Observational Study

Percutaneous Endoscopic Surgery Alone to Treat Severe Infectious Spondylodiscitis in the Thoracolumbar Spine: A Reparative Mechanism of Spontaneous Spinal Arthrodesis

I-Hao Lin, MD[1], Chia-Yu Lin, MD[1], Chien-Chun Chang, MD, PhD[1-3], Yen-Jen Chen, MD, PhD[1,2,4], Pang-Hsuan Hsiao, MD[1,2], Hsi-Kai Tsou, MD, PhD[5,6], Hui-Yi Chen, MD[7], and Hsien-Te Chen, MD, PhD[1,2,8]

From: [1]Department of Orthopaedic Surgery, China Medical University Hospital, China Medical University, Taiwan (R.O.C.); [2]Spine Center, China Medical University Hospital, China Medical University, Taiwan (R.O.C.); [3]PhD Degree Program of Biomedical Science and Engineering, National Chiao Tung University, Taiwan (R.O.C.); [4]School of Medicine, China Medical University, Taiwan (R.O.C.); [5]Functional Neurosurgery Division, Neurological Institute, Taichung Veterans General Hospital, Taiwan (R.O.C.); [6]Department of Rehabilitation, Jen-Teh Junior College of Medicine, Nursing and Management, Taiwan (R.O.C.); [7]Department of Medical Image, China Medical University Hospital, China Medical University, Taiwan (R.O.C.); and [8]Department of Sport Medicine, College of Health Care, China Medical University, Taiwan (R.O.C.)

Address Correspondence: Hsien-Te Chen, MD, PhD School of Chinese Medicine, College of Chinese Medicine, China Medical University, No. 91 Hsuehshih Road, North District, Taichung 40402, Taiwan, R.O.C. Department of Orthopaedic Surgery, China Medical University Hospital, No. 2 Yuhder Road, North District, Taichung 40447, Taiwan, R.O.C. E-mail: bonekid1@gmail.com

Disclaimer: : I-Hao Lin, MD and Chia-Yu Lin, MD both contributed equally to this work. There was no external funding in the preparation of this manuscript.

Conflict of interest: Each author certifies that he or she, or a

Background: Infective spondylodiscitis has been treated solely with antibiotics based on the pathogen identified. Surgical intervention was used in cases of unidentified pathogens, failed antibiotic treatment, neurological deficit, or instability. The standard surgical procedure was debridement and interbody fusion with a bone graft through the anterior approach, followed by posterior instrumentation. Recently, percutaneous endoscopic surgery has been proven to be safe and effective for treating infectious spondylodiscitis. The results of endoscopy surgery treatment alone for infectious spondylodiscitis with severe bony destruction were analyzed in this study.

Objective: To describe the clinical and radiological outcomes in patients with infectious spondylodiscitis and severe bony destruction, who were treated with minimally invasive endoscopic surgery alone.

Study Design: Retrospective observational study (Institutional Review Board: CMUH 105-REC2-101).

Setting: An inpatient surgery center.

Methods: The study included 24 patients with infectious spondylodiscitis and severe bony destruction treated with endoscopy surgery. The patients were treated according to the endoscopic surgical protocol and were followed up for at least 5 years. A retrospective chart review was conducted to evaluate the locations, symptoms and signs, comorbidity, pain scale, and functional outcome. Laboratory data, such as erythrocyte sedimentation rate and C-reactive protein level, and clinical outcomes, including the pain scale, visual analogue scale, and functional score of Oswestry disability index, were recorded. All patients underwent a preoperative magnetic resonance imaging (MRI) scan and were carefully reviewed and classified based on the severity, including endplate erosion, bone edema (low T1, high T2), loss of vertebral height, paravertebral inflammation, paravertebral abscess, and epidural abscess. All patients underwent a plain film follow-up at 3, 6, 9, 12, and 18 months after surgery and computed tomography at 12 months postoperatively.

Results: The comorbidities of patients were categorized according to the Charlson Comorbidity Index. The results revealed 10 lesions on the thoracic or upper lumbar spine (between T10 and L3) and 14 on the lower lumbar spine (between L3 and S1). Bone destruction as a result of severe infection and loss of disc height was observed in most cases. During the final follow-up, no significant changes were observed in the sagittal alignment, and a kyphotic angle change of less than 10° was observed in 20 cases. Syndesmophyte formation along the anterior longitudinal ligament (ALL), paravertebral syndesmophyte formation, intervertebral bony fusion, and bony ankylosis of the facet joints in the form of osteophyte formation and fusion were noted. No posterior instrumentation surgery was performed for instability in our case series.

Limitations: This was a retrospective observational clinical case series with small sample size.

member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted manuscript.

Manuscript received: 08-17-2021
Revised manuscript received: 10-19-2021
Accepted for publication: 11-09-2021

Free full manuscript: www.painphysicianjournal.com

Conclusions: A trend of spontaneous spinal arthrodesis, including syndesmophyte formation along the ALL, paravertebral ligaments, direct intervertebral bone growth, and bony ankylosis of the facet joint were observed after a minimally invasive endoscopy treatment for infectious spondylodiscitis. The stability of the 3 columns resulted in segmental stability, which prevented the progression of the kyphotic deformity. Percutaneous endoscopic surgery is safe and effective for treating infectious spondylodiscitis even in patients with severe bony destruction.

