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Clinical Effectiveness of the Posterior Affected-Vertebrae Fixation Method in Posterior-Anterior Surgery to Treat Thoracic Spinal Tuberculosis

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■ OBJECTIVE: **The present retrospective comparative analysis was conducted to assess the effectiveness of affected-vertebrae fixation versus short-segment fixation to treat thoracic spinal tuberculosis.**

■ METHODS: **The present study included 110 patients receiving treatment for thoracic spinal tuberculosis at our hospital from January 2006 to June 2013. All cases involved the use of posterior spinal correction, posterior lateral fusion, internal fixation, anterior decompression, radical debridement, and intervertebral supporting bone grafts. The cases were divided by the scope of posterior internal fixation into the affected-vertebrae fixation group ($n = 62$) and the short-segment fixation group ($n = 48$). Statistical analysis was used to compare the clinical effectiveness, laboratory test results, and imaging findings.**

■ RESULTS: **The mean surgical blood loss, mean operating time, and mean inpatient expenditures were all significantly less in the affected-vertebrae fixation group than in the short-segment fixation group ($P < 0.05$). The affected-vertebrae fixation group had a lower mean graft fusion time (5.21 vs. 5.06 months), mean healing time (5.73 vs. 5.91 months), mean degree of correction of thoracic vertebrae kyphosis Cobb angle (16.9° vs. 18.4°), and mean loss of angle (2.6° vs. 2.1°) compared with the short-segment fixation group. However, these differences all lacked statistical significance. Postoperatively, neurological deficits and pain were effectively relieved in all patients, and the lesion had healed at the final follow-up evaluation (≥5 years postoperatively).**

■ CONCLUSIONS: **As long as the surgical indications are strictly observed, posterior affected-vertebrae fixation in posterior-anterior surgery for thoracic spinal tuberculosis is safe, effective, and feasible; entails minimal surgical trauma; and has a lower inpatient cost.**

Key words
- Affected-vertebrae fixation
- Combined posterior-anterior approach
- Short-segment fixation
- Supporting bone grafts
- Thoracic spinal tuberculosis

Abbreviations and Acronyms
ASIA: American Spinal Injury Association
CRP: C-reactive protein
CT: Computed tomography
ESR: Erythrocyte sedimentation rate
ODI: Oswestry Disability Index
RMB: Renminbi
VAS: Visual analog scale

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INTRODUCTION

Thoracic spinal tuberculosis is a common form of spinal tuberculosis that can severely disrupt the stability of the thoracic vertebrae, leading to high rates of deformity and disability. As a consequence, surgical restoration of the correct alignment of thoracic vertebrae and restoration of spinal stability are extremely important.[1,2] Posterior internal fixation has been used to restore spinal stability during surgery for thoracic spinal tuberculosis.[3,4] At present, routine clinical methods of fixation include the long-segment fixation method, which involves fixation of ≥2 normal segments both above and below the affected vertebrae, and the short-segment fixation method, which involves fixation of 1 normal segment above and below the affected vertebrae.[5-7] Although both methods can achieve effective spinal correction, they also increase surgical trauma, increase the economic burden of treatment, and cause adjacent normal segments to lose their motor function, increasing the incidence of adjacent segment disease.[8,9]

To overcome the shortcomings of long-segment and short-segment fixation, we sought to shorten the fixation segment by introducing a new concept for spine surgery, which includes radical debridement, correction, decompression, bone grafting, and internal fixation of the affected segment.[10,11] All these surgical procedures are performed within the affected vertebral segment only, without involving normal adjacent vertebral segments. This approach seeks to optimize the preservation of the spine's mechanical functions. However, the feasibility of affected-vertebrae fixation relative to short-segment fixation to treat thoracic spinal tuberculosis has not been previously reported. Therefore, we sought to assess the clinical effectiveness of affected-vertebrae fixation to treat thoracic spinal tuberculosis through a retrospective comparative analysis of clinical data from 110 patients with thoracic spinal tuberculosis who had received either posterior affected-vertebrae fixation or posterior short-segment fixation when undergoing posterior-anterior surgery and who had also received follow-up care for ≥5 years.

METHODS

Patient Data

The institutional review board of the General Hospital of Ningxia Medical University approved the present study, and all patients provided written informed consent. The indications for affected-vertebrae fixation were 1) single-segment or multisegment spinal tuberculosis without severe kyphosis (<60°); 2) correction possible via posture, manual manipulation, or mechanical methods; 3) imaging revealed that the lesion did not invade the vertebral end plates above and below the bone graft area, permitting reliable implantation of supporting bone grafts; and 4) the pedicle of the affected vertebrae was not yet involved in the tubercular lesion. The contraindications for affected-vertebrae fixation were 1) severe osteoporosis and/or 2) healed or fused spinal tuberculosis requiring osteotomy for correction.

The present study included 110 patients with thoracic spinal tuberculosis who had received treatment in our department from January 2006 to June 2013 and had met the criteria for affected-vertebrae fixation surgery. All the patients included in the present study had cases suitable for affected-vertebrae fixation. However, before 2010, because the affected-vertebrae fixation theory and techniques were not yet mature, some patients with indications for affected-vertebrae fixation received short-segment fixation. In the present study, we used these short-segment fixation cases as a control group to assess the effectiveness of spinal fixation.

The surgical indications for thoracic spinal tuberculosis in the present study consisted of compression of the spinal cord or nerves, causing functional impairment; spinal instability and relatively severe kyphosis; continuous back pain; and the formation of large abscesses, necrotic bone, or sinuses that persistently failed to heal. All patients underwent radical debridement of the affected segment, graft fusion, decompression, and correction procedures. The patients were included in the affected-vertebrae fixation group ($n = 62$) when internal fixation had been completed within the affected segment. When the scope of internal fixation included, not only the affected vertebrae, but also 1 normal segment both above and below the affected vertebrae, the patients were assigned to the short-segment fixation group ($n = 48$). The baseline data of the 2 groups are listed in Table 1.

