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Comparison of the Clinical Efficacy of 3 Surgical Methods for Treating Spinal Tuberculosis in Children

Authors' Contribution:

Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

ACDEF **Weidong Liang***
ACDEF **Jian Zhang***
BC **Zhouliang Ren**
B **Maierdan Maimaiti**
B **Fulati Mamati**
B **Yakefu Abulizi**
C **Tao Xu**
C **Rui Cao**
AE **Jun Sheng**
AE **Weibin Sheng**

Department of Spine Surgery, The First Affiliated Hospital of Xinjiang Medical University, Urumqi, Xinjiang, P.R. China

* Weidong Liang and Jian Zhang contributed equally to this work

Corresponding Authors: Weibin Sheng, e-mail: wbshengvip@sina.com, Jun Sheng, e-mail: shjx@sina.com
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Background: This study aimed to investigate the safety and clinical efficacy of 3 different surgical methods for treating spinal tuberculosis (ST) in children.





Material/Methods: We reviewed the cases of 62 children with ST who were treated in our hospital from January 2010 to December 2014. In this study, erythrocyte sedimentation rate (ESR), C-reactive protein (CRP) level, Frankel classification of neurological function, pain visual analog scale (VAS) score, and kyphosis Cobb (k-Cobb) angle were dynamically monitored to evaluate the efficacy of different surgical methods. Complications in the patients were evaluated at 3 time points: before surgery (T1), after surgery (T2), and during final follow-up (T3). The average follow-up was 27.4 months. Twenty-two patients underwent simple anterior debridement alone or combined with internal fixation (Method A), 13 patients underwent posterior debridement alone (Method B), and 27 patients received anteroposterior debridement and bone graft fusion together with internal fixation (Method C).

Results: In all 3 groups after surgery, ESR, CRP levels, VAS scores, and k-Cobb angles significantly decreased. However, compared with patients who received Methods B and C, patients who received Method A had a significant rebound in k-Cobb angle and a higher incidence of complications at the T3 time point. The overall reoperation rate during follow-up was 37.10%. Fourteen patients (22.58%) had kyphosis, 2 patients (3.23%) had tuberculosis recurrence combined with kyphosis, and other complications were reported in 5 patients (8.06%).

Conclusions: Considering the incidence of complications and level of postoperative biochemical indicators, we concluded that caution should be exercised in using an anterior approach to treat pediatric ST.

MeSH Keywords: **Child • General Surgery • Spine • Tuberculosis**

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Background

The first documented record of spinal tuberculosis (ST) dates to 3400 BC in Egypt, making it one of the oldest known diseases and a common form of extrapulmonary tuberculosis (TB). ST is characterized by local pain and tenderness, muscle stiffness and cramps, and even apparent degenerative scoliosis [1]. According to previous reports, the majority of cases of ST in infants and young children occur in developing countries, especially in mainland China, where the distribution of medical resources varies greatly among regions [2].

Three types of surgery are widely used to treat ST in adults: simple anterior debridement with bone fusion or plus internal fixation (Method A), simple posterior debridement (Method B), and simple posterior or anteroposterior debridement with bone fusion plus internal fixation (Method C) [3]. Intense debate continues about the selection of a surgical method for infants and children, especially those who are young. Therefore, we compared the advantages and disadvantages of the aforementioned procedures for ST in children, hoping to provide a reliable reference for clinical treatment. In the present study, we collected and retrospectively analyzed clinical data from 62 children with ST who underwent surgery with one of the 3 methods at our hospital from January 2010 to December 2014. Of the children, 29 were male and 33 were female, with an average age of 6.27 years (range, 8 months–14 years).

In adults, diagnosis and treatment of ST are relatively standard [4]. However, in the early stage in children, ST progression is slow, subtle, and even asymptomatic. In young children, symptoms of early TB often are overlooked by parents and doctors because of lack of specificity in growing stages, patient inability to communicate complaints, noncompliance with physical examination, and other factors. Therefore, ST in infants and young children often may only come to medical attention when these patients are in severe pain or have an apparent spinal deformity or neurological abnormalities. Consequently, ST significantly affects spinal development in children, often resulting in spinal deformity, cardiopulmonary dysfunction, and in severe cases, nerve dysfunction or paralysis.

