] A recent systematic review noted a growing trend since 1999 toward non-surgical management for neurologically intact patients, favoring several weeks of intravenous antibiotics alongside close monitoring of neurological status. Nevertheless, treatment practices remain inconsistent across medical centers.[5]

Despite the growing prevalence of SEA, data on the medical burden and functional outcomes associated with surgical treatment are insufficient. Furthermore, as previously mentioned, there is no universally accepted treatment guideline. In this study, we aimed to assess the effectiveness of surgical decompression and explore clinical and demographic factors influencing the medical burden and functional outcomes in patients diagnosed with spontaneous PSI with epidural abscess, specifically those presenting without motor deficits in the lower extremities.

MATERIALS AND METHODS

Patients and clinical data
This retrospective study involved the 156 patients diagnosed with spontaneous pyogenic SEA on the thoraco-lumbo-sacral who presenting sciatica with no motor deficit of lower extremity during the treatment course in a single tertiary hospital from March 2015 to December 2021. Patients were excluded if they had any of the following: neurological deficit with leg weakness or bowel/bladder symptoms (present at initial diagnosis or newly development during the treatment), additional fixation surgery due to spinal instability, accompanying bone infection at another site, tuberculous spondylitis, trauma, tumors, follow-up period of shorter than six months, data loss, or age <19 years. Under the approval of the Institutional Review Board, clinical and radiological data were obtained and reviewed retrospectively from electronic charts.

Diagnosis of pyogenic SEA
The diagnosis of pyogenic SEA was established based on a combination of clinical symptoms, radiological findings, and laboratory test results. The clinical manifestations included localized back pain, with or without accompanying radiating pain and/or fever. Diagnostic indicators also involved elevated erythrocyte sedimentation rate (ESR, normal range: <20 mm/h) or C-reactive protein (CRP, normal range: <0.5 mg/dL) or both with characteristic findings on MR imaging. On MR imaging, pyogenic SEA lesions often presented alongside vertebral osteomyelitis, discitis, septic arthritis of the facet joints, and abscesses in adjacent structures, including the paraspinal region, psoas muscle, or erector spinae muscles. These specific features were systematically analyzed. The extent of pyogenic SEA was defined as a count of vertebral bodies involving the spondylodiscitis and/or extent of epidural abscess. For example, a case involving spondylodiscitis from L3 to L5, with an epidural abscess spreading from L1 to S1, which were defined as having three primary levels of spondylodiscitis and six total levels of epidural abscess involvement.

Causative bacteria and antibiotic therapy
In patients with diagnosis of pyogenic SEA, microbiological identification was attempted using at least two sets of blood cultures or tissue samples obtained from the abscess site through computed tomography-guided needle biopsy or open surgical biopsy. Cases with relevant clinical symptoms and radiological findings without confirmed causative bacteria

were categorized as culture-negative SEA, while those with identified pathogens were classified as culture-positive SEA. The selection of intravenous antibiotics was based on the clinical evaluation and guided by according to recommendations from infectious disease specialists. Following the completion of intravenous antibiotic therapy, all patients were monitored for at least six months to assess treatment outcomes.

Cure and recurrence
All patients received medication for sciatica based on appropriate antibiotic treatment, and in some cases, surgical decompression was added as part of the treatment plan. Cure was considered if fever subsided, clinical symptoms improved, and CRP levels remained normalized over a minimum of four weeks following intravenous antibiotic treatment. Recurrence was defined as the reappearance of clinical issues, including CRP elevation, newly developed or worsening SEA lesions on MR imaging, or aggravated back pain, with or without fever.[39]

Evaluation of medical burden
Medical burden was evaluated based on the duration and financial cost of hospitalization. Hospital costs included expenses related to medications, injections, consultations, nursing care, medical procedures, diagnostic tests (laboratory and radiological), and room charges. These costs accounted for the management of medical complications arising from SEA treatment and care for pre-existing conditions during the hospital stay.

Functional outcome in pyogenic SEA
Functional outcome was assessed using the Short Form 36 (SF-36) questionnaire. SF-36 measures health-related quality of life, which consists of 36 questions, generating scores from 0 to 100, with higher scores indicating better quality of life. A low back-specific version of the SF-36 is commonly used to describe the status of chronic low back pain,[18] and is also used for measuring morbidity, and surgical outcomes.[22] SF-36 evaluations were conducted both at the time of initial diagnosis (initial SF-36) and six months after the cessation of intravenous antibiotic therapy (6-month SF-36). We analyzed the clinical and demographic factors including additional surgical decompression (decompressive laminectomy and debridement without fixation) associated with functional outcome.