Preoperative Preparation

A quadruple antituberculosis regimen of RHZS (rifampicin [10 mg/kg/day], isoniazid [10 mg/kg/day], pyrazinamide [25 mg/kg/day], streptomycin [20 mg/kg/day]) was administered preoperatively for 2–5 weeks (mean, 2.4). Liver function and kidney function were monitored, with any liver and kidney damage managed promptly. After the patient's general condition had improved, surgery was performed. A feasible and reasonable surgical plan was developed for each patient according to the

Table 1. Preoperative Patient Characteristics

Characteristic	Affected-Vertebrae Fixation Group	Short-Segment Fixation Group	P Value
Patients	62	48	
Gender			0.905
Male	29	23	
Female	33	25	
Age (years)	39.3 ± 8.3	41.5 ± 7.7	0.173
Disease duration (months)	7.2 ± 1.9	7.8 ± 1.4	0.069
Clinical manifestations			
Back pain	53	41	0.992
Low-grade fever	46	37	0.727
Night sweating	52	39	0.429
Weakness	49	40	0.569
Cold abscess formation	51	39	0.149
Lesion location			
Upper-middle thoracic	24	19	
Lower-middle thoracic	29	22	0.995
Lower thoracic	9	7	
Affected segments (n)			0.080
1	42	26	
2	12	15	
3	6	4	
≥3	2	3	
Neurological dysfunction	23	19	0.918
Follow-up period (months)	76.8 ± 9.7	75.1 ± 8.9	0.347

Data presented as number of patients or mean ± standard deviation.

imaging data from radiographs, computed tomography (CT), magnetic resonance imaging, and ultrasonography.

Surgical Methods

All patients received posterior-anterior surgery, which involved initial posterior pedicle screw fixation, malformation correction, posterior lateral intervertebral graft fusion, anterior intervertebral radical debridement, spinal canal decompression, and implantation of supporting bone grafts from the ilium and/or ribs. Surgery was completed in 1 or 2 sessions, depending on the surgical conditions.

Surgical Methods Used in Affected-Vertebrae Fixation Group. Affected-vertebrae fixation was used in the affected-vertebrae fixation group as follows (Figures 1 and 2). After administration of general anesthesia, the skin and deep fascia were incised and the erector spinae muscle was dissected, exposing the posterolateral vertebrae in the affected segment. Pedicle screws were inserted through the adjacent affected vertebrae, the connecting rods were installed, and the manual technique, patient's position, and instrument application were used to correct the deformity. After correction using an internal fixation device, the connecting rods were tightened, completing spinal fixation. Transverse