Key words: Bone destruction, debridement, endoscopic surgery, interbody fusion, minimally invasive, spinal arthrodesis, spondylodiscitis, syndesmophyte

Pain Physician 2022: 25:E299-E308

Infectious spondylodiscitis has been a challenging clinical condition to manage due to the difficulty in diagnosis, identification of the causative pathogen, and controversial treatment guidelines for infection control. Eradicating infection, protecting neurologic function, and maintaining structural alignment are the 3 major treatment objectives for infectious spondylodiscitis. Traditionally, infective spondylodiscitis has been treated solely with antibiotics, based on pathogen identification by computed tomography (CT)-guided biopsy or blood culture. Surgical intervention was used in cases of unproven pathogens, failed antibiotic treatment, neurological deficit, or instability. The standard surgical procedure was debridement and interbody fusion with bone graft through the anterior approach, followed by posterior instrumentation (1,2); however, patients who suffered from infectious spondylodiscitis were relatively older and had more comorbidities, making them unsuitable for major invasive surgeries (3-6). Several considerably minimal invasive surgeries involved debridement and percutaneous pedicle screw fixation (7).

Recently, percutaneous endoscopic surgery has gained popularity due to its minimally invasive nature. In terms of culture rate, recurrence rate, and complications, several studies have found that percutaneous endoscopic surgery is safe and effective for treating infectious spondylodiscitis (8-12); however, evidence of the effectiveness of endoscopic surgery for extensive destruction of the vertebral body due to spinal infections may be limited (12). Surprisingly, all patients showed minimal kyphotic angle change, with a mean change of 2°. Acceptable structural alignment at the level where infection occurred was observed in the follow-up series, even in patients with severe bony destruction and endplate erosion in preoperative magnetic resonance imaging (MRI) (9). A process of spontaneous bone union in the infected segment was observed after surgery, which resulted in segmental stability without further anterior or posterior surgery.

To the best of our knowledge, no studies have described the image changes and findings in a case series after a minimally invasive endoscopic surgery for infectious spondylodiscitis with severe bony destruction. Herein, we aim to present the radiographic findings and analyze the mechanism of spontaneous arthrodesis in the thoracic and lumbar spine, which may result in the re-establishment of spinal stability.

Methods

Patient Selection

Between September 2006 and December 2019, 64 patients underwent endoscopic surgery for infectious spondylodiscitis. The indications of percutaneous endoscopic surgery for infectious spondylodiscitis included tissue sampling for pathogen identification, and irrigation, debridement, drainage for patients for whom medical treatment failed. Conventional surgery was adopted for patients with motor weakness or vertebral body height loss > 50% or kyphotic Cobb angle > 30°.

Inclusion criteria were patients with findings of bony destruction (endplate erosion or loss of vertebral height over a quarter of normal vertebral height) in a preoperative plain film. Exclusion criteria were patients with cervical lesions, loss of follow-up within 3 months, patients with implant retention, and patients with incomplete image data (preoperative MRI and postoperative CT). Finally, 24 patients [12 men and 12 women; mean age: 61 years (range: 39–77 years)] were included in this study. All patients were treated according to the

endoscopic surgical protocol and were followed up for at least 5 years.

Treatment Protocol

All patients received percutaneous endoscopic surgery with adequate irrigation, debridement, and sampling for pathogen culture. A 1/4-inch drainage tube was inserted for the drainage of exudate and necrotic debris through a Hemovac.

The drainage was maintained in place for 7–14 days until the daily drainage amount was less than 5 mL. Empirical broad-spectrum antibiotics were administered immediately after surgery and were switched to sensitive antibiotics once the pathogens were identified. Intravenous antibiotics were used for 4–6 weeks based on the bacterial species and weekly monitoring of white cell count and inflammation markers [C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR)]. Once the CRP values normalized, the antibiotics were changed to oral medications and discontinued when both CRP and ESR values were within the normal range. The patients remained in bed for 2 weeks after endoscopic surgery to relieve pain and maintain structural alignment. A rigid thoracolumbar spinal orthosis was employed when the patients were allowed to get out of bed and ambulate.

Clinical Evaluation

A retrospective chart review of patients was conducted to evaluate the locations, symptoms and signs, comorbidity, pain scale, and functional outcome. Laboratory data such as ESR and CRP were recorded. Clinical outcomes such as the pain scale, visual analog scale (VAS), and functional score of Oswestry disability index (ODI) were also recorded.

Radiographic Evaluation

All patients underwent a preoperative MRI and were carefully reviewed and classified based on the severity, including endplate erosion, bone edema (low T1, high T2), loss of vertebral height, paravertebral inflammation, paravertebral abscess, and epidural abscess.

All patients underwent a plain film follow-up at 3, 6, 9, 12, and 18 months after surgery as well as a follow-up CT at 12 months after surgery. The kyphotic angle was measured as the angle between the upper endplate of the first involved vertebral body and the lower endplate of the last involved vertebral body in the lateral plain view. The CT scans were reviewed for postoperative spinal bony change.

