



Posterior fixation, anterior debridement and bone grafting in the treatment of thoracic and lumbar tuberculosis in children younger than 3 years of age

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Abstract

Purpose This study aimed to investigate the clinical outcomes of posterior fixation, combined with one- or two-stage anterior debridement and bone grafting in treating children younger than 3 years of age with thoracic and lumbar tuberculosis.

Methods This was a retrospective study involving 16 young children with thoracic or lumbar tuberculosis. Surgical data were recorded. Frankel Grade was used to assess neurological function. The regional kyphosis angle was measured to evaluate the deformity correction. Erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) levels were detected to assess the activity of tuberculosis. Bony fusion and complications were also recorded.

Results The mean operation time was 204.4 ± 41.8 min. The mean estimated blood loss was 126.3 ± 94.4 ml. Preoperative Frankel Grade results indicated five patients with Grade C, six with Grade D, and five with Grade E. At the final follow-up, all patients were in Grade E. Twelve patients were brought back to normal spinal alignment and the rest four patients remained kyphotic. There was an improvement of $29.3^\circ \pm 18.3^\circ$ in regional kyphotic angle postoperatively. And the deformity correction was $27.4^\circ \pm 19.1^\circ$ at the final follow-up. ESR and CRP decreased to a normal range at three months follow-up. Bony fusion was achieved in all patients. None of the cases developed fixation failure, pseudoarthrosis, or tuberculosis recurrence.

Conclusion Posterior fixation, combined with one- or two-stage anterior debridement and bone grafting, is a safe and effective surgical strategy for treating young children with thoracic and lumbar tuberculosis.

Keywords Young children · Thoracic tuberculosis · Lumbar tuberculosis · Posterior fixation · Anterior debridement

Introduction

It is estimated that about one million children are infected with tuberculosis each year around the world, but most children have never been diagnosed or received any treatment

[20]. The gaps in diagnosis and linkage to care result in a mortality of 21.9% among children with tuberculosis [10]. Spinal tuberculosis is the most common osteoarticular tuberculosis. Moreover, young children aged under three years are a special population with immature immune system, appearing to be more susceptible to spinal tuberculosis. The incidence of spinal tuberculosis in young children is unclear.

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By reviewing a dataset of 1,652 patients with spinal tuberculosis, Garg et al. [5] reported that children younger than 10 years old accounted for approximately 6.1% of these cases.

The vertebral bodies in children have a cartilaginous nature, particularly susceptible to rapid destruction. Therefore, if the tubercular infection affects the vertebral bodies, the cartilage loss occurs rapidly and consecutively, resulting in severe deformities and nerve compression [8, 9]. In the early stage, accurate diagnosis and appropriate anti-tuberculosis therapy are the core of treatment, which may minimize sequelae, ameliorate clinical outcome, and avoid surgery. However, because of the insidious nature of tuberculosis, most infected children are in advanced stages when they seek medical care, and surgery may be inevitable for them.

However, thoracic and lumbar tuberculosis in young children was relatively rare compared with adults. To date, only a few case reports focused on the surgical treatment for spinal tuberculosis in children younger than three years old. Surgical approaches for children include anterior [22], posterior [26], and combined anterior–posterior approaches [7]. Limited clinical evidence is available to support the clinical efficacy of the combined approach for pediatric patients. Therefore, the present study was designed to investigate the clinical safety and efficacy of the combination of posterior fixation, anterior debridement, and bone grafting for treating thoracic and lumbar tuberculosis in young children.

Material and methods

Research subjects

From January 2012 to January 2020, children with thoracic and lumbar tuberculosis were enrolled. The diagnosis of spinal tuberculosis was made based upon: (i) clinical manifestations; (ii) laboratory tests, including erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), and T-cell spot test (T-SPOT); and (iii) radiographic examinations, including X-ray, computed tomography (CT), and magnetic resonance imaging (MRI).