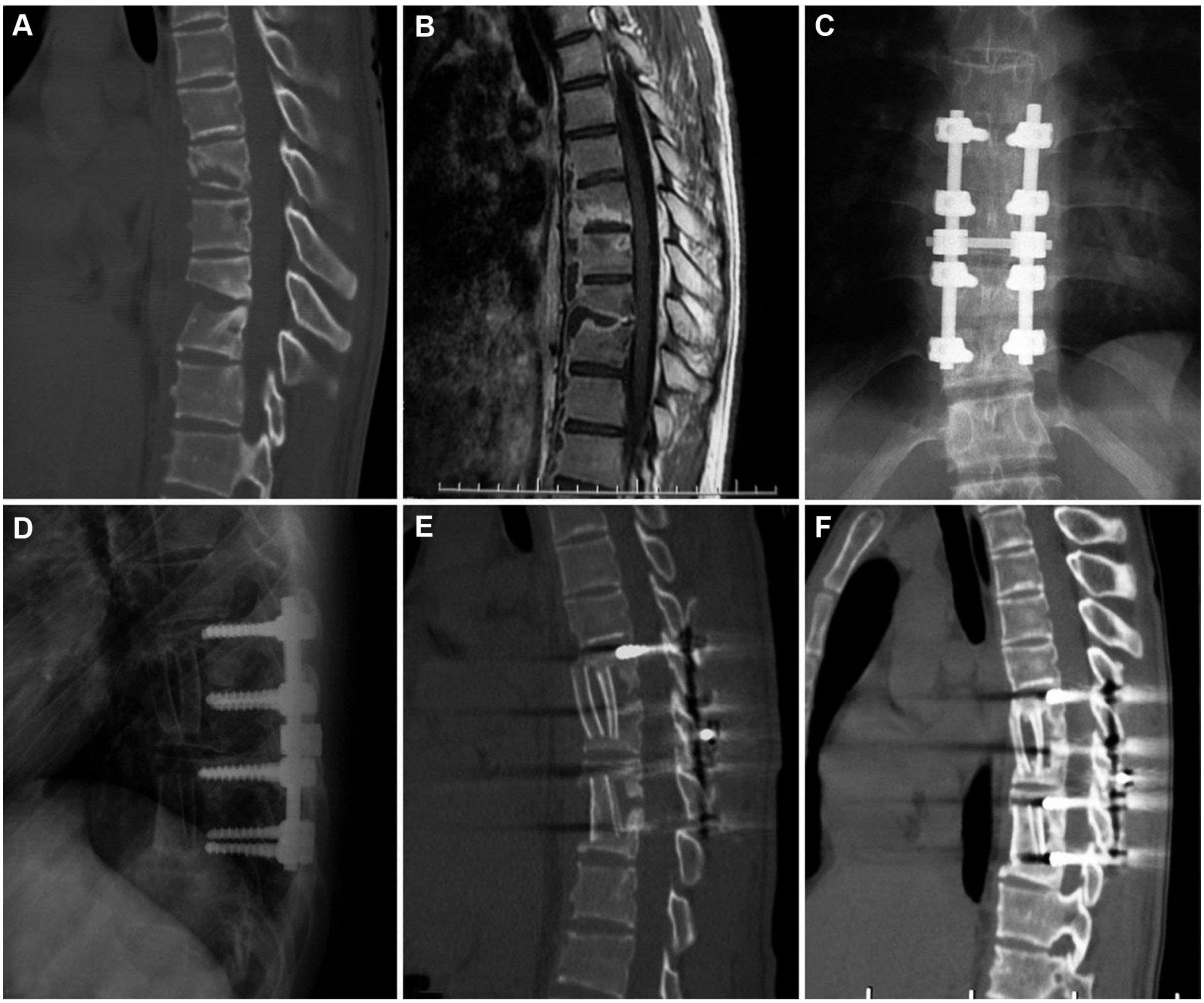

Figure 1. An 18-year-old male patient had undergone anterior-posterior surgery and posterior affected-vertebrae fixation. (**A**) Preoperative sagittal computed tomography (CT) reconstruction showing destruction of the T7—T10 vertebrae and narrowing of the T7-T8 and T9-T10 intervertebral spaces. (**B**) The preoperative sagittal contrast-enhanced magnetic resonance imaging scan showed destruction of the T7—T10 vertebrae and destruction of the T7-T8 and T9-T10 intervertebral disks. (**C, D**) At 1 month after surgery, the anteroposterior and lateral radiographs showed excellent fixation of the affected vertebrae. All the vertebrae had been fixed with short pedicle screws. (**E**) At 3 months after surgery, sagittal CT reconstruction showed that the lesion in the T7—T10 vertebrae had debrided completely, and the bone grafts were firm. (**F**) At 5 years after surgery, sagittal CT reconstruction showed that the T7-T8 and T9-T10 tuberculosis lesions had been cured, and the bone graft fusion was solid.

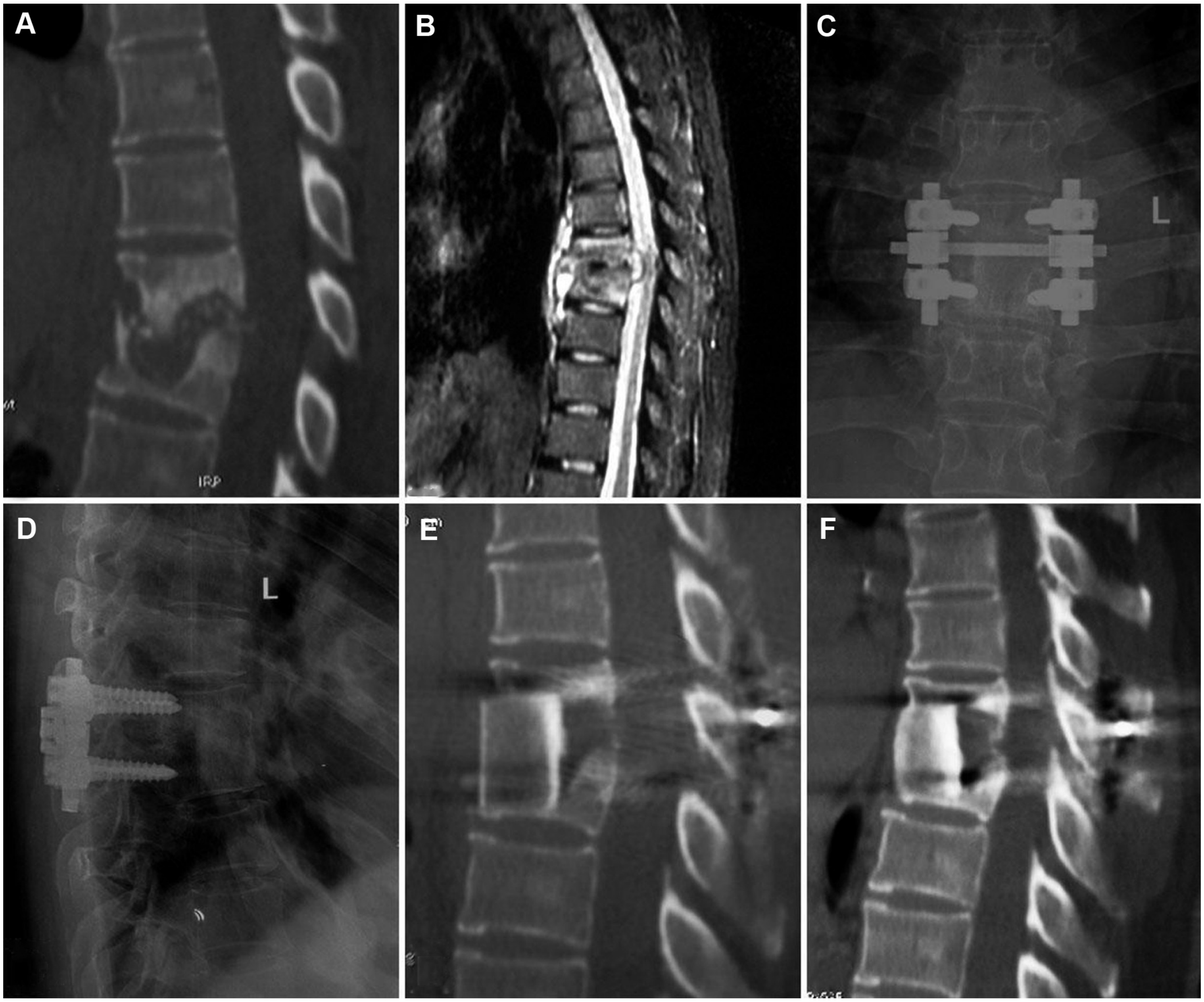

Figure 2. A 45-year-old female patient with T7-T8 tuberculosis had undergone anterior-posterior surgery and posterior affected-vertebrae fixation. (**A**) Preoperative sagittal computed tomography (CT) reconstruction scan showing destruction of the T7 and T8 vertebrae and narrowing of the T7-T8 intervertebral space. (**B**) Preoperative sagittal contrast-enhanced magnetic resonance imaging scan showing destruction of the T7 and T8 vertebrae, destruction of the T7-T8 intervertebral disks, and prevertebral and intraspinal abscess formation. (**C, D**) At 1 month after surgery, the anteroposterior and lateral radiographs showed excellent fixation of the affected vertebrae. (**E**) At 3 months after surgery, sagittal CT reconstruction scan showed that the lesions in the T7 and T8 vertebrae had debrided completely, and the bone grafts were firm. (**F**) At 4 years after surgery, sagittal CT reconstruction scan showed that the T7-T8 tuberculosis lesions had been cured, and the bone graft fusion was solid.