Results

Patient Population

The study sample consisted of 12 men and 12 women. The mean age of the patients was 61 years (range: 39–77 years). Patients' comorbidities were categorized according to the Charlson Comorbidity Index [mean: 5.54 ± 2.62 points (range: 1–11 points)]. The results revealed 10 lesions on the thoracic or upper lumbar spine (between T10 and L3, 41.66%) and 14 on the lower lumbar spine (between L3 and S1, 58.33%). Pathogens were identified in 16 patients, with the majority being Staphylococcus, Streptococcus, and E. coli (Table 1).

Clinical Outcomes

For pain evaluation, VAS scores were recorded preoperatively and at 12 months postoperatively. The mean values of preoperative and postoperative VAS were 8.95 and 1.08, respectively, with a mean change of 7.87 points in pain improvement. Regarding functional disability evaluation, ODI was recorded preoperatively and at 12 months postoperatively. The mean values of ODI were 81% and 26%, respectively, with a mean change of 55% in functional outcome (Table 2).

Table 1. *Patient characteristics*.

	Value
Numbers of patients	24
Men	12
Women	12
Mean age	61 ± 11.71
Level	
thoracic or upper lumbar spine (T10 to L3)	10 (41.66%)
lower lumbar (L3 to S1)	14 (58.33%)
Charlson Comorbidity Index (mean)	5.54 ± 2.62
Visual Analogue Scale (mean)	
Pre-operative	8.95 ± 1.12
Post-operative	1.08 ± 0.97
Oswestry Disability Index (mean)	
Pre-operative	80.75 ± 11.77%
Post-operative	26.08 ± 15.21%
Bacteria culture	
Staphylococcus	4
Streptococcus	4
Escherichia coli	3
Candida albicans	2
others	4
no growth	8

Table 2. *Preoperative MRI factor.*

No.	Bony destruction			Soft tissue involvement			Loss of disc height
	End plate erosion	Bone edema	Loss of vertebral height >1/4	Paravertebral inflammation	Paravertebral abscess	Epidural abscess	
1	1	1	1	1	1	1	1
2	1	1	1	1	1	0	1
3	1	1	0	1	1	1	1
4	1	1	1	1	1	0	1
5	1	1	0	1	1	0	1
6	1	1	0	1	1	0	1
7	1	1	1	1	1	1	1
8	1	1	0	1	1	1	1
9	1	1	0	1	1	1	1
10	1	0	0	1	1	1	1
11	1	1	0	1	1	0	1
12	1	1	0	1	1	1	1
13	1	1	0	1	1	1	1
14	0	1	0	1	0	1	0
15	0	1	0	1	0	1	1
16	1	1	0	1	1	1	1
17	0	1	0	1	0	0	1
18	0	1	0	1	1	1	1
19	1	1	0	1	0	1	1
20	1	1	0	1	1	1	0
21	1	1	1	1	1	1	1
22	1	1	1	1	1	1	1
23	1	1	0	1	1	0	1
24	0	1	1	1	0	1	1
	79.16%	95.83%	29.16%	100%	79.16%	70.80%	91.66%

CRP and ESR values were recorded to monitor infectious conditions. CRP was normalized in 70.83% of the cases within 1 month postoperatively and 16.66% cases in 3 months. ESR was normalized in 8.33% of the cases within 1 month postoperatively, 37.50% cases in 3 months, and 25% of the cases at the last follow-up; the values in 29.16% of the cases remained abnormal (Table 2).

Radiological Outcomes

To evaluate the severity of infective spondylodiscitis, preoperative MRI scans were reviewed (Table 3). Bony destruction resulting from severe infection was observed in most cases, with at least one finding of endplate erosion and loss of vertebral height over a quarter of normal body height. Bony destruction in the form of endplate erosion was observed in 21 cases (87.5%), bone edema of the vertebral body was observed in 23 cases (95.83%), and loss of vertebral body height was observed in 9 cases (37.5%). Regarding soft tissue involvement, paravertebral soft tissue involvement in the form of inflammation (100%) and abscess formation (79.16%) were noted. Epidural abscess formation was noted in 17 cases (70.88%). Loss of disc height was also observed in most cases (91.66%).

Preoperative and postoperative kyphotic angle was evaluated using plain radiographs. No significant changes were observed in the sagittal alignment (mean change of kyphotic angle: -0.33°), and a kyphotic angle change of less than 10° was observed in 20 cases (83.33%) during the final follow-up (Table 4). In the postoperative plain radiography performed at 18 months follow-up, syndesmophyte formation along the anterior longitudinal ligament (ALL) was observed

in the lateral view in 16 (66.66%) cases. Paravertebral syndesmophyte formation was observed in the anteroposterior view in 23 (95.83%) cases. All cases (100%) showed a decrease in disc height. In the CT scan performed at 12 months follow-up, intervertebral bony fusion was noted in 18 (75%) cases. Bony ankylosis of the facet joints in the form of osteophyte formation and fusion was noted in 20 (83.33%) cases (Table 5). No posterior instrumentation surgery was performed for instability in our series.