Eligible patients should satisfy the following inclusion criteria: (i) patients younger than three years old with a definitive diagnosis of thoracic and/or lumbar tuberculosis; (ii) patients with vertebral collapse and spinal instability according to Rajasekaran's Kyphosis Classification System [17]; (iii) patients received posterior fixation, anterior debridement, and bone grafting; (iv) with a minimum of 2-year follow-up. The exclusion criteria were as follows: (i) loss of follow-up data; (ii) a history of spinal surgery at the same levels; (iii) presence of other spinal infective diseases such as pyogenic spondylitis and brucellosis spondylitis.

Written informed consent was obtained from the patients' parents, and the study protocol was approved by the Ethics Committee of our institution (No. K202105-18).

Operative techniques

Under general anesthesia, the patients were placed in a prone position. A midline incision was made, and the subcutaneous tissue and myofascia were subperiosteally stripped to expose the lamina and facet joints. Pedicle screws with a diameter of 3.5 or 4.0 mm were implanted at one to three levels above and below the affected vertebrae. If possible, short pedicle screws were inserted into the diseased vertebrae. Then the connecting rods were placed to correct the deformity. After the cortical bone of the articular process and lamina were removed, morselized bone was used for bone grafting and fusion. After placement of drainage tube, the incision was closed in layers.

Based on the patient's general condition, the anterior procedure was performed in one- or two-stage. The patient was placed in a lateral position, with the more severely destroyed side upward. A 5-cm incision was made to expose the affected vertebrae through a retroperitoneal, transthoracic, or thoracoabdominal approach. Sequestra, granulation, and pus were removed. The incision was rinsed with a large amount of normal saline, and the structural allograft was installed into the interbody. Then 0.5 g of streptomycin powder was sprinkled into the lesions, and the incision was closed in layers.

Postoperative management and follow-up

The removed lesions were sent for pathological examination. The drainage tube was removed when the drainage volume was less than 10 ml/24 h. X-ray and CT were conducted within one week after surgery. The traditional regimen of anti-tuberculous therapy (rifampicin 10 mg/kg/d, isoniazid 10 mg/kg/d, pyrazinamide 25 mg/kg/d, ethambutol 15 mg/d) was continued. The course of anti-tuberculous therapy was 12–15 months. If adverse effects such as drug-induced hepatotoxicity or nephrotoxicity were found, the drug regime should be adjusted accordingly. Complete blood count, liver function, ESR level, and CRP level were monitored weekly during hospitalization and monthly after discharge. Follow-up examinations were performed at 1, 3, 6 months and 1 year postoperatively. Subsequent follow-ups occurred at one-year intervals. X-ray was used for each follow-up. If necessary, CT and MRI were performed further to confirm the bony fusion and the absorption of abscesses.

Evaluation standard

The surgical outcomes included operation time, estimated blood loss, and postoperative complications. Neurological function was evaluated by using the Frankel Scale. Regional kyphosis angles were measured by Cobb's method—the angle between the upper surface of the first normal vertebra above the lesion and the lower surface of the first normal vertebra below the lesion on the standing lateral X-ray image [16]. Data from Cil et al.'s study [2] were used as references to judge the restoration of sagittal spinal alignment. Levels of inflammatory markers such as ESR and CRP were documented to assess the activity of tuberculosis. Bony fusion was evaluated by using the Bridwell standard [1]. Complications and recurrence were recorded to evaluate the clinical effectiveness of surgery.

Statistical analysis

Statistical analysis was performed using SPSS software (ver. 22.0; SPSS, Inc., Chicago, IL, USA). Descriptive statistics were presented as mean with standard deviation for continuous data. Changes in CRP and ESR levels and Cobb angles at different time points were analyzed using paired *t*-test. A *P* value less than 0.05 was considered statistically significant.

Results

Basic characteristics of the eligible patients

Sixteen patients (six males and ten females) with a mean age of 26.6 ± 6.2 months (15–36 months) met the inclusion criteria. The duration from symptom onset to diagnosis was 2.6 ± 1.9 months (0.7–8.0 months). There were nine patients with thoracic tuberculosis, two with thoracolumbar tuberculosis, and five with lumbar tuberculosis. Nine patients (56.3%) had a definite contact history of pulmonary tuberculosis.