connecting rods were used in all internal fixation procedures to increase stability. When an affected vertebra had severe damage or large defects, such that ordinary pedicle screws could not be inserted, short pedicle screws (30–35 mm) were used to perform fixation. After internal fixation was completed, the articular facets, transverse process, pars interarticularis, and lamina of the affected vertebrae were decorticated, and intervertebral posterior lateral fusion was performed.

After completion of posterior surgery, a drainage tube was placed and the wound closed. Anterior surgery was performed through the transthoracic or extrapleural route, and the thoracoabdominal approach[12] was used to expose the lesion in the affected vertebrae and its upper and lower edges. After removal of pus by suction, radical debridement[13] was performed to debride the granulation tissue, caseous matter, necrotic bone, sclerotic wall, and damaged disc, and the spinal cord within the spinal canal was decompressed. After repeated local flushing, the height of the vertebral bone defect was measured, and an autograft of appropriate size was created from the ilium and/or rib, cut, bound securely, and tightly pressed into the vertebral bone defect. Depending on the patient's physical condition, these 2 surgeries were performed in either 1 or 2 sessions. Of the 62 patients in the affected-vertebrae fixation group, 51 had undergone posterior-anterior surgery in 1 session and 11 in 2 sessions.

Surgical Methods Used in Short-Segment Fixation Group. The patients in the short-segment fixation group received short-segment fixation as follows (Figure 3). The method of anesthesia, operative route, and operative steps were largely the same as those in the affected-vertebrae fixation group. The chief difference was that the pedicle screws used in internal fixation were inserted, not only into the pedicle of the affected vertebrae, but also into the vertebral bodies adjacent to the affected vertebrae on either side. The posterior lateral bone graft and anterior supporting bone grafts were similarly intervertebral as for the affected-vertebrae fixation group and did not involve the normal segments that had already undergone fixation. Of the 48 patients undergoing posterior-anterior surgery in this group, 36 underwent surgery in 1 session, and 12 in 2 sessions.

Postoperative Procedures

Negative-pressure drainage tubes were left in the incisions after surgery and were removed after drainage of <20 mL during a