Discussion

The prevalence of infectious spondylodiscitis is on the rise- especially among the elderly, immunocompromised, and those with comorbidities- and its treatment remains a challenging clinical scenario. In previous studies, patients with a high Charlson Comorbidity Index score were associated with poor fusion rate, high complication rate, and high re-admission rate after spine surgery (13-16); however, surgical treatment still played an important role in treating infectious spondylodiscitis, including decompression for the neurological deficit, debridement for failed medical treatment, biopsy for pathogen identification, and alignment reconstruction for patients with deformities. Traditional surgical intervention involving anterior debridement and interbody reconstruction, with or without posterior instrumentation, is a major procedure (17-19). High rates of postoperative complications were observed, especially among the immunocompromised, the elderly, or those with multiple comorbidities. Minimally invasive surgery with percutaneous endoscopes gained popularity and gradually replaced traditional surgery due to its high pathogen identification rate, high culture rate, low relapse rate, and safety (12,20-22); however, endoscopic surgery for patients with infectious spondylodiscitis with severe bony destruction remains controversial. With the possibility of progressive kyphotic (or sagittal alignment) deformity due to massive bone destruction, open surgery may be inevitable; however, a previous study showed that endoscopy treatment for infectious spondylodiscitis resulted in a favorable outcome, including minimal kyphotic angle change (mean: 2°) and significant improvement in VAS and ODI, even in patients with severe bone destruction (9). A trend of stability re-establishment after a minimally invasive endoscopy treatment may contribute to these outcomes. In this study, the series of image changes after a minimally invasive endoscopic surgery for infectious spondylodiscitis with severe bony destruction were analyzed.

Table 3. *Laboratory and clinical outcomes.*

ESR normalization		
1 month	2	8.33%
3 months	9	37.50%
last f/u	6	25%
abnormal in last f/u	7	29.16%
CRP normalization		
1 month	17	70.83%
3 months	4	16.66%
last f/u	3	12.50%
Pre-op VAS		
> = 7	23	96%
< = 3	0	0%
Post-op 3 months VAS		
< = 3	24	100%
0	8	33.30%
Pre-op ODI		
Minimal disability	0	0%
Moderate disability	0	0%
Severe disability	1	4.20%
Crippled	10	41.70%
Bed Bound	13	54.20%
Post-op ODI 3 months VAS		
Minimal disability	11	45.80%
Moderate disability	9	37.50%
Severe disability	4	16.70%
Crippled	0	0%
Bed Bound	0	0%

Table 4. *Kyphotic angle change in infected level.*

< 0	15	62.50%
0-5	5	20.83%
5-10	2	8.33%
> 10	2	8.33%
Kyphotic angle change in last f/u (mean)	-0.33	

Findings in our Series

There are several reparative mechanisms to regain the stability of an infected segment claimed from the review of follow-up radiography and CT scan in patients with severe bone destruction. These reparative mechanisms include, paravertebral syndesmophyte formation, direct intervertebral bone growth, and bony ankylosis of the facet joints. In this study, 75% of cases had all 3 findings (paravertebral syndesmophyte formation, intervertebral bone growth, and bony

Table 5. *Postoperative radiographic factors.*

Patient no.	Level	Anterior column ankylosis		Middle column ankylosis	Posterior column ankylosis
		ALL syndesmophyte	Paravertebral syndesmophyte	Vertebral body fusion	Facet joint ankylosis
1	L2/L3	0	1	1	1
2	T12	1	1	1	1
3	L1/L2	0	1	1	0
4	L3/L4	1	1	1	1
5	L5/S1	0	1	0	1
6	T11/T12	1	1	0	1
7	L3/L4	0	1	0	1
8	T10/T11/ L4/L5	1	1	1	1
9	L3/L4	1	1	1	1
10	L5/S1	1	1	1	1
11	T12/L1/L2	1	0	0	0
12	L2/L3	0	1	1	1
13	L4/L5	1	1	1	1
14	L1/L2	0	1	1	0
15	L4/L5	1	1	1	1
16	L3/L4	1	1	1	1
17	L3/L4	1	1	0	0
18	L3/L4	1	1	1	1
19	L3/L4	1	1	0	1
20	T8/T9	1	1	1	1
21	L2/L3	1	1	1	1
22	L3/L4	1	1	1	1
23	L1/L2	0	1	1	1
24	L4/L5	0	1	1	1
		66.66%	95.83%	75%	83.33%

ankylosis of the facet joints). These image findings explain the small change of segmental kyphotic angle before and after surgery in patients with severe bone destruction associated with infective spondylodiscitis. Most of our patients developed ALL and paravertebral syndesmophytes within 6 months of percutaneous endoscopic surgery. Following the ALL and paravertebral syndesmophyte formation, intervertebral bone growth was observed in the 12 months' follow-up radiography. The last reparative phenomenon, bony ankylosis of the facet joints, was detected on the follow-up CT scan. Through this spontaneous spinal arthrodesis, the spinal stability was re-established postoperatively, and no further instrumentation was needed.