The most common clinical manifestations were regional kyphosis (100%), paralysis (68.8%), fever (62.5%), spinal pain (81.3%), and loss of appetite (68.8%). The MRI imaging indicated that 13 (81.3%) patients were accompanied by intraspinal abscesses, and 12 (75%) patients were accompanied by paravertebral abscesses.

Surgical outcomes

Of the 16 patients, ten receive one-stage posterior fixation, deformity correction, anterior debridement, and bone

grafting. Because of poor general condition, the other six patients received one-stage posterior fixation, deformity correction, and a second-stage anterior debridement and bone grafting. The mean operation time was 204.4 ± 41.8 min (150–320 min), and the mean estimated blood loss was 126.3 ± 94.4 ml (50–350 ml). The mean length of follow-up was 38.4 ± 12.3 months (24–62 months).

Recovery of neurological function

Neurological function was evaluated by using the Frankel Grade. Preoperative Frankel Grade indicated five patients with Grade C, six with Grade D, and five with Grade E. At six months of follow-up, four patients improved from Grade C to Grade D, one improved from Grade C to Grade E, and six improved from Grade D to Grade E. At the final follow-up, the neurological function of all patients improved to Grade E (Table 1).

Recovery of regional kyphosis

Regarding the deformity correction, twelve patients were brought back to normal spinal alignment and the rest four patients remained kyphotic. There was an improvement of $29.3^\circ \pm 18.3^\circ$ in regional kyphotic angle postoperatively. The correction of regional kyphotic angle was $27.4^\circ \pm 19.1^\circ$ at the final follow-up (Fig. 1 and Fig. 2).

Declines of inflammatory markers

The preoperative levels of CRP and ESR were 37.0 ± 24.9 mg/l and 37.9 ± 16.0 mm/h, respectively. Three months after surgery, the levels of CRP and ESR reduced to 5.3 ± 1.7 mg/l and 12.2 ± 10.0 mm/h. At the final follow-up, the levels of CRP and ESR were 4.3 ± 1.4 mg/l ($P < 0.01$) and 7.3 ± 2.9 mm/h ($P < 0.01$), respectively (Table 2).

Bony fusion

Bony fusion was achieved in all patients. The mean fusion time was 6.5 ± 1.1 months (5–10 months). At the final follow-up, there were no patients with failure of fixation, pseudoarthrosis, or recurrence of tuberculosis.

Postoperative complications

A total of two complications occurred in the patients. One patient suffered from superficial incision infection, managed with two weeks of antibiotic therapy. The other patient suffered from poor incision healing. The incision healed ten days later with dressing change and other supporting treatments.

Table 1 Clinical characteristics of all included patients

Patient ID	Age (mons)/gender	Onset time (mons)	Affected segments	Staged procedures	Surgical duration (min)	Fixation segments	Blood loss (ml)	Frankel grading		Kyphotic angle (°)		Bony fusion duration (mons)	Follow-up (mons)	
								Pre-op	6-month FU	Pre-op	Post-op FU			
1#	29/M	4	T9-T11	Yes	320	T7-L1	150	D	E	50	9	13	7	24
2#	19/F	2	T10-T12	No	150	T9-L1	50	C	D	32	13	10	6	34
3#	29/F	1	L1-L2	No	150	T12-L3	100	D	E	14	-9	-5	10	27
4#	32/M	2	L2-L3	No	210	T12-L4	60	D	E	28	19	15	7	46
5#	25/F	2	T12-L2	Yes	190	T10-L3	250	E	E	35	11	16	6	26
6#	34/F	2	T5-T8	No	180	T3-T10	100	C	D	59	11	18	7	29
7#	25/M	6	L1-L2	No	210	T12-L3	50	D	E	25	5	4	6	42
8#	21/M	0.7	L2-L3	No	190	T12-L5	60	D	E	33	19	16	5	57
9#	15/M	3	T4-T6	No	250	T2-T8	50	E	E	28	1	4	6	62
10#	21/M	2	T6-T8	No	160	T4-T10	60	E	E	36	16	18	7	45
11#	33/F	8	T7-T9	Yes	190	T6-T11	120	C	E	33	10	21	6.5	32
12#	28/F	2	T5-T7	Yes	210	T3-T9	200	D	E	56	10	17	6	56
13#	36/F	1	T5-T8	No	240	T3-T10	50	E	E	25	5	12	7	30
14#	27/F	2	T11-L1	Yes	220	T9-L3	350	C	D	109	22	17	6	25
15#	34/F	1	T7-T9	Yes	170	T5-T11	70	C	D	32	14	16	5	50
16#	18/F	2.5	L3-L4	No	230	L1-L5	300	E	E	44	14	8	7	29