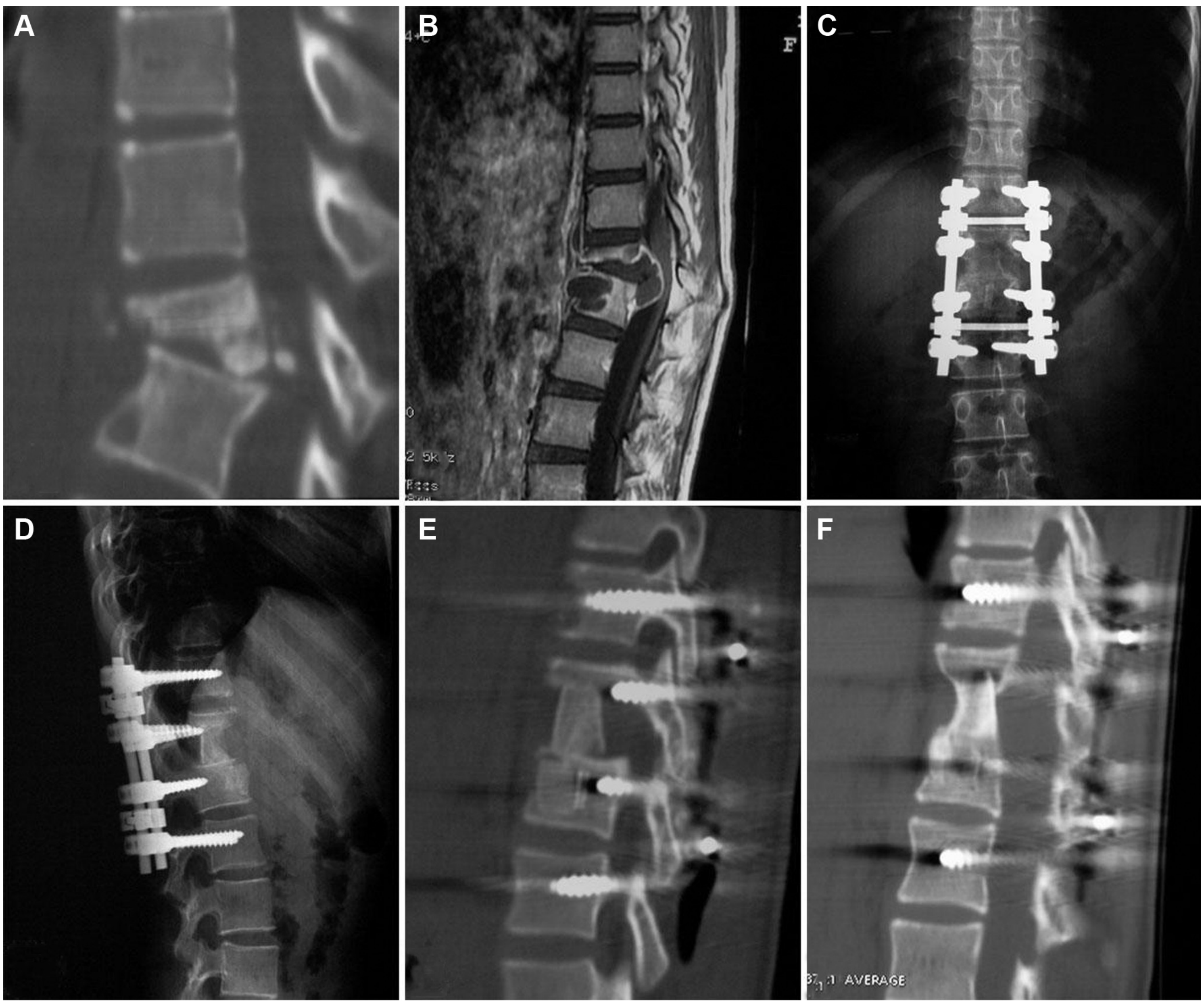

Figure 3. Views from a 45-year-old female patient who had undergone anterior-posterior surgery and short-segment fixation. (**A**) Preoperative sagittal computed tomography (CT) reconstruction scan showing destruction of T12 and L1 vertebrae and narrowing of the T12—L1 intervertebral space. (**B**) Preoperative sagittal contrast-enhanced magnetic resonance imaging scan showing destruction of the T12 and L1 vertebrae, destruction of the L2-L3 intervertebral space, prevertebral and intraspinal abscess formation, and spinal cord compression. (**C, D**) Postoperative anteroposterior radiograph showing that the strut bone was located firmly between the affected vertebrae, the short-segment fixation was excellent, and the T12 and L1 vertebrae had been fixed with short pedicle screws. (**E**) At 2 months after surgery, the sagittal CT reconstruction scan showed that the lesions of the T12 and L1 vertebrae had been removed completely, and the strut bone was located firmly. (**F**) At 6 years after surgery, the sagittal CT reconstruction scan showed healing of the T12 and L1 tuberculosis lesions and bone graft fusion.

Table 2. Operative Time, Intraoperative Blood Loss, and Hospitalization Cost

Group	Patients (*n*)	Operative Time (minutes)	Intraoperative Blood Loss (mL)	Hospitalization Cost (RMB 10,000)
Affected-vertebrae fixation	62	205.3 ± 39.2	738.6 ± 65.8	3.3 ± 1.5
Short-segment fixation	48	276.3 ± 65.3	934.9 ± 81.7	4.9 ± 1.3
P value	NA	0.000	0.000	0.000

Data presented as mean ± standard deviation, unless otherwise noted.
RMB, renminbi; NA, not applicable.

24-hour period. The patients were confined to bed for 2 weeks postoperatively and then wore a brace to get out of bed. The patients were instructed to avoid movement as much as possible until the bone graft had healed and then began spinal exercises in various directions at 2–3 months postoperatively. The postoperative chemotherapy regimen consisted of 2HRZS/2-xHRZ, with an intensive medication stage of 2 months and a consolidation stage of 2–7 months.[14] Specifically assigned personnel ensured that each patient received follow-up care and a full-course of chemotherapy.

Follow-Up Care and Assessment

The patients received in-hospital follow-up care each month for 6 months postoperatively, at 9 and 12 months in the first year, annually until year 5, and every other year until 10 years postoperatively. The clinical presentation, erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), hepatorenal function, ultrasound scan findings, and state of chemotherapy were recorded. The American Spinal Injury Association (ASIA) scale was used to assess neurological function, and the visual analog scale (VAS) scale was used to assess pain. The Oswestry Disability Index (ODI) scale was used to assess the degree of functional deficit recovery. Radiographic examination, CT reconstruction, and magnetic resonance imaging examination were performed before surgery, 2 weeks after surgery, every year for the first 5 years postoperatively, and during the 10th year postoperatively to observe correction of the kyphosis Cobb angle of the thoracic vertebrae and the state of loss, focal healing, and graft fusion. The degree of graft fusion was determined from reconstructed 3-dimensional CT images using the following criteria: the graft was not dislocated or tilted; the interface between the graft bed and the graft was not absorbed or hardened; and depending on the length of postoperative time, tight bonding of the bone–graft interface, an ambiguous interface, trabecula spanning the gap, linking bone bridges near the gap, and remodeling could be present. We used Christensen's criteria to define the quality and extent of the posterolateral fusion on plain radiographs. Christensen's criteria define "fusion" as a continuous intertransverse bony bridge at least on 1 side, "doubtful fusion" as suboptimal quality of fusion, and "nonunion" as a definite lack of fusion.[15] The thoracic spinal tuberculosis focal healing criteria were good physical condition, no local pain or compression pain, no cold abscesses or sinus formation, complete fusion of the bone graft and no formation of new tubercular focus on imaging; and uniformly normal results on several follow-up ESR and CRP tests.

Statistical Analysis

Statistical analysis was performed using the SPSS, version 22.0 (IBM Corp., Armonk, New York, USA), statistical software package. Differences in age, blood loss volume, operative time, hospitalization cost, VAS score, ODI score, CRP, ESR, and Cobb's angle between the 2 groups were compared using the Student *t* test or nonparametric test. Gender, clinical symptoms, number of affected segments, number of fixed segments, bone graft fusion rate, rate of tuberculosis healing, and incidence of complications were compared using the χ^2 test. A statistical significance level of 0.05 was adopted.

RESULTS

Patient Demographic Data

To reduce the bias caused by the different lengths of the follow-up period, we used June 2015 as the last follow-up time for the short-segment fixation group in the present report. June 2018 was used

Table 3. Preoperative and Postoperative Erythrocyte Sedimentation Rate* and C-Reactive Protein*

		Before Surgery		6 Months After Surgery		Final Follow-Up	
Group	Patients (*n*)	ESR (mm/hour)	CRP (mg/L)	ESR (mm/hour)	CRP (mg/L)	ESR (mm/hour)	CRP (mg/L)
Affected-vertebrae fixation	62	38.9 ± 11.3	26.4 ± 13.1	17.8 ± 3.9	1.9 ± 1.5	9.1 ± 3.1	1.2 ± 1.1
Short-segment fixation	48	41.2 ± 13.8	25.5 ± 14.3	16.5 ± 4.2	2.1 ± 1.9	8.4 ± 2.8	1.4 ± 1.3
P value		0.339	0.735	0.097	0.551	0.223	0.395

Data presented as mean ± standard deviation, unless otherwise noted.
ESR, erythrocyte sedimentation rate; CRP, C-reactive protein; NA, not applicable.
*Normal range for ESR: male, 0–15 mm/hour; female, 0–20 mm/hour; normal range for CRP, 0–2.87 mg/L.