Patients in our series were observed following these re-stabilization processes. Figure 1A shows a postoperative image series of a 60-year-old male patient, with hypertension and Child-Pugh class C liver cirrhosis, who was diagnosed with infectious spondylodiscitis in L4-5 with psoas muscle and epidural abscess (tissue culture: Fusobacterium nucleatum). After percutaneous endoscopic surgery and postoperative treatment protocol, the patient showed an improvement in the laboratory and clinical outcomes (VAS: 10 to 2; ODI: 80% to 28%). A decrease in disc height was observed in the preoperative image. In the 3-month postoperative image, obvious syndesmophyte formation was observed along ALL in the lateral view and paravertebral region in the anteroposterior view. At 9 months postoperatively, high bone signals were observed between the L4 and L5 vertebral bodies, indicating

the interbody fusion process. At 12 months postoperatively, CT revealed ankylosis of the facet joint with spur formation and fusion. The kyphotic angle change in the last follow-up was 2°, which was limited, and no further segmental imbalance was noted.

Figure 1B shows a preoperative image of a 73-year-old woman without underlying disease and severe bone destruction of L2 and L3. Percutaneous endoscopic surgery was performed. The pathogen was identified as Staphylococcus aureus, which was treated with adequate antibiotics. At 3 months postoperatively, obvious ALL and paravertebral syndesmophyte were noted. In the last follow-up radiography at 20 months postoperatively, interbody fusion was noted. Though the final kyphotic angle change between the preoperative and postoperative period was 11°, the patient showed an improvement in VAS score from 8 to 1. No further posterior instrumentation was needed for this case.

The same re-stabilization process was noted in the case shown in Fig. 1C, a 49-year-old woman with polycystic liver and kidney, who received a liver transplant and was diagnosed with Candida albicans spondylodiscitis at L1-2 by percutaneous endoscopic tissue sampling. There was obvious bony destruction at the anterior L1 vertebral body with narrowing of disc height. Though ALL was not observed in this patient, obvious paravertebral syndesmophyte and interbody fusion were observed in the last