Statistical analysis
The data distribution was checked for normality using the Kolmogorov-Smirnov test. Depending on the type of continuous variables, comparisons were made using either Student's t-test for parametric data or the Mann-Whitney U test for non-parametric data. For categorical variables, the χ^2 test was used to assess relationships between the variables. To identify factors influencing binary outcomes, both univariate and multivariate logistic regression analyses were conducted to estimate odds ratios (ORs) with 95% confidence intervals. Statistical analyses were conducted using SPSS software (version 27.0;IBM Corp., Armonk, NY, USA), and a p-value <0.05 was considered statistically significant.

RESULTS

Clinical data
Among the 156 patients diagnosed as PSI, 97 patients were excluded due to no epidural abscess (n=48), leg weakness (n=32), bowel and/or bladder symptoms (n=2), death (n=3),

incomplete antibiotic therapy (n=3), data loss (n=6), follow-up loss (n=2), and additional fixation surgery due to spinal instability (n=1). The final analyses were performed on the data from 59 patients (49 men and 10 women) confirmed as pyogenic SEA with a mean age of 65.73±12.29 [41–89] years. Diabetes mellitus was the most common underlying disease (23.7%, 14/59). All of patients accompanied with back pain as a main symptom, and followed by leg sciatica (62.7%, 37/59) and fever (18.6%, 11/59). The severity of comorbidity was presented using the Charlson comorbidity index (CCI) with 2.69±1.48 [0–6]. In the features of MR imaging, 2.37±0.61 [2–5] levels of the main extent of PSI lesions, 3.68±1.69 [2–10] levels of the total extent of PSI lesions, 27.1% (16/59) of psoas abscess, and 35.6% (21/59) of back muscle abscess were noted. The indices of the initial (at the time of diagnosis) blood inflammatory markers including white blood cells (WBC), ESR, and CRP were 9,879.32±4,709.55 [5,120–28,790], 72.24±32.70 [2–120], and 8.33±9.08 [0.03–37.99], respectively. The final blood inflammatory marker indices at the time of discontinuing parenteral antibiotics were recovered for WBC, ESR, and CRP as 5,390.17±1,502.73 [2,340–11,610], 36.90±24.36 [6–103], and 0.55±0.72 [0.02–3.38].

Surgical decompression was performed in 52.5% (31/59) of the patients on 3.55±4.62 [0–20] days after starting antibiotic therapy. There were five (15.2%, 5/33) unplanned operations to control leg sciatica among the patients with initially non-surgical plan on 12.80±4.44 [8–20] days after starting antibiotic therapy, and 28 patients were finally treated with only antibiotics (group N-S). The length and cost of hospitalization as medical burdens were 54.00±25.49 [20–172] days and 13,396.28±7,043.72 [3,636.10–41,549.00] US dollars (mean exchange rate from March 2015 to December 2021; 1 US dollar ($)=1,146.44 Korea Won) during the treatment of pyogenic SEA. In functional disabilities, there was a significant improvement of SF-36 score from 40.47±8.94 [13–57] at initial diagnosis to 52.75±6.48 [27–60] at 6-month after the completion of the treatment (p<0.001). All patients were followed up for the minimum of 6-months, and the mean follow-up period was 17.47±13.93 [6–67] months. There were recurrences in 6.8% (4/59).

The detailed data are presented in **TABLE 1**.

Microbiologic findings

The causative bacteria were identified in 23.0% (23/59) of the pyogenic SEA lesion and/or blood culture. *Staphylococcus aureus* was the most common causative bacteria (20.3%, 12/59). Bacteremia was accompanied in 15.3% (9/59) of the patients. The mean duration of susceptible parenteral antibiotics for pyogenic SEA was 46.05±18.27 [21–140] days. The detailed data are presented in **TABLE 2**.