The features of spinal anatomy and physiology in children lead to more ST lesion-involved spinal segments than in adults [5]. Research has shown that the number of lesion-involved spinal segments in children is 1.9 times greater than in adults. The selection of surgical methods for children with ST in different age groups remains the subject of debate. Some clinicians believe that debridement is unsuitable for children younger than age 4 years because it could result in visible spinal deformities in late stages of ST [6]. According to Rajasekaran et al., high-risk factors for postoperative spinal kyphosis deformity include

age younger than 10 years, preoperative convex kyphosis Cobb (k-Cobb) angle $>30^\circ$, and vertebral loss score >1 point [7].

To date, there is no consensus about standard surgical treatment of ST in children [8–11]. Therefore, we compared the advantages and disadvantages of 3 surgeries for ST in children: simple anterior debridement with bone fusion alone or plus internal fixation (Method A); simple posterior debridement (Method B); and simple posterior or anteroposterior debridement with bone fusion plus internal fixation (Method C). We collected and retrospectively analyzed clinical data from 62 children with ST who underwent surgery as described above at our hospital from January 2010 to December 2014, 29 of whom were male and 33 female, with an average age of 6.27 years (range, 8 months–14 years). The surgical methods included simple anterior debridement with bone fusion alone or plus internal fixation, simple posterior debridement, and simple posterior or anteroposterior debridement with bone fusion plus internal fixation. Results with these procedures for treatment of ST in children were retrospectively analyzed and compared to analyze the efficacy and complications of these 3 different approaches and to evaluate the practicality of performing them on children with ST.

Material and Methods

Subjects

Sixty-two children with ST who underwent 3 surgical procedures in the Department of Spine Surgery from January 2010 to December 2014 were included in this study. The patients ranged in age from 8 months to 14 years (average 6.27 ± 3.98 years); 29 were male and 33 female. Among these patients, 5 had lesions in the cervical spine, 5 had lesions in the chest and thoracic segment, 28 had lesions in the thoracic segment, 7 had lesions in the thoracolumbar segment, and 17 had lesions in the lower lumbar and sacral vertebrae. According to the Frankel grading of neurological function, 8 of 62 cases of ST were Grade B, 13 were Grade C, 16 Grade D, and 25 cases were Grade E. Thirty-two of 62 cases were complicated by kyphosis (average preoperative k-Cobb angle, 77.75 ± 26.02), with a mean erythrocyte sedimentation rate of 35.7 mm/h on admission, together with a C-reactive protein level of 19.9 $\mu\text{g/L}$ and a visual analog scale (VAS) score of 8.1 points. All patients were followed up for an average of 27.4 months (range, 12–60 months). This study was conducted in accordance with the Declaration of Helsinki with approval from the Ethics Committee of Xinjiang Medical University. Written informed consent was obtained from the legal guardians of all participants.

Diagnostic criteria

ST typically is diagnosed based on a combination of clinical manifestations and findings on X-rays, computed tomography

(CT) scans, and magnetic resonance imaging (MRI). Results of laboratory testing also can be used. Clinical manifestations suspicious for ST included in diagnostic criteria are symptoms of systemic tuberculosis poisoning, such as night sweats, low-grade fever, lack of appetite, and fatigue. The most common chief complaints in children with early-stage ST are stiffness and pain in the neck, back, and waist or restricted movement of the spine and limbs. As the disease progresses, some children with ST have obvious kyphosis, which causes compression of the spinal cord, resulting in abnormal posture and even varying degrees of limb paralysis. CT scans and X-rays of patients with ST show obvious spinal bone destruction, including dead bone formation, spinal structure damage, and kyphosis; MRI shows typical vertebral body and intervertebral disc destruction, abscess formation, and spinal nerve compression. Indicators of ST on laboratory testing include increased ESR, CRP levels, and *Mycobacterium tuberculosis* (TB)-positive culture of a blood sample.

Surgical methods and indications

The indications for surgery in children with ST are as follows: (1) massive abscess formation; (2) large areas of dead spinal bones or small dead bones found in the spinal canal; (3) spinal instability caused by damage to the vertebral body or intervertebral disc; (4) varying degrees of neurological dysfunction caused by compression of the spinal cord; and (5) severe spine deformity or destruction of more than 1 vertebral body growth plate.