Pre-op, preoperative; *Post-op*, postoperative; *FU*, final follow-up

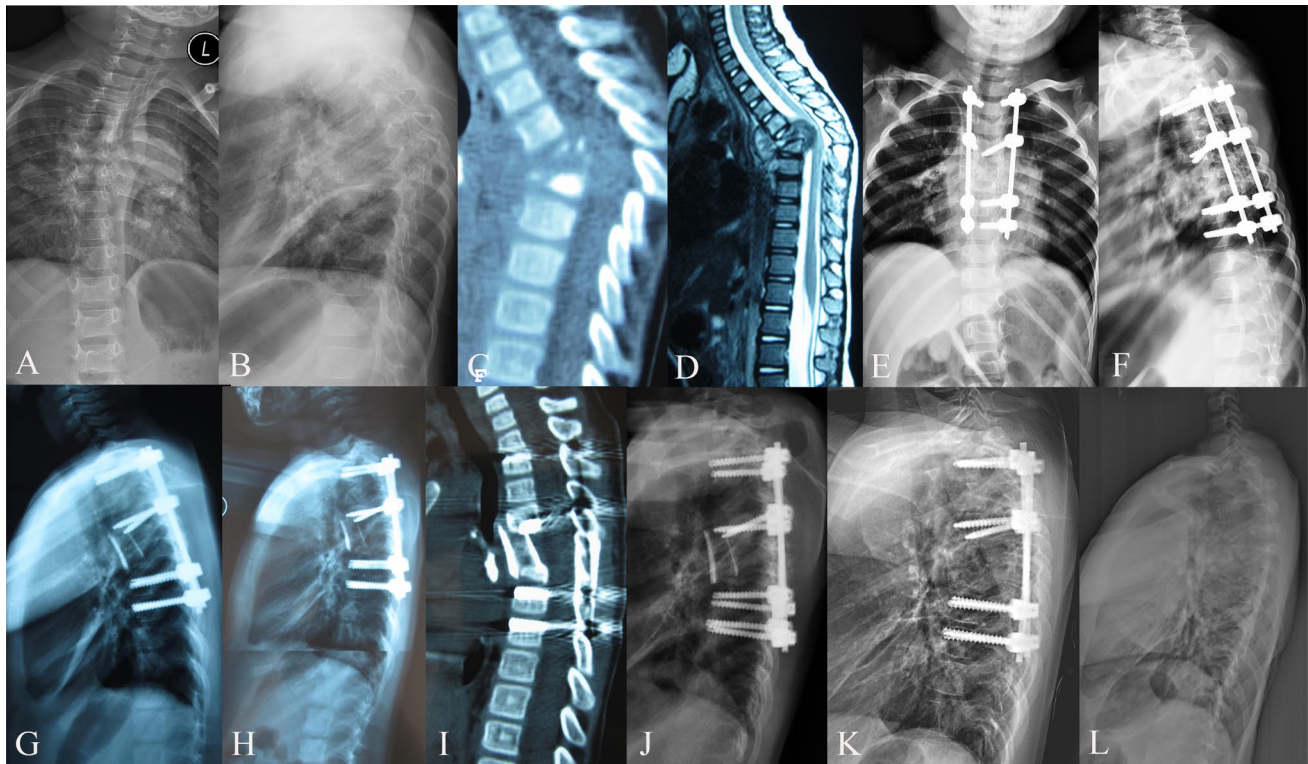


Fig. 1 A 28-month-old female child with T5–7 tuberculosis. The child underwent staged posterior fixation, and anterior debridement and bone grafting. (A–D) Preoperative X-ray, CT and MRI images showed severe bone destruction, kyphotic deformity, and paravertebral and intraspinal abscesses. (E–F) Postoperative X-ray images showed that the kyphosis was well corrected. (G) X-ray image at

3-month follow-up. (H–I) At 6-month follow-up, X-ray and CT images indicated that bony fusion was achieved. (J) X-ray image at 12-month follow-up. (K) At 32-month follow-up, the deformity correction was well maintained, and the implants were removed. (L) At 56-month follow-up, X-ray image showed the spinal alignment was well maintained

Discussion

Spinal tuberculosis in young children mainly results from prolonged contact with adults infected with pulmonary tuberculosis [4]. Through carefully investigating the medical history, nine patients (56.3%) had a definite contact history of pulmonary tuberculosis in this cohort. Besides, this study indicated that regional kyphosis (100%), paralysis (68.8%), fever (62.5%), pain (81.3%), and loss of appetite (68.8%) were the primary clinical manifestations of spinal tuberculosis in young children. However, due to its insidious nature, these clinical manifestations might be unrecognized by care providers.