Comparison of clinical features depending on surgical decompression

We analyzed the differences in the clinical factors depending on performing surgical decompression (31 of group S with surgical decompression and antibiotic treatment; 28 of group N-S with only antibiotic treatment). The group S showed higher cost of hospitalization (15,856.37±7,952.83 vs. 10,672.62±4,654.17 US dollars, p=0.004) with statistically significances compared to group N-S. However, there were no statistically significant differences in age, sex, CCI, fever, sciatica, initial blood inflammatory markers, positive culture of causative bacteria, bacteremia, radiological features of MR imaging, duration of antibiotics, length of hospitalization, functional outcomes, and recurrence between the two groups. The detailed data are presented in **TABLE 3**.

TABLE 1. Clinical data

Factors	Values (%)
Age (years)	65.73±12.29 [41–89]
Sex, male : female	49:10 (83.1:16.9)
Underlying diseases	
Diabetes mellitus	14 (23.7)
Rheumatic disease	4 (6.8)
Liver disease	1 (1.7)
Chronic kidney disease	0 (0)
Clinical symptoms	
Fever, ≥37.3°C	11 (18.6)
Back pain	59 (100)
Sciatica	37 (62.7)
CCI	2.69±1.48 [0–6]
Features of MR imaging	
Extent of lesion (main), level	2.37±0.61 [2–5]
Extent of lesion (total), level	3.68±1.69 [2–10]
Psoas abscess	16 (27.1)
Back muscle abscess	21 (35.6)
Initial WBC (count)	9,879.32±4,709.55 [5,120–28,790]
Initial ESR (mm/h)	72.24±32.70 [2–120]
Initial CRP (mg/dL)	8.33±9.08 [0.03–37.99]
Last WBC (count)	5,390.17±1,502.73 [2,340–11,610]
Last ESR (mm/h)	36.90±24.36 [6–103]
Last CRP (mg/dL)	0.55±0.72 [0.02–3.38]
Additional surgical decompression*	31 (52.5)
Timing of surgical decompression (days)†	3.55±4.62 [0–20]
Unplanned surgical decompression‡	5 (15.2)
Timing of unplanned surgical decompression (days)†	12.80±4.44 [8–20]
Length of hospitalization (days)	54.00±25.49 [20–172]
Cost of hospitalization ($)	13,396.28±7,043.72 [3,636.10–41,549.00]
Initial SF-36	40.47±8.94 [13–57]
6-month SF-36	52.75±6.48 [27–60]
Δ SF-36	12.27±5.83 [3–35]
Initial SF-36, favorable : unfavorable	47 : 12 (79.7:20.3)
6-month SF-36, favorable : unfavorable	45 : 14 (76.3:23.7)
Follow up period (after completion of antibiotic therapy) (months)	17.47±13.93 [6–67]
Recurrence	4 (6.8)

CCI: Charlson comorbidity index, MR: magnetic resonance, Initial: at diagnosis, Last: at completion of antibiotic therapy, 6-month: 6 months after completion of antibiotic therapy, WBC: white blood cell, ESR: erythrocyte sedimentation ratio (normal range <20 mm/h), CRP: C-reactive protein (normal range <0.5 mg/dL), $: US dollar (mean exchange rate from March 2015 to December 2021; 1 US dollar=1,146.44 Korea Won), SF-36: short form 36, Δ SF-36: changes of SF-36, Favorable SF-36: above average of SF-36, Unfavorable SF-36: below average of SF-36. *Decompressive laminectomy and debridement with no fixation; †After starting antibiotic therapy; ‡Surgical decompression to control leg sciatica in the 33 patients with initially non-surgical plan.

Comparison of clinical factors associated with functional outcomes

Clinical factors associated with favorable and unfavorable (above and below average, respectively) SF-36s were analyzed at the initial diagnosis and 6-month after discontinuing of antibiotic therapy. In the initial SF-36, there were 47 of favorable and 12 of unfavorable outcomes (43.96±5.12 vs. 26.83±7.58 SF-36 scores, $p<0.001$). Increased initial CCI ($p=0.033$) and positive culture of causative bacteria ($p=0.007$) were related to unfavorable outcome with statistically significances. In the 6-month SF-36, there were 45 of favorable and 14 of unfavorable outcomes (55.38±3.24 vs. 44.43±7.13 SF-36 scores, $p<0.001$). There were no statistically significant clinical factors related to favorable and unfavorable 6-month SF-36. However, the initial SF-36 showed statistically significant difference between favorable and unfavorable outcomes (43.58±6.12 vs. 30.50±9.47 SF-36 scores, $p<0.001$). The detailed data are presented in **TABLE 4**.