Of the 9 children with cervical TB in this study, 4 children were treated with right lateral oblique incision through the sternocleidomastoid muscle, 3 with posterior cervical incision, and 2 with anterior and posterior approaches combined. Of the 38 patients with thoracic vertebra or thoracolumbar TB, 7 were treated with a paraspinous process approach or a combined thoracoabdominal approach, 8 with a posterior median thoracic approach, and 23 with a single-stage anterior and posterior approach. Of the 15 patients with lumbar TB, 11 were treated with anterior inverted incision, 2 with a posterior median incision, and 2 with anterior and posterior approaches combined. In the operations, pus and necrotic tissue were removed as much as possible. If the spinal cord was compressed, anterior or lateral anterior decompression of the spinal canal was performed at the same time. The kyphosis deformity was corrected intraoperatively. If 2 or more growth plates were lost in front of the vertebral body, a posterior lamina fusion was performed concurrently. Children older than age 8 years underwent posterior laminectomy and facet osteotomy, and were treated with pedicle screw plate fixation and bone graft fusion. In all cases, 1.0 g streptomycin powder was applied to the lesion before wound closure. A closed thoracic drain was placed in patients with pleural rupture.

Preoperative preparation

The diagnosis of ST was confirmed in all patients with plain X-ray film, CT, and MRI. In patients who had kyphosis, routine and lateral X-rays were performed, together with whole-spine CT and MRI. Routine laboratory testing for ESR and CRP levels, and cardiopulmonary function examination also were performed to exclude active and miliary TB.

All of the patients were treated with quadruple anti-TB drugs for 2 to 5 weeks before surgery. First-line anti-TB drugs include isoniazid, rifampin, pyrazinamide, ethambutol, and streptomycin. Recommended drug dosages in children with ST are as follows: isoniazid, 5 to 15 mg/kg/day; rifampin, 10 to 20 mg/kg/day; pyrazinamide, 30 to 40 mg/kg/day; ethambutol, 15 to 25 mg/kg/day; and streptomycin, 12 to 18 mg/kg/day. These dosages were adjusted based on patient age and weight. For younger and lighter patients, the dosage was decreased. ESR, CRP levels, and liver and kidney function were monitored every 1 to 2 weeks because side effects such as auditory nerve damage and nephrotoxicity are commonly associated with anti-TB drugs.

Surgical procedures

Appropriate surgical methods were carefully selected according to the extent of TB lesions, degree of bone destruction, angle of kyphosis, extent of spinal cord compression, combination of abscesses, and the general conditions of the patients. In this study, patients were divided into 3 groups: Group A (22 patients) underwent simple anterior debridement alone or plus with internal fixation [9]; Group B (13 patients) had posterior debridement alone [10]; and Group C (27 patients) underwent single-stage anteroposterior debridement, bone graft fusion, and internal fixation (11 patients) or multi-stage anterior debridement, bone graft fusion, and internal fixation (16 patients) [11]. In all surgeries, the goal was to remove as many lesions and as much necrotic tissue as possible. Decompression was performed for any cases of nerve compression. In patients with kyphosis, a correction was made to bring the spine back to normal physiological curvature. For bone grafting, allogeneic ilium (Bone Bank of Shanxi Province) or autologous ilium or rib was used. Importantly, before surgery, 1.0 g of streptomycin was injected into each lesion as a skin test. In addition, patients with pleural rupture underwent conventional pleural drainage using a closed thoracic drainage tube.

Postoperative treatment

After surgery, patient vital signs, including blood pressure, breathing, and pulse, were monitored. Drainage tubes were removed when the amount of postoperative fluid decreased to <50 mL in 24 h. Patient postoperative recovery and internal fixation were evaluated every 1 to 2 weeks. Following surgery,

Table 1. Comparison of erythrocyte sedimentation rates, C-reactive protein levels, and visual analog scale scores among the 3 groups at different time points.