Table 4. Preoperative and Postoperative American Spinal Injury Association Grade

	Affected-Vertebrae Fixation Group (n = 62)			Short-Segment Fixation Group (n = 48)		
ASIA Grade	Before Surgery	After Surgery	Final Follow-Up	Before Surgery	After Surgery	Final Follow-Up
A	0	0	0	0	0	0
B	1	1	0	2	1	0
C	4	2	1	3	2	1
D	18	12	2	14	12	1
E	39	47	59	29	33	46

Data presented as number of patients.
ASIA, American Spinal Injury Association Grade.

as the last follow-up time for the affected-vertebrae fixation group. The mean follow-up duration for the affected-vertebrae fixation group and the short-segment fixation group was 74.4 months (range, 61–108) and 75.8 months (range, 64–121), respectively. Descriptive patient characteristics are listed in **Table 1**. The 62 patients in the affected-vertebrae fixation group and the 48 patients in the short-segment fixation group did not differ significantly in age, sex, disease duration, clinical manifestations, lesion location, or number of affected segments.

Surgical Results

The affected-vertebrae fixation group and the short-segment fixation group had a mean operating time of 205.3 minutes and 276.3 minutes ($P = 0.000$), mean surgical blood loss of 738.6 mL and 934.9 mL ($P = 0.000$), and mean inpatient cost of renminbi (RMB) 33,000 and RMB 49,000 ($P = 0.005$), respectively. All of these differences were statistically significant (**Table 2**). The total number of affected segments in the affected-vertebrae fixation group and short-segment fixation group was 94 and 75 segments, with an average of 1.52 and 1.71 affected segments per patient, respectively. The total number of segments subjected to fixation was 94 and 171 in the affected-vertebrae fixation group and the short-segment fixation group, with a mean number of segments subjected to fixation of 1.52 and 3.56, respectively. Thus, compared with the short-segment fixation group, the affected-vertebrae fixation group had 2.04 fewer segments fixed per patient.

Laboratory Test Results

The preoperative ESR levels for the affected-vertebrae fixation and short-segment fixation groups were 38.9 mm/hour and 41.2 mm/hour, respectively. The corresponding CRP levels were 26.4 mg/L and 25.5 mg/L. The 6-month postoperative ESR and CRP levels for both groups had returned to normal, and no abnormalities were

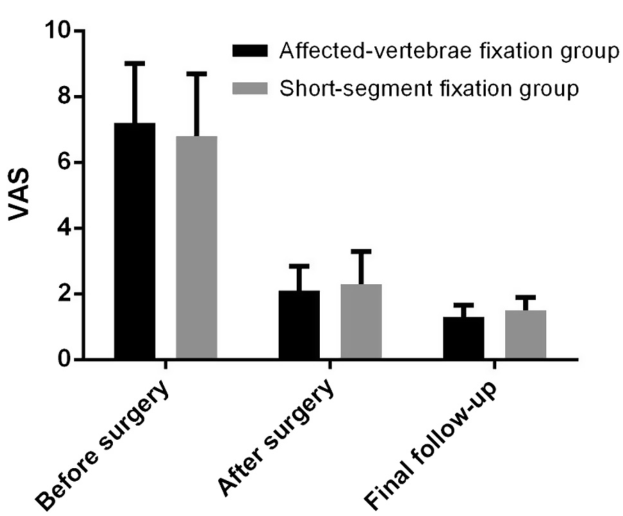

Figure 4. Graph showing visual analog scale (VAS) scores of the affected-vertebrae fixation group and short-segment fixation group stratified by examination point.

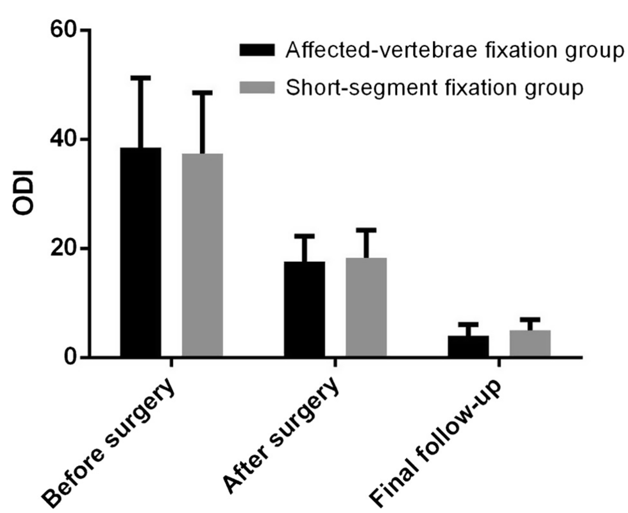

Figure 5. Graph showing the Oswestry Disability Index (ODI) results stratified by examination point.

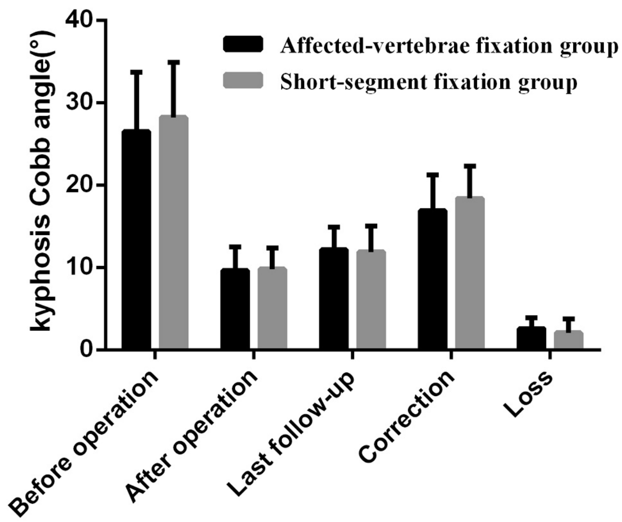

Figure 6. Graph showing postoperative correction and loss of kyphosis Cobb angle in the affected-vertebrae fixation and short-segment fixation groups.

seen throughout the follow-up period, including the final follow-up assessment (Table 3).