TABLE 2. Microbiologic findings

Causative pathogens	Values (%)
Culture-positive	23 (39.0)
Gram-positive bacteria	
Staphylococcus aureus	12 (20.3)
Methicillin-sensitive	10
Methicillin-resistant	2
Coagulase-negative staphylococci	2 (3.4)
Streptococcus species	3 (5.1)
Gram-negative bacteria	
Acinetobacter	1 (1.7)
Achrombacter	1 (1.7)
Klebsiella	2 (3.4)
Escherichia coli	1 (3.4)
Pseudomonas	1 (1.7)
Culture-negative	36 (61.0)
Bacteremia	9 (15.3)
Duration of parenteral antibiotics (days)	46.05±18.27 [21–140]

TABLE 3. Comparison of clinical features according to additional surgical decompression

Factors	Group S	Group N-S	p-value
Total	31 (52.5)	28 (47.5)	
Age (years)	62.97±10.35	68.79±13.67	0.074
Sex, female	6 (19.4)	4 (14.3)	0.734
CCI	2.35±1.31	3.07±1.59	0.062
Fever, ›37.3°C	7 (22.6)	4 (14.3)	0.414
Sciatica	22 (71.0)	15 (53.6)	0.168
Initial WBC	10,415.55±4,740.60	9,285.71±4,688.27	0.362
Initial ESR	73.23±35.34	71.14±30.12	0.809
Initial CRP	9.86±9.42	6.64±8.55	0.176
Positive culture of causative bacteria	13 (41.9)	10 (35.7)	0.625
Bacteremia	6 (19.4)	3 (10.7)	0.477
Extent of lesion (main), level	2.32±0.54	2.43±0.69	0.512
Extent of lesion (total), level	3.81±1.96	3.54±1.35	0.543
Psoas abscess	6 (19.4)	10 (35.7)	0.158
Back abscess	10 (32.3)	11 (39.3)	0.573
Duration of parenteral antibiotics (days)	49.16±22.75	42.61±10.89	0.159
Length of hospitalization (days)	59.61±32.42	47.79±12.32	0.067
Cost of hospitalization ($)	15,856.37±7,952.83	10,672.62±4,654.17	0.004**
Initial SF-36	40.81±8.29	40.11±9.75	0.767
6-month SF-36	53.65±4.74	51.75±7.96	0.266
Δ SF-36	12.84±6.32	12.11±6.74	0.436
Favorable initial SF-36	26 (83.9)	21 (75.0)	0.398
Favorable 6-month SF-36	24 (77.4)	21 (75.0)	1.000
Recurrence	3 (9.7)	1 (3.6)	0.614

Values are presented as number (%) or mean ± standard deviation.
Group S: patients with surgical decompression and antibiotic treatment, Group N-S: patients with only antibiotic treatment, CCI: Charlson comorbidity index, Initial: at diagnosis, 6-month: 6 months after completion of antibiotic therapy, WBC: white blood cell, ESR: erythrocyte sedimentation ratio (normal range ‹20 mm/h), CRP: C-reactive protein (normal range ‹0.5 mg/dL), SF-36: short form 36, Δ SF-36: changes of SF-36, Favorable SF-36: above average of SF-36.
**p‹0.01.

Analysis of clinical factors associated with unfavorable functional outcomes
Multivariable logistic regression analyses were performed with the clinical factors with p‹0.10 in univariable logistic regression analyses. Finally, positive culture of causative bacteria (OR=6.235, p=0.038) and initial SF-36 (OR=0.767, p=0.001) were statistically significant factors associated with initial and 6-month unfavorable SF-36s. However, there was no statistical significance of surgical treatment in unfavorable 6-month SF-36. The detailed data are presented in **TABLE 5**.