Item	Stage	Group A (n=22)	Group B (n=13)	Group C (n=27)	F	P
ESR (mm/h)	T1	40.31±16.54	35.62±21.00	18.14±14.95	1.77	0.179
	T3	3.86±1.80	6.95±7.53	1.02±1.71	34.56	0.019*
	t (P)	44.272 (0.000)*	25.469 (0.001)*	18.218 (0.003)*		
CRP (mg/L)	T1	21.47±21.08	10.51±13.34	22.30±18.66	1.93	0.153
	T3	10.32±1.67	6.71±5.45	3.02±1.71	20.84	0.033*
	t (P)	10.026 (0.010)*	4.544 (0.142)	17.013 (0.005)*		
VAS (points)	T1	9.04±1.53	7.76±1.69	8.88±1.63	1.36	0.263
	T3	4.45±0.80	1.76±0.92	3.33±0.68	10.38	0.047*
	t (P)	7.049 (0.020)*	12.610 (0.000)*	9.539 (0.012)*		

* The postoperative ESR, CRP, VAS of three groups were significantly decreased ($P<0.05$) except CRP in Group B ($P>0.05$). Value is expressed as the mean±standard deviation. Normal ESR for children: 0–10 mm/h; Normal CRP for children: 0–5 mg/L; VAS range (children over 6 years old): 0–10 points. Value is expressed as the mean±standard deviation (Group A – simple anterior debridement or combined with internal fixation; Group B – posterior debridement alone; Group C – one-stage or multi-stage simultaneous anteroposterior debridement, bone-graft fusion, and internal fixation. T1 – before surgery; T3 – the final follow-up).

patients who did not have severe neurological dysfunction were advised to wear a brace during early ambulation. For those with severe neurological dysfunction or paraplegia, improvements in neurological function dictated the pace of return to physical activity. A full range of anti-TB treatments were regularly administered, together with regular testing of ESR, CRP levels, liver and kidney function, and imaging studies.

Clinical assessment

To compare and evaluate the outcomes of the 3 different surgical outcomes, we collected information about procedure duration, blood loss, ESR, CRP levels, neurological function, VAS scores, k-Cobb angle at different time points, and complications.

Statistical analysis

SPSS26.0 was used to analyze the differences between the Frankel grades, ESR, CRP levels, VAS scores, and k-Cobbs angles preoperatively and postoperatively using a paired *t* test. Similarly, analysis of variance was used to compare intergroup differences. $P<0.05$ was considered statistically significant for both analyses.

Results

Demographics

All patients were followed up for 12 to 60 months (average 27.4 months). The average blood loss was 215 mL (range,

90–520 mL) and the average operative time was 160 min (range, 110–340 min). The results of the paired *t* test showed that ESR, CRP levels, and VAS scores at the T3 time point were significantly lower than those at T1 in patients with ST who underwent surgery. After surgery, ESR and VAS scores in the 3 groups of patients with ST decreased into the normal range (ESR, 0–10 mm/h; VAS, 0–10 points). The greatest reduction in ESR, which was statistically significant, was seen in Group A, (T1 40.31 mm/h–T3 3.68 mm/h), whereas the smallest change was seen in Group C (T1 18.14 mm/h–T3 1.02 mm/h). Reductions in VAS scores were similar in all 3 groups. Moreover, although CRP levels decreased significantly in all 3 groups following surgery, only in Group C (T1 22.30 mg/L–T3 3.02 mg/L) were the reductions into the normal range (0–5 mg/L) (Table 1).

Improvements in neurological function

According to Frankel's classification, 21 of 62 patients with ST were diagnosed with neurological dysfunction (Grades A to C) before surgery, with 12 cases in Group A (6 Grade B, 6 Grade C), 5 cases in Group B (2 Grade B, 3 Grade C3), and 4 cases in Group C (all Grade C). All patients basically had a return to normal neurological function (Grades D and E) except for 1 who did not recover (Grade B) and 3 patients in Group A who improved from Grade B to C (Table 2).

Comparison of k-Cobb angle

Our results have demonstrated that with any of the 3 surgical treatments, the k-Cobb angle in children with cervical TB,

Table 2. Frankel grades for all patients at T3.

Frankel grade at T1	n	Frankel grade at T3				
		A	B	C	D	E
A	0					
B	8		1	3	4	
C	13				5	8
D	16				6	10
E	25					25

T1– Grade B+C 21 children combined with neurological dysfunction returned to normal except for 1 case without recovery (Grade B) and 3 cases improved from grade B to C at T3. Frankel grades: A – Complete neurological injury. B – Preserved sensation only. C – Preserved motor, nonfunctional. D – Preserved motor, functional. E – Normal motor function. T3 – the final follow-up. Group A – simple anterior debridement or combined with internal fixation. Group B – posterior debridement alone. Group C – one-stage or multi-stage simultaneous anteroposterior debridement, bone-graft fusion, and internal fixation.