Assessment of Function

As assessed using the ASIA scale, neurological function had recovered significantly in both the affected-vertebrae fixation and short-segment fixation groups, with satisfactory results (Table 4). The mean preoperative VAS pain score for the affected-vertebrae fixation and short-segment fixation groups was 7.2 (range, 4–9) and 6.7 (range, 4–8). The corresponding mean scores at the final follow-up assessment were 1.3 (range, 0–2) and 1.5 (range, 0–3; Figure 4). The mean preoperative ODI score was 38.5 in the affected-vertebrae fixation group and 37.3 in the short-segment fixation group. The corresponding mean postoperative scores and at the final follow-up assessment were 17.6 and 18.3 and 3.9 and 5.1; none of these differences were statistically significant (Figure 5).

Assessment of Imaging Studies

The mean degree of correction of the thoracic kyphosis Cobb angle in the affected-vertebrae fixation and short-segment fixation groups was 16.9° and 18.4° and the mean loss of angle was 2.6° and 2.1°, respectively (Figure 6). Thus, the correction and maintenance of correction in the affected-vertebrae fixation group was slightly inferior to that in the short-segment fixation group. However, the differences were not statistically significant (Table 5). Subgroup analysis showed that in the affected-vertebrae fixation group (single segment subgroup vs. multiple segment subgroup), the average number of degrees of Cobb's angle correction was 15.4° compared with 20.1° ($P < 0.05$) and the mean correction loss was 2.6° versus 2.6° ($P > 0.05$). In the short-segment fixation group (single segment subgroup vs. multiple segment subgroup), the average number of degrees of Cobb's angle correction was 16.5° compared with 20.7° ($P < 0.05$), and the mean correction loss was 1.9° versus 2.4° ($P < 0.05$). For both the affected-vertebrae fixation group and short-segment fixation group, the average number of degrees of Cobb's angle correction for multiple-segment spinal tuberculosis was larger than that of single-segment spinal tuberculosis (20.1° vs. 15.4° and 20.7° vs. 16.5°). However, the difference in the mean correction loss was not great (2.6° vs. 2.6° and 2.4° vs. 1.9°; Table 6). The mean graft fusion times of the patients in the affected-vertebrae fixation and short-segment fixation groups were 5.21 months and 5.06 months (Figure 7), respectively. The corresponding lesion healing rates were 93.5% and 91.7% at 6 months and 96.8% and 98.0% at 1 year postoperatively. None of these differences were statistically significant.

Complications

No patient experienced injury to the spinal cord, nerves, or major blood vessels during the surgery. Four cases of superficial infection occurred postoperatively (2 in each group). Healing was achieved 3 weeks after the medication was changed. Five patients experienced postoperative pleural effusion with improvement observed after several days of closed drainage (2 in the affected-vertebrae fixation group and 3 in the short-segment fixation group). Two cases of failed healing resulting from a lack of thoroughness in debridement occurred (1 in each group), with prevertebral abscesses developing at 2 months postoperatively in both patients. One of the patients was given extended antitubercular treatment and the other underwent a second surgery. Both, ultimately, achieved full healing. The follow-up review revealed 3 cases of loosening of internal fixation (2 in the affected-vertebrae fixation group and 1 in the short-segment fixation group). In each case, graft fusion was achieved after revision surgery.

Table 5. Postoperative Recovery of Kyphosis Cobb Angle

Group	Patients (*n*)	Kyphosis Cobb Angle (°) Preoperatively	Postoperatively	Last Follow-Up	Correction	Loss
Affected-vertebrae fixation	62	26.5 ± 7.2	9.6 ± 2.9	12.2 ± 2.7	16.9 ± 4.3	2.6 ± 1.3
Short-segment fixation	48	28.2 ± 6.7	9.8 ± 2.6	11.9 ± 3.1	18.4 ± 3.9	2.1 ± 1.7
P value		0.208	0.708	0.589	0.062	0.095

Data presented as mean ± standard deviation, unless otherwise noted.

Table 6. Postoperative Correction and Loss of Kyphosis Cobb Angle Stratified by Subgroup

Group	Patients (*n*)	Kyphosis Cobb Angle (°)				
		Preoperatively	Postoperatively	Last Follow-Up	Correction	Loss
Affected-vertebrae fixation						
Single segment	42	24.2 ± 5.9	8.8 ± 2.6	11.4 ± 2.1	15.4 ± 3.3	2.6 ± 1.2
Multiple segments	20	31.4 ± 7.3*	11.3 ± 2.8*	13.9 ± 2.8*	20.1 ± 4.6*	2.6 ± 1.3
Short-segment fixation						
Single segment	26	25.2 ± 6.5	8.7 ± 2.4	10.5 ± 3.3	16.5 ± 4.1	1.9 ± 1.6†
Multiple segments	22	31.8 ± 4.9*	11.1 ± 2.2*	13.5 ± 3.1*	20.7 ± 2.8*	2.4 ± 1.5*

*$P < 0.05$, single segment vs. multiple segments in the same group.
†$P < 0.05$, single segment vs. single segment in the 2 groups.