TABLE 4. Clinical factors associated with functional outcomes

Factors	Initial SF-36			6-month SF-36		
	Favorable (n=47)	Unfavorable (n=12)	*p*-value	Favorable (n=45)	Unfavorable (n=14)	*p*-value
Age (years)	64.64±11.96	70.00±13.14	0.180	65.51±11.82	66.43±14.14	0.810
Sex, female	8 (17.0)	2 (16.7)	1.000	8 (17.8)	2 (14.3)	1.000
CCI	2.49±1.44	3.50±1.38	0.033*	2.58±1.41	3.07±1.69	0.279
Fever, >37.3°C	9 (19.1)	2 (16.7)	1.000	8 (17.8)	3 (21.4)	1.000
Leg sciatica	31 (66.0)	6 (50.0)	0.308	28 (62.2)	9 (64.3)	0.889
Initial WBC	9,008.94±3,335.28	13,288.33±7,383.41	0.074	9,124.22±3,433.39	12,306.43±7,123.30	0.127
Initial ESR (mm/h)	74.32±33.12	64.08±30.97	0.337	72.58±35.28	71.14±23.57	0.862
Initial CRP (mg/dL)	7.27±8.35	12.45±10.95	0.078	7.25±8.32	11.79±10.81	0.103
Positive culture of causative bacteria	14 (29.8)	9 (75.0)	0.007**	16 (35.6)	7 (50.0)	0.333
Bacteremia	6 (12.8)	3 (25.0)	0.369	7 (15.6)	2 (14.3)	1.000
Additional surgical decompression	-	-	-	24 (53.3)	7 (50.0)	0.827
Extent of lesion (main), level	2.32±0.59	2.58±0.67	0.185	2.33±0.60	2.50±0.65	0.404
Extent of lesion (total), level	3.51±1.43	4.33±2.43	0.133	3.76±1.82	3.43±1.16	0.433
Psoas abscess	12 (25.5)	4 (33.3)	0.718	11 (24.4)	5 (35.7)	0.495
Back muscle abscess	15 (31.9)	6 (50.0)	0.315	14 (31.1)	7 (50.0)	0.197
Initial SF-36	43.96±5.12	26.83±7.58*	<0.001***	43.58±6.12	30.50±9.47	<0.001***
6-month SF-36	-	-	-	55.38±3.24	44.29±7.13	<0.001***

Values are presented as number (%) or mean ± standard deviation.
CCI: Charlson comorbidity index, Initial: at diagnosis, 6-month: 6 months after completion of antibiotic therapy, WBC: white blood cell, ESR: erythrocyte sedimentation ratio (normal range <20 mm/h), CRP: C-reactive protein (normal range <0.5 mg/dL), SF-36: short form 36, Favorable SF-36: above average of SF-36, Unfavorable SF-36: below average of SF-36.
*$p<0.05$; **$p<0.01$; ***$p<0.001$.

TABLE 5. Logistic regression analysis of clinical factors associated with unfavorable functional outcomes

Factors	Unfavorable initial SF-36						Unfavorable 6-month SF-36					
	Univariable analysis			Multivariable analysis			Univariable analysis			Multivariable analysis		
	OR	95% CI	*p*-value	OR	95% CI	*p*-value	OR	95% CI	*p*-value	OR	95% CI	*p*-value
Age (years)	1.040	0.982–1.101	0.182				1.006	0.958–1.057	0.806			
Sex, female	0.975	0.178–5.327	0.977				0.771	0.114–4.139	0.761			
CCI	1.631	1.019–2.612	0.042*	1.735	0.987–3.049	0.055	1.259	0.832–1.904	0.276			
Fever, >37.3°C	0.844	0.157–4.545	0.844				1.261	0.285–5.585	0.760			
Leg sciatica	0.516	0.143–1.861	0.312				1.093	0.314–3.808	0.889			
Initial WBC	1.188	1.034–1.365	0.015*	1.231	0.983–1.543	0.071	1.140	1.004–1.294	0.043*	1.030	0.884–1.200	0.704
Initial ESR (mm/h)	0.990	0.971–1.010	0.333				0.999	0.980–1.017	0.885			
Initial CRP (mg/dL)	1.059	0.991–1.131	0.088	0.932	0.827–1.050	0.245	1.053	0.988–1.121	0.111			
Positive culture of causative bacteria	7.071	1.661–30.101	0.008**	6.352	1.156–34.919	0.033*	1.812	0.539–6.093	0.336			
Bacteremia	2.278	0.477–10.866	0.302				0.905	0.165–4.954	0.908			
Additional surgical decompression	-	-	-				0.875	0.263–2.906	0.827			
Extent of lesion (main), level	1.862	0.722–4.805	0.198				1.509	0.603–3.777	0.379			
Extent of lesion (total), level	1.301	0.914–1.851	0.144				0.880	0.593–1.305	0.525			
Psoas abscess	1.458	0.371–5.725	0.589				1.717	0.474–6.222	0.410			
Back muscle abscess	2.133	0.589–7.728	0.249				2.214	0.652–7.523	0.203			
Initial SF-36	-	-	-				0.774	0.667–0.899	<0.001***	0.780	0.669–0.908	0.001**