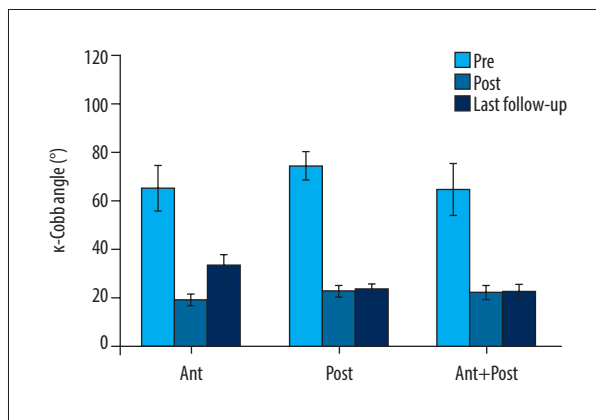


Figure 1. Changes in the kyphosis Cobb angle at different time points in the 3 groups.

thoracic tuberculosis (TT) and lumbar tuberculosis (LT) can be restored to the normal angle range (<25°) in the short term (T2). However, long-term follow-up showed that the recurrence rate for TT and LT treated with Method A was higher than that for Methods B and C. After the patients with TT and LT underwent surgery with Method A, their average k-Cobb angle increased from 21.36° at T2 to 37.45° at T3, and 19.71° at T2 to 35.00° at T3, respectively. The k-Cobb angle of patients with ST treated with Method A at time T3 reached an average of 24° and approached the threshold. Compared with Method A, Methods B and C methods showed similar and excellent stability in maintaining a normal k-Cobb angle postoperatively in patients with ST (Figure 1, Table 3A–3C).

Complications and treatment during follow-up

During postoperative follow-up, 20 patients in Group A underwent a second surgery. Six of the procedures were attributed to bone graft absorption/collapse, internal fixation looseness, or fracture. The other 14 patients underwent repeat surgery

because of a kyphotic deformity, which increased, on average, by 14.68° at T3 compared with T2 (Figure 1). Two patients in Group A exhibited single-stage healing and had no significant postoperative aggravation of their kyphosis (Table 4). One patient in Group B had an incision sinus after surgery, which was treated successfully with debridement, catheterization, and therapy for symptoms. Two patients in Group C underwent another surgery because of bone graft absorption/collapse or internal fixation loosening/fracture. No complications were reported in the remaining patients.

Discussion

Pediatric ST (PST) is the most common form of childhood extrapulmonary TB. ST is more likely to spread in different segments or along potential anterior vertebral cavities in children because of the special characteristics of their anatomy and the physiology of the spine in childhood [8]. In addition, research has revealed that the number of TB lesion-involved spinal segments in children is 1.9 times more than that in adults. In the present study, 227 injured segments were found in 62 patients, with an average of 3.66 lesion-involved segments per case. Childhood is a critical period for spine growth and development. Children infected with ST who do not receive timely treatment for it may go on to experience spinal deformity and irreversible nervous system damage [12–14]. In approximately 39% of children, ST develops into progressive kyphosis, and in roughly 3% of PST cases, the k-Cobb angle is >60° [15]. The goals of surgery for PST are to relieve spinal cord compression, restore the stability of the spine, and correct and prevent deformities.

To be suitable for surgery, patients PST should meet the following criteria: (1) ongoing and in some cases, aggravated symptoms after >4 weeks of conservative treatment; (2) formation

Table 3A. Changes of k-Cobb angle of different segmental spinal tuberculosis in Group A.

	CT (4)	TT (7)	LT (11)
T1 (°)	42.25±6.60	72.55±24.65	71.14±23.60
T2 (°)	14.75±3.20*	21.36±3.83*	19.71±4.39*
T3 (°)	24.00±8.76	37.45±8.94#	35.00±26.17
F	18.006	32.191	22.372
P	0.001	<0.001	<0.001

Group A – simple anterior debridement or combined with internal fixation. CT – cervical tuberculosis; TT – thoracic tuberculosis; LT – lumbar tuberculosis; T1 – before surgery; T2 – after surgery; T3 – the final follow-up. * k-Cobb angle of different segmental spinal tuberculosis in three groups all significantly decreased after surgery ($P<0.05$). # Besides, k-Cobb angle of thoracic tuberculosis in group A significantly increased in the final follow-up compared with post-operation ($P<0.05$). Value is expressed as the mean±standard deviation.