Egea-Gómez et al. [4] summarized the characteristic of spinal tuberculosis in young children under two years of age. Among the seven patients, the median age was 13 months (8–24 months). Lan et al. [12] reviewed 112 children with spinal tuberculosis and found that children aged 0–3 years were more susceptible to paralysis and severe kyphosis. Besides, the mean duration from onset of symptoms to diagnosis was 3.0 ± 1.6 months (1.5–9.0 months), consistent with findings of this study (mean 2.6 ± 1.9 months; 0.7–8.0 months).

The kyphotic angle, which is the most critical indicator of deformity correction, improved from $39.9^\circ \pm 21.2^\circ$ preoperatively to $12.5^\circ \pm 6.6^\circ$ at the final follow-up. Of the 16 patients, the mean bony fusion duration was 6.5 ± 1.1 months, and none of these cases developed fixation failure. Neurological function significantly improved in patients with neurological deficits. Mushkin et al. [15] reported that tuberculosis recurrence, pseudoarthrosis, and deformity progression were the most common complications in young children who received spinal reconstruction. However, there was no pseudoarthrosis or recurrence in this study. The satisfactory outcomes mainly benefit from complete debridement, favorable bone grafting, robust fixation, and effective anti-tuberculous therapy.

For managing bone defects after debridement, autologous iliac crest is the most favorable graft material in adults. However, because iliac crest is cartilaginous in children, it cannot provide solid and reliable intervertebral support. In this study, allogeneous iliac bone was used as the grafting material. All the cases reached bony fusion, suggesting the allogeneous iliac bone is a satisfactory alternative for autograft.