SF-36: short form 36, Unfavorable SF-36: below average of SF-36, Initial: at diagnosis, 6-month: 6 months after completion of antibiotic therapy, OR: odds ratio, CI: confidence interval, CCI: Charlson comorbidity index, WBC: white blood cell, ESR: erythrocyte sedimentation ratio (normal range <20 mm/h), CRP: C-reactive protein (normal range <0.5 mg/dL).
*$p<0.05$; **$p<0.01$; ***$p<0.001$.

DISCUSSION

The introduction of antibiotics in the 1940s significantly reduced the mortality rate associated with SEA.[21,25] However, despite advances in antibiotic regimens, the core principles of treatment have remained largely unchanged since then.[21] In 1999, Rigamonti et al.[43] conducted the first large-scale cohort studies comparing surgical and non-surgical management of SEA. Since that time, many institutional reports have been published, reflecting ongoing debate over the optimal approach to treatment.[2,7,11,13,14,30,32,40,43,45,47,50]

The majority of published reports have tended to that any patient presenting with acute neurological deficits is best managed with urgent surgery, usually by the means of laminectomy combined with intravenous antibiotics.[2,13,32,46,47,49,54] Nevertheless, the published previous studies include relatively small patients' cohort under retrospective design, there is still no definite conclusive conclusion in the treatment strategy for SEA. Additionally, since the turn of the century there has been substantial interest in avoiding major surgery in the patients with SEA who either present with minor symptoms, or alternatively are older and frailer.[21] With earlier detection through MR imaging and the use of image-guided aspiration or drainage to obtain reliable culture samples, targeted antibiotic therapy has become a feasible option. For carefully selected patients, especially those without neurological impairments, non-operative treatment can be an option with active monitoring by a spinal surgical team may be a viable alternative.[21]

Nevertheless, the current clinical literature indicates that only a small percentage of patients with SEA receive non-surgical treatment. The prevailing consensus, drawn from numerous retrospective studies, favors surgical drainage combined with systemic antibiotic therapy as the preferred treatment strategy.[6,14-16,25,26,37,38,41,43,54] Due to the unpredictable nature of neurological deterioration, decompressive laminectomy and removal of infected tissues are typically performed without delay to prevent further complications.[4,16,19,23,37] Although a few retrospective studies have reported comparable outcomes between surgical and non-surgical treatment,[17,24,30,53] it has been unclear whether non-surgical treatment is effective due to the selection bias in the participants, prevalence of surgical treatment for various reasons mentioned above, and the possibility of selective publication.[24,53] In this study, to eliminate the risk of bias, we analyzed the effect of additional surgical decompression to conservative antibiotic treatment for pyogenic SEA in the patients with no leg weakness at the time of diagnosis and during the treatment course. Considering that there are no statistically significant differences in the overall preoperative clinical factors, it is assumed that surgeon's preference may mainly influence to the decision of treatment strategy in the patients with no neurological deficits. Our results showed that surgical treatment had a statistically significant increased cost of hospitalization with no superiority in 6-month functional outcome as well as relatively low incidence of failure in non-surgical treatment. In addition, there was a longer length of hospitalization by an average of 12 days in patients who underwent surgical treatment, although this difference was not statistically significant. This result suggests that surgical treatment does not affect treatment and recovery in our patients' cohort. From these data, we think non-surgical management could be considered as a primary or initial treatment option in pyogenic SEA without motor deficit of lower extremity.

The effects of various clinical factors on unfavorable functional outcomes in the patients with pyogenic SEA were analyzed using logistic regression analysis. In multivariable analysis based on the main factors including CCI, initial WBC, initial CRP, and positive culture of causative bacteria selected from univariable analysis, positive culture of causal bacteria (OR=6.235) was the only statistically significant factor affecting the initial SF-36. We think that the initial functional outcome mainly depends on the severity of infectious condition including involved pyogenic SEA lesion. WBC and CRP levels are indicators of an inflammatory response, with higher levels often observed in profound infectious conditions.[36] Notably, previous studies have shown that patients with culture-negative pyogenic PSI tend to exhibit fewer clinical signs of infection and lower inflammatory marker levels, possibly due to small inocula of pathogens.[8,31,36,55] Kim et al.[31] presented that positive culture PSI is more frequently associated with body temperatures of 37.8ºC or higher, elevated initial ESR and CRP levels, and the