Table 3B. Changes of k-Cobb angle of different segmental spinal tuberculosis in Group B.

	CT (3)	TT (8)	LT (2)
T1 (°)	70.33±17.90	64.36±18.65	63.50±10.61
T2 (°)	20.34±6.03*	21.00±4.41*	27.00±2.83*
T3 (°)	24.34±4.51	22.50±4.81	26.50±2.54
F	17.212	37.279	20.312
P	0.003	<0.001	0.018

Group B – posterior debridement alone. CT – cervical tuberculosis; TT – thoracic tuberculosis; LT – lumbar tuberculosis; T1 – before surgery; T2 – after surgery; T3 – the final follow-up. * k-Cobb angle of different segmental spinal tuberculosis in three groups all significantly decreased after surgery ($P<0.05$). # Besides, k-Cobb angle of thoracic tuberculosis in group A significantly increased in the final follow-up compared with post-operation ($P<0.05$). Value is expressed as the mean±standard deviation.

Table 3C. Changes of k-Cobb angle of different segmental spinal tuberculosis in Group C.

	CT (2)	TT (23)	LT (2)
T1 (°)	66.50±22.33	97.74±21.71	60.00±4.24
T2 (°)	23.00±2.83*	22.96±4.83*	24.00±8.49*
T3 (°)	23.00±1.41	23.78±4.75	23.5±9.51
F	6.825	246.004	17.465
P	0.076	<0.001	0.022

Group C – one-stage or multi-stage simultaneous anteroposterior debridement, bone-graft fusion, and internal fixation. CT – cervical tuberculosis; TT – thoracic tuberculosis; LT – lumbar tuberculosis; T1 – before surgery; T2 – after surgery; T3 – the final follow-up. * k-Cobb angle of different segmental spinal tuberculosis in three groups all significantly decreased after surgery ($P<0.05$). # Besides, k-Cobb angle of thoracic tuberculosis in group A significantly increased in the final follow-up compared with post-operation ($P<0.05$). Value is expressed as the mean±standard deviation.

of a large number of abscesses or entry of dead bone blocks into the spinal canal, constricting the spinal cord nerves and resulting in nerve dysfunction; (3) severe kyphosis (age, <15 years; kyphotic angle, >30°) or destruction of >2 vertebral growth plates; and (4) spinal instability for which surgical decompression is essential [16–19]. All 62 patients in the present

study underwent surgery and their mean ESR, CRP levels, and VAS scores significantly decreased postoperatively. In the 21 patients with neurological dysfunction (33.87%), all but 4 had a return to normal. The exceptions were 1 patient with Grade B ST who did not recover and 3 patients in whom ST improved from Grade B to C.

Table 4. Distribution of complications among the 3 groups.

Complications	Group A	Group B	Group C
Kyphosis deformity	14	0	0
Bone graft absorption/Internal fixation loosening	6	0	2
Incision sinus	0	1	0

Group A – simple anterior debridement or combined with internal fixation. Group B – posterior debridement alone. Group C – one-stage or multi-stage simultaneous anteroposterior debridement, bone-graft fusion, and internal fixation.

Various surgical methods are available for the treatment of ST in children, but few studies have evaluated the different procedures. The results of the present research verified the authors' hypothesis that all 3 methods described were suitable for PST treatment. Notably, the anterior approach significantly aggravated symptoms of kyphosis in children with ST who underwent primary surgery. This implies that caution is warranted in using an anterior approach to treat children with ST who do not meet the criteria for surgery.

Anterior debridement, spinal cord decompression, and bone graft fusion are classic surgical methods for treating ST [9,20,21]. Anterior debridement has obvious advantages of full exposure, complete debridement, and anteroventral spinal bone graft fusion. However, intraoperative and postoperative complications are associated with the procedure the most serious of which is aggravation of kyphosis during follow-up. Some researchers believe that complete anterior debridement with bone graft fusion undermines the ability of the anterior spine to grow [22] and reduces the potential of the spine to shape itself, which leads to kyphosis. Pediatric kyphosis not only appears in both active stages [23] and quiescent periods of TB but also in the spines of patients who have been cured of the infection. Growth imbalance between the front and back vertebra also can lead to kyphosis [24]. Thus, to avoid postoperative kyphosis, the choice of surgical method in PST is crucial [25]. In the present study, the main reason for a second surgery in Group A was a secondary or aggravated kyphosis, which occurred in 63.64% of patients in that group (14/22). Our results demonstrated that the k-Cobb angle in Group A increased, on average, by 14.68° at T3 compared with T2, which was significantly more than in Groups B and C at T3 ($P < 0.05$). In addition, there was no significant difference in k-Cobb angle in 3 patients older than age 10 years in Group A at T2 and T3. To the contrary, compared with T2, the average increase in the k-Cobb angle in 0- to 3-year-old patients in Group A at T3 was 19.15°, and it was 12° in 4- to 7-year-old patients in Group A, which revealed a decreasing trend compared with the 0- to 3-year-old patients. However, no further statistical analysis was performed because the sample size was insufficient.