DISCUSSION

Mechanical internal fixation is an extremely important surgical step in the treatment of thoracic spinal tuberculosis to correct malformation and maintain the proper angle after correction.[16,17] Thoracic spinal tuberculosis places great demands on internal fixation, chiefly because the thoracic vertebrae, ribs, and sternum form a cylindrical thoracic cage structure that makes correction of the malformations of the thoracic vertebrae difficult. In addition, after correction, because of the elastic contraction of the thoracic cage, the corrected angle can be easily lost. At present, short-segment and long-segment fixation are often used to treat thoracic spinal tuberculosis. However, because these methods involve fixation of adjacent normal segments, in addition to pathological segments, fixation of excessively long segments can restrict the spine's normal motion. Furthermore, clinical research has revealed that the longer the segment subject to fixation and fusion, the greater the pressure on the discs of adjacent segments and the greater the likelihood of degeneration of adjacent segments.[8,18] The affected-vertebrae fixation used in the present study was not limited to internal fixation, but also included debridement, decompression, correction, and bone grafts placed exclusively within the affected segment, and not affecting adjacent normal segments.

We sought to determine whether affected-vertebrae fixation can reconstruct spinal stability and maintain the correction of the deformity postoperatively in patients with thoracic spinal tuberculosis. The findings of the present study indicate that the kyphosis Cobb angle of the thoracic vertebrae, an important indicator of the ability to correct spinal tuberculosis and restore spinal stability, was corrected by an average of 16.9° and 18.4° and the mean loss of angle at the final follow-up examination was 2.6° and 2.1° in the affected-vertebrae fixation and short-segment fixation groups, respectively. By subgroup analysis, we found that in both single-segment and multiple-segment spinal tuberculosis, the mean degree of correction and loss of Cobb's angle with affected-vertebrae fixation were very close to those with short-segment fixation, without clinically significant differences. These differences indicate that affected-vertebrae fixation provides slightly less corrective ability and correction maintenance ability than short-segment fixation. However, these differences were not statistically significant. In terms of the correction angle and the loss of angle, the effectiveness of affected-vertebrae fixation in the present study was consistent with that of short-segment fixation as reported by Luo et al.[19] and Ran et al.[20] As a consequence, we believe that affected-vertebrae fixation can safely and effectively reconstruct spinal stability when used to treat thoracic spinal tuberculosis and can maintain the correction results for an extended period. In addition, our 2 groups had similar VAS pain scores, ASIA neurological function grades, ESR and CRP results, focal healing rates, bone graft healing rates, and complication rates.

Because of the structural characteristics of the thoracic vertebrae and to ensure the effectiveness of affected-vertebrae fixation in cases of thoracic spinal tuberculosis, the following surgical guidelines must be strictly upheld. First, the pedicle screws must

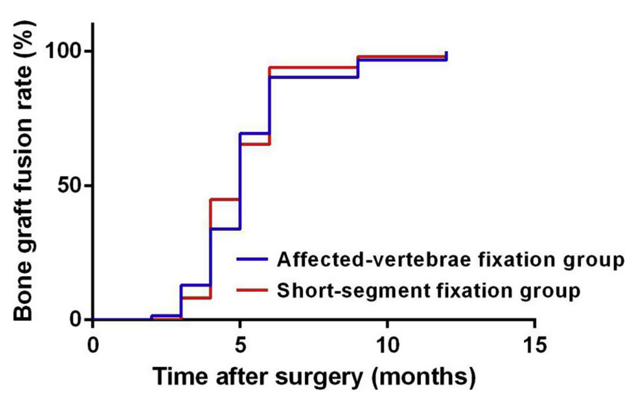

Figure 7. Graph showing the graft fusion rate of the affected-vertebrae fixation and short-segment fixation groups stratified by the postoperative period.

achieve reliable internal fixation.[21] If pedicles have been severely damaged by the focus or if severe osteoporosis has occurred, affected-vertebrae fixation should be used only after a careful consideration of circumstances, and short-segment or long-segment fixation can be used, as necessary. Second, the use of effective anterior and intervertebral supporting bone grafts is important in ensuring the success of spinal fixation. Intervertebral supporting bone grafts can reduce the load and stress from the posterior fixation device in the corresponding segments of the spine and, thus, have a protective effect on the internal fixation device. Third, affected-vertebrae fixation must routinely use lateral linkage.[22] Our early research found that lateral linkage can clearly enhance the stability of a posterior internal fixation device. Finally, regarding the difficulty in correcting severe kyphosis in cases of spinal tuberculosis during the active period, treatable and dormant-stage bone tuberculosis accompanied by kyphosis will require correction by osteotomy. Affected-vertebrae fixation will often be ineffective in these cases and short- or long-segment fixation will often be needed.

The affected-vertebrae fixation group had the following advantages. The surgical blood loss was reduced by 196.3 mL; the operating time was shortened by 71.0 minutes; and the inpatient cost was reduced by RMB 16,000. In addition, the mean number of segments requiring fixation was reduced by 2.04 per patient, and the mean number of pedicle screws used was reduced by 4. Affected-vertebrae fixation to treat spinal tuberculosis has the following advantages. First, it can maintain the normal motion of the vertebrae adjacent to the affected vertebrae. Second, it can restore and maintain the stability of the spine and also provide an optimal dynamic environment for adjacent segments, lessening the risk of degeneration. Third, surgical trauma will be minimized because the size of the surgical field is relatively small. Fourth, the method can significantly shorten the hospitalization time, reduce the use of consumable materials during surgery, and significantly lessen surgical expenditures. For patients with spinal tuberculosis in developing countries with a high incidence of tuberculosis, this method will have a high application value.

Study Limitations

One limitation of the present study was that it was a retrospective clinical study. In addition, we performed a single-center study, and the sample size was relatively small. A multicenter, large-sample, prospective, long-term randomized controlled study is needed to confirm the results of our study.

CONCLUSION

The results of the present study have indicate that when effective antituberculosis measures are taken and the surgical indications rigorously assessed, posterior affected-vertebrae fixation combined with anterior debridement and graft fusion offers a safe, effective, feasible surgical method of treating thoracic spinal tuberculosis. Its advantages include preservation of motion, minimization of trauma, and reduction of hospital costs.

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