presence of paraspinal abscess. In the multivariable analysis of 6-month SF-36 based on initial WBC, initial CRP, and initial SF-36 selected from univariable analysis, initial SF-36 (OR=0.780) was the only statistically significant factor. This means that 6-month functional outcome is absolutely dependent on the initial functional outcome affected by the severity of infective condition at the time of diagnosis. We expect that the medical burden and functional outcome mainly related with the severity of initial infectious status. Therefore, in the treatment of pyogenic SEA with no leg weakness, effective medical treatment with appropriate antibiotics is a most important factor to achieve favorable long-term functional outcome.

A paradigm shift in management approach has emerged, favoring non-surgical treatment with careful monitoring for worsening neurological deficits in patients with SEA presenting back pain and no neurological deficits.[32] However, for the patients who failed to non-surgical treatment due to neurologic compromise or spinal instability, a delayed surgery including decompression and/or fixation surgery is required. In addition to the neural compression with progression of infectious lesion, which may also lead to spinal macro-instability with profound destruction of intervertebral disc, facet joints, and surrounding structures related with stability. While antibiotics play a crucial role in the treatment of PSI, they do not contribute to provide spinal stability.[3,12,27,34,35,44,52] In this study, after excluding one patient who underwent additional fixation surgery due to the instability occurred in pyogenic SEA lesions, we analyzed the pure difference in functional outcome depending on additional decompressive laminectomy surgery in the patients with no leg weakness. Although there is a trend of non-surgical treatment in the patients with no leg weakness, it cannot be ruled out the possibility of merit from early surgical treatment to prevent development of leg weakness and insufficient control of sciatica under the progression of the infectious lesion. There were five cases of unplanned operations to control leg sciatica among the patients with initially non-surgical plan (15.2%, 5/33) on 12.80±4.44 [8–20] days after starting antibiotic therapy, which implies that non-surgical treatment could not be feasible treatment strategy in all patients. However, we need to consider subjective personal nature in pain sensation and no newly developed leg weakness during the non-surgical treatment based on the no statistically significant function outcomes between surgical and non-surgical treatment.

There are several limitations in our study. First, inherent drawbacks are associated with the retrospective study design and relatively small sample size. Unlike prospective studies, our approach carries a risk of selection bias due to non-random participant recruitment, which may affect the generalizability of our results. Furthermore, we recognize the possibility of type 1 errors stemming from multiple comparisons in this retrospective analysis. However, conducting a large-scale randomized controlled trial comparing surgical and non-surgical management of SEA is neither practical nor ethical, given the considerable morbidity and mortality associated with this condition. Second, five patients underwent delayed surgery in the surgical group of this study, for control of sciatica and not development of leg weakness, which can be considered as a treatment failure of non-surgical treatment. Surgical treatment fundamentally blocked the possibility of treatment failure when it underwent non-surgical treatment. This may overlook the risk of treatment failure in non-surgical treatment compared to the advantages and the feasibility as first treatment option of non-surgical treatment emphasized in this study. However, considering the relatively low frequency of treatment failure in non-surgical treatment in this study, the need for early surgery due to concerns about treatment failure of non-surgical treatment cannot be feasible, even in pyogenic SEA without motor deficit of lower extremity. Third, this study focused on pyogenic SEA developed in the thoraco-lumbo-sacral spine, especially most of the lumbar spine.

Therefore, there is a possibility of low reliability and reproducibility in the thoracic spine, and the hypothesis of this paper cannot be applied in the cervical spine due to the exclusion of pyogenic SEA of cervical spine.

CONCLUSION

This study, for the first time, reports the efficacy of additional surgical decompression to antibiotic treatment for pyogenic SEA without motor deficit of lower extremity in views of medical burden and functional outcome. Additional surgical decompression is associated with the increased medical burden and no superiority in 6-month functional outcome compared to conservative antibiotic treatment. We think that effective antibiotic treatment with appropriate antibiotics seems to be a most important factor in the treatment of pyogenic SEA without motor deficit of lower extremity. However, it should also be considered that in certain situations, unplanned surgery may be required to control leg sciatica during conservative treatment.

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