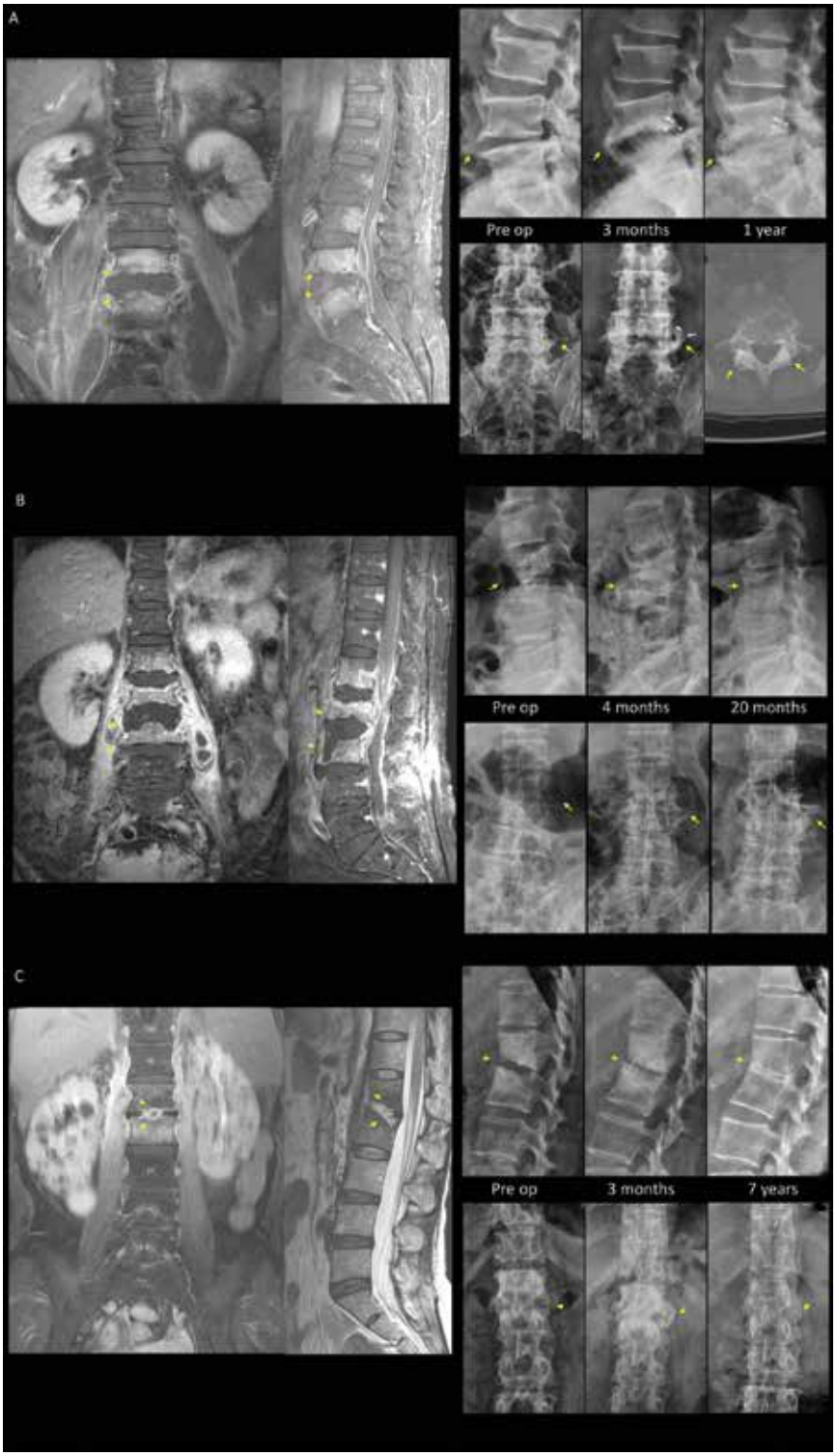

Fig. 1. *Re-stabilization processes in the 3 patients in our series*

follow-up image. The kyphotic angle change was 2° after segmental auto-fusion and further posterior instrumentation was not needed.

Mechanism

The re-stabilization mechanisms of the spine have been previously reported. In cases of diffuse idiopathic skeletal hyperostosis, ALL and paravertebral syndesmophyte formation have been mentioned (23,24); however, the mechanism of bone growth remains undetermined. Some believe that these osteogeneses were oriented by cytokines or genes. In the spinal infective condition, bony destruction may cause segmental instability, while the abscess beneath ALL and paravertebral soft tissue may cause local inflammation. The repetitive mechanical stimulation and inflammation may stimulate mesenchymal cell activity around the junction of the annulus, vertebral ligaments, and perichondral endplate. Mesenchymal cell activity results in local osteogenesis and formation of syndesmophyte over the ALL and paravertebral region, which may provide stability over the anterior column within a short period after infection control (Fig. 1B and 1C).

Two additional features of re-stabilization (intervertebral bone growth and bony ankylosis of the facet joint) were reported in some patients with segmental instability, which included non-fusion stabilization surgery, infectious spondylodiscitis, and posterior instrumentation after a fracture (25-29). In our study, intervertebral bone fusion occurred in 75% of the cases. We hypothesized that the fusion resulted from the decreased disc height with disc destruction and endplate erosion, inducing direct bone growth across the disc. We remove the infected disc for adequate debridement during endoscopic surgery because the intervertebral disc is an avascular region. A decrease in disc height after surgery was noticed in all patients in our study. Furthermore, the endplate erosion, which may result from infection or the debridement procedure, may expose the subchondral and cancellous bone of the vertebral body. These 2 factors induce intervertebral bone growth, establishing the stability of the middle column. Though intervertebral fusion was not observed in all patients in our study, we believe that with longer imaging follow-up, the remaining cases may also develop a total or partial fusion of the infected body through direct intervertebral bone growth (Fig. 2D).

The last finding was bony ankylosis of the facet joint, presenting as narrowing of the facet joint space, osteophyte formation, and hypertrophy of the articular process, which was observed in 83.33% of cases (30). Due to the minimally invasive endoscopic surgery, the posterior ligamentous complex remained intact and functioned as a tension band for anterior column stability. With the previously established anterior and middle column stability, the facet joint may become less mobile. With long-term immobilization of the infected spine, the following bony ankylosis and auto-fusion of the facet joint resulted in the posterior column stability (Fig. 2E). The stability of the 3 columns resulted in segmental stability, which prevented the progression of kyphotic deformity (Fig. 2F) (31).

Treatment Protocol and Clinical Outcomes

Our treatment protocol of bed rest for 2 weeks after surgery for pain relief and inflammation control may have contributed to the rapid progression of the bony ankylosis process. The use of a Boston spinal brace during ambulation may also have played an important role. These treatment protocols may have contributed to the very mild change of kyphotic angle compared to that observed in previous studies.

Although the mean kyphotic angle progression was limited, 2 patients gained more than 10° of kyphosis in our series (8.33%). Nevertheless, these 2 patients showed significant improvement and were satisfied with the surgery. One of them had VAS change from 10 to 2 and ODI from 81% to 38%, and the other patient had VAS change from 8 to 1 and ODI from 84% to 14%. Bony destruction due to infection may not progress postoperatively, but may cause kyphosis. Interestingly, all patients were satisfied with the stooped posture in daily living. One possible explanation is that in our series, the patients were older, immunocompromised, and had comorbidities, making them less demanding for labor work or high-impact activity. Hence, the limited kyphotic angle changes may be acceptable for these cases and may not impact the outcomes. Furthermore, with the aforementioned re-stabilization processes, these changes did not progress with time, and none of them needed further posterior instrumentation for deformity correction.

In our series, none of the patients received further posterior instrumentation for instability or alignment correction. All patients received adequate pain relief after endoscopic debridement, infection control, and the abovementioned processes, and the stability was restored within 18 months postoperatively.