Simple posterior debridement, bone graft fusion, and internal fixation are suitable for lesions located inside the posterior

column or intervertebral space that are not accompanied by anterior or paraspinal abscess. For these lesions, reports have shown that posterior vertebral lesion debridement, single-stage bone graft fusion, and internal fixation also can achieve good results [26,27]. The main advantages of that surgical method are: (1) ability to simultaneously perform complete debridement, single-stage bone graft fusion, and internal fixation, which eliminates the need for secondary anterior surgery; (2) much more reliable fixation of pedicle screws, resulting in a better corrective effect; and (3) less risk of injuring important organs, such as the chest, abdomen, or large vessels. Nevertheless, if the lesions are only in the anteroventral column or a paraspinal abscess covers a larger area, simple posterior surgery may not result in complete removal of lesions and may destroy normal structures in the posterior column. Some researchers believe that the main reasons to perform posterior surgery for PST are to fuse the vertebral lamina, block growth in the posterior column, and stabilize the spine. Vertebral fusion must be performed 1 segment above and 1 segment below the lesions to prevent the occurrence of the crankshaft phenomenon. Therefore, internal fixation must be on normal vertebral bodies above and below the lesions, and no 2 groups of screws should be mounted (above and below the lesions) to avoid having an excessive negative impact on a child's growth.

Anteroposterior debridement, bone graft fusion, and internal fixation

Based on their general condition, patients with larger lesions, in whom selection of anterior fixation material is difficult, and who require correction of combined kyphosis should be assessed for single-stage anteroposterior debridement plus bone graft fusion and orthopedic internal fixation, or multi-stage anterior debridement plus bone graft fusion and posterior orthopedic internal fixation [28,29].

In addition to the advantages of simple anterior or posterior surgery, some researchers believe that in PST, kyphosis is caused not only by loss of height in the anterior vertebral column but also because of an imbalance in growth between the anterior and posterior vertebral bodies. Growth ratio indicators for the anterior and posterior vertebral bodies show that

anterior debridement with bone graft fusion plus posterior debridement with bone graft fusion can reduce the incidence of growth imbalance between the anterior and posterior vertebral bodies, thus avoiding the aggravation of kyphosis in late-stage ST [29]. Of the 27 patients in Group C, 1 had postoperative hemopneumothorax and was cured following closed thoracic drainage; 1 patient had formation of an anterior incision sinus, which was treated successfully with re-debridement; and 1 patient had a fracture of internal fixation, which was repaired with surgery. None of the 27 patients had signs of aggravation of kyphosis.

Based on the results of the present study, we concluded that each surgical method was effective in clearing TB lesions and satisfactory for decompressing the spinal cord, improving neurological function, and correcting preoperative kyphosis. Follow-up of the patients revealed that 63.64% of patients (14/22) in Group A required repeat surgery for kyphosis, which was a much higher rate than in younger patients, but such a phenomenon was not observed in Groups B or C.

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It is necessary to note that our research had several limitations. First, follow-up in our series is indicative of short-term but not long-term results and revealed a high rate of revision in the anterior group. In addition, the small sample sizes in each group limited the power of our conclusions. Therefore, a randomized controlled trial is required to compare different treatments for TB in children. However, the preliminary results from our study can serve as an aid to surgeons in decision-making and help direct future studies.

Conclusions

In summary, we concluded that the 3 surgical methods can be used in the treatment of PST. However, considering the higher complication rate associated with it, caution should be exercised in using an anterior approach to treat PST and research is still needed to track the long-term adverse effects of that method.

Conflicts of interest

None.

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