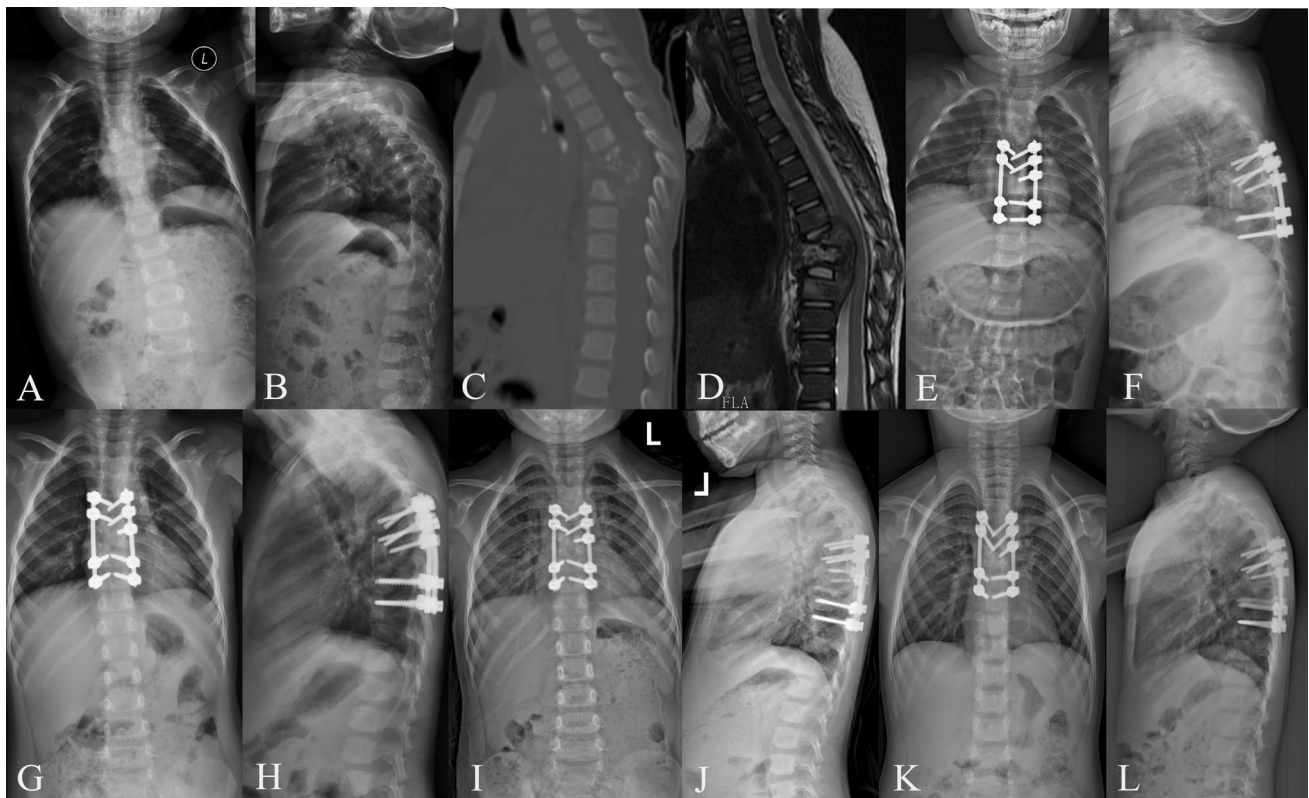


Fig. 2 A 33-month-old female child with T7–9 tuberculosis. The child underwent staged posterior fixation, and anterior debridement and bone grafting. (A–D) Preoperative X-ray, CT and MRI images showed severe bone destruction, kyphotic deformity, and intraspinal

abscess. (E–F) Postoperative X-ray image showed that the kyphosis was corrected. (G–H) X-ray image at 6.5-month follow-up. (I–J) X-ray image at 18-month follow-up. (K–L) At 32-month follow-up, the spinal alignment was well maintained

Through a 15-year follow-up of 65 children with post-tubercular kyphosis, Rajasekaran [16] found that 25 children (39%) suffered a significant deterioration of kyphosis. In addition, Rajasekaran [16] summarized the risk factors for the development of severe kyphosis, including (i) age younger than seven years; (ii) involvement of three or more vertebral bodies; (iii) the lesion was in cervicothoracic or thoracolumbar junction; (iv) presence of radiological signs of ‘spine at risk’. Based on previous literature, the surgical indications for thoracic and lumbar tuberculosis in young children were summarized as: (i) progressive neurological deficits; (ii) massive paravertebral or intraspinal abscesses; (iii) persistent pain and impaired mobility caused by instability; (iv) progressive kyphosis; and (v) involvement of three or more vertebral bodies.