Limitations

This study has several limitations. First, its sample

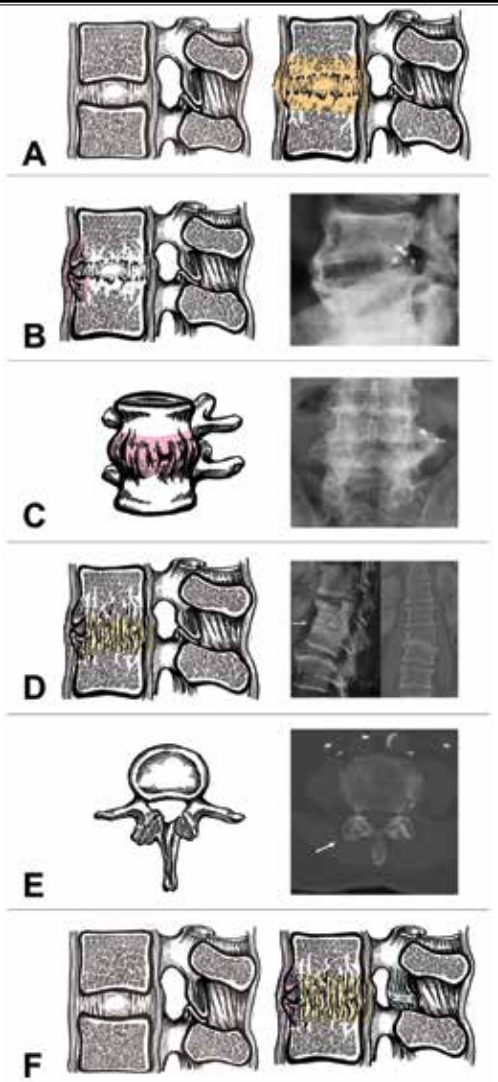

Fig. 2. *Mechanism of spontaneous spinal arthrodesis in infectious spondylodiscitis.* A. *An infected segment causes inflammation and micro-instability, inducing osteoblast activity in ALL and perichondral ligaments. Repetitive mechanical stimulation and inflammation lead to reparative osteogenesis around the infected segment.* B. *Reparative osteogenesis results in anterior syndesmophyte formation, which stabilizes the anterior column of the infected segment.* C. *Paravertebral syndesmophyte in the infected segment.* D. *Decreased disc height and endplate erosion induce intervertebral bone growth, which stabilizes the middle column.* E. *Sclerosis, osteophyte, and extinguished joint space in the CT scan. A sign of bony ankylosis ensuring posterior column stability.* F. *Three column stabilizations are achieved to prevent the progression of kyphosis, including anterior syndesmophyte (B) and paravertebral syndesmophyte (C) in the anterior column, interbody fusion (D) in the middle column, and facet ankylosis in the posterior column (E).*

size was small because most patients with infective spondylodiscitis in our institution were diagnosed in the early stage, with only a few cases progressing to prominent bony destruction. A larger patient sample may achieve a more robust correlation between bony destruction and re-stabilization. Second, this study was a retrospective observational study. Hence, we could only describe the association of image features and the outcomes. The acceptable kyphotic angle may vary based on an individual's daily needs. The risk for general anesthesia and conventional surgery may vary according to the patients' comorbidity and the severity of systemic infection. The Charlson comorbidity index may help to hint at the patients' general condition, but may not be the only guide for inclusion or exclusion criteria. The best indication for endoscopic surgery alone needs further research.

Conclusions

Without instrumentation for stability or anterior reconstruction, the kyphotic angle may not progress after endoscopic surgical treatment. The process of stability restoration, including syndesmophyte formation along the ALL and paravertebral ligaments, direct intervertebral bone growth, and bony ankylosis of facet joints, were observed, which showed a trend to develop segmental bony ankylosis. Limited sagittal kyphosis is tolerable for most patients, especially among the elderly and fragile patients. Percutaneous endoscopic surgery alone may be a safe and effective choice for patients with infective spondylodiscitis, even with severe bony destruction.

References

1. Gregori F, Grasso G, Iaiani G, et al. Treatment algorithm for spontaneous spinal infections: A review of the literature. *J Craniovertebr Junction Spine* 2019; 10:3-9.
2. Berbari EF, Kanj SS, Kowalski TJ, et al. Executive summary: 2015 Infectious Diseases Society of America (IDSA) clinical practice guidelines for the diagnosis and treatment of native vertebral osteomyelitis in adults. *Clin Infect Dis* 2015; 61:859-863.
3. DiGiorgio AM, Stein R, Morrow KD, et al. The increasing frequency of intravenous drug abuse–associated spinal epidural abscesses: A case series. *Neurosurg Focus* 2019; 46:E4.
4. Lu YA, Sun WC, Kuo G, et al. Epidemiology and Outcomes of Infectious Spondylodiscitis in Hemodialysis Patients. *Spine (Phila Pa 1976)* 2018; 43:869-876.
5. Dubost JJ, Lopez J, Pereira B, et al. Primary infectious spondylodiscitis in 51 patients over 75 years old: A comparative study. *Med Clin (Barc)* 2018; 150:371-375.
6. Waheed G, Soliman MAR, Ali AM, et al. Spontaneous spondylodiscitis: Review, incidence, management, and clinical outcome in 44 patients. *Neurosurg Focus* 2019; 46:E10.
7. Ogden AT, Kaiser MG. Single-stage debridement and instrumentation for pyogenic spinal infections. *Neurosurg Focus* 2004; 17:1-5.
8. Mao Y, Li Y, Cui X. Percutaneous Endoscopic Debridement and Drainage for Spinal Infection: Systemic Review and Meta-Analysis. *Pain Physician* 2019; 22:323-330.
9. Lin CY, Chang CC, Chen YJ, et al. New Strategy for Minimally Invasive Endoscopic Surgery to Treat Infectious Spondylodiscitis in the Thoracolumbar Spine. *Pain Physician* 2019; 22:281-293.
10. Fu TS, Wang YC, Lin TY, et al. Comparison of Percutaneous Endoscopic Surgery and Traditional Anterior Open Surgery for Treating Lumbar Infectious Spondylitis. *J Clin Med* 2019; 8(9):1356.
11. Youn MS, Shin JK, Goh TS, et al. Minimally invasive percutaneous endoscopic treatment for acute pyogenic spondylodiscitis following vertebroplasty. *Euro Spine* 2018; 27:458-464.
12. Ito M, Abumi K, Kotani Y, et al. Clinical outcome of posterolateral endoscopic surgery for pyogenic spondylodiscitis: Results of 15 patients with serious comorbid conditions. *Spine* 2007; 32:200-206.
13. Shinonara K, Ugawa R, Arataki S, et al. Charlson comorbidity index is predictive of postoperative clinical outcome after single-level posterior lumbar interbody fusion surgery. *J Orthop Surg Res* 2021; 16:235.
14. Laor A, Tal S, Guller V, et al. The Charlson Comorbidity Index (CCI) as a Mortality Predictor after Surgery in Elderly Patients. *Am Surg* 2016; 82:22-27.
15. Larson KJ, Hamlin RJ, Sprung J, et al. Associations between Charlson Comorbidity Index and surgical risk severity and the surgical outcomes in advanced-age patients. *Am Surg* 2014; 80:555-560.
16. Voskuijl T, Hageman M, Ring D. Higher Charlson Comorbidity Index Scores are associated with readmission after orthopaedic surgery. *Clin Orthop Relat Res* 2014; 472:1638-1644.
17. Faciszewski T, Winter RB, Lonstein JE, et al. The surgical and medical perioperative complications of anterior spinal fusion surgery in the thoracic and lumbar spine in adults: A review of 1223 procedures. *Spine* 1995; 20:1592-1599.
18. McDonnell MF, Glassman SD, Dimar JR, 2nd, et al. Perioperative complications of anterior procedures on the spine. *J Bone Joint Surg Am* 1996; 78:839-847.
19. Kaneda K, Taneichi H, Abumi K, et al. Anterior decompression and stabilization with the Kaneda device for thoracolumbar burst fractures associated with neurological deficits. *J Bone Joint Surg Am* 1997; 79:69-83.
20. Chen HC, Huang TL, Chen YJ, 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.
21. Choi EJ, Kim SY, Kim HG, et al. Percutaneous endoscopic debridement and drainage with four different approach methods for the treatment of spinal infection. *Pain Physician* 2017; 20:E933-E940.
22. Pola E, Autore G, Formica VM, et al. New classification for the treatment of pyogenic spondylodiscitis: Validation study on a population of 250 patients with a follow-up of 2 years. *Euro Spine* 2017; 26:479-488.
23. Jin ZW, Song KJ, Lee NH, et al. Contribution of the anterior longitudinal ligament to ossification and growth of the vertebral body: An immunohistochemical study using the human fetal lumbar vertebrae. *Surg Rad Anat* 2011; 33:11-18.
24. Mader R, Verlaan JJ, Buskila D. Diffuse idiopathic skeletal hyperostosis: Clinical features and pathogenic mechanisms. *Nat Rev Rheumatol* 2013; 9:741-750.
25. Cahill PJ, Marvil S, Cuddihy L, et al. Autofusion in the immature spine treated with growing rods. *Spine* 2010; 35:E1199-1203.
26. Huang KT, Adogwa O, Babu R, et al. Radiological evidence of spontaneous spinal arthrodesis in patients with lower lumbar spondylolisthesis. *Spine* 2014; 39:656-663.
27. Hasegawa K, Kitahara K, Shimoda H, et al. Lumbar degenerative spondylolisthesis is not always unstable: Clinicobiomechanical evidence. *Spine* 2014; 39:2127-2135.
28. Nagashima H, Morio Y, Nishi T, et al. Spontaneous fusion of isthmic spondylolisthesis after discitis: A case report. *Clin Orthop Relat Res* 2002; (403):104-107.
29. Di Martino A, Russo F, Denaro V. Spontaneous fusion of L5 spondyloptosis: Should we learn from nature? *Spine J* 2012; 12:529.
30. Gazzeri R, Panagiotopoulos K, Princiotto S, et al. Spontaneous Spinal arthrodesis in stand-alone percutaneous pedicle screw fixation without in situ fusion in patients with lumbar segmental instability: Long-term clinical, radiologic, and functional outcomes. *World Neurosurg* 2018; 110:e1040-e1048.
31. Denis F. The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. *Spine* 1983; 8:817-831.