Hodgson et al. [11] advocated anterior debridement and fusion to treat spinal tuberculosis. The anterior approach gives a direct view of the affected area, allows radical debridement, and enables robust bone grafting. However, disadvantages of the anterior approach must be addressed. For children, anterior debridement impedes the growth potential of anterior column and influences the capacity of spinal remodeling, which may contribute to progressive

kyphosis. Besides, the anterior approach cannot correct the preexisting kyphosis [18, 25]. Therefore, this procedure is rarely applied in young children.

With the improvement of posterior instrumentations, Güven et al. [6] reported the posterior-only approach for debridement and fixation for spinal tuberculosis. Since then, the posterior approach has become increasingly popular, mainly due to the ability to correct kyphotic deformities and achieve spinal stabilization. Posterior vertebral column resection (PVCR), which emerges as a popular technique for correction of rigid kyphotic deformity, has been widely used in post-tuberculous kyphosis. Compared to the anterior-only and combined approaches, PVCR allows thorough decompression, shortening of the posterior column, and lengthening of the anterior column simultaneously, with less probability of injuries to important organs, blood vessels, and thoracic cavity [14]. In addition, PVCR has less technical difficulties and complications [23]. Wang et al. [24] employed the eggshell osteotomy combined with PVCR technique in nine patients affected with severe tuberculous kyphotic deformity, and obtained a deformity correction from 100.3° to 15.9°. The enrolled patients in their cohort achieved bony fusion

Table 2 Control of tuberculosis and postoperative complications

Patient ID	CRP (mg/L)			ESR (mm/h)			Recurrence	Complications
	Pre-op	3-mons	FU	Pre-op	3-mons	FU		
1#	13	5	6	28	9	5	No	Incision infection
2#	16	6	5	30	13	12	No	None
3#	36	4	4	48	7	8	No	None
4#	38	3	4	56	11	6	No	None
5#	55	5	1	70	12	5	No	None
6#	14	6	2	66	46	12	No	Poor incision healing
7#	39	5	4	18	5	6	No	None
8#	15	4	5	40	12	7	No	None
9#	80	6	4	35	11	7	No	None
10#	32	2	3	26	4	4	No	None
11#	24	7	6	23	12	13	No	None
12#	40	5	5	30	2	3	No	None
13#	77	8	6	20	8	6	No	None
14#	21	4	4	40	19	10	No	None
15#	21	9	4	22	20	8	No	None
16#	71	5	6	54	4	6	No	None

Pre-op, preoperative; *FU*, final follow-up

without major complications [24]. Rathod et al. [19] treated 16 patients with post-tuberculous kyphotic deformity by using PVCR. The deformity was corrected from 90.1° to 38.1°, and three patients suffered from complications. Maziad et al. [14] performed PVCR on 57 patients with severe post-tuberculous kyphosis and concluded that the PVCR technique was safety with optimal clinical and radiographic outcomes. Deng et al. [3] treated 16 patients with severe tuberculous kyphosis by using one-stage PVCR. The patients achieved bony fusion and obtained a kyphotic deformity correction from 64.6° to 20.3° without significant complications.

During the posterior fixation, as the bony structures in the vertebral lamina are weak, pedicle screws should be considered for robust fixation [13, 21]. Due to small pedicle sizes in young children, it carries higher risks when inserting pedicle screws. Preoperative CT scanning is encouraged to measure the transverse pedicle diameter, as well as the transverse and sagittal angle, thus guaranteeing accurate insertion of pedicle screws. Complications such as pedicle fracture, neurological injury, and vascular compromise did not occur in the included patients.

Despite the posterior-only approach applied to the majority of thoracic and lumbar tuberculosis, the combined anterior and posterior approach is recommended in conditions including (i) three or more vertebrae are involved; (ii) patients with critical bone defects; (iii) robust bone grafting and spinal reconstruction cannot be reached through a posterior approach; (iv) considerable paravertebral abscess cannot be removed via the posterior approach. However, through a 10-year follow-up of 117 children with thoracic

spinal tuberculosis, Schultz et al.[22] found that the combined anterior and posterior approach had significant advantages, such as better deformity correction and fusion rate. Similarly, this study showed that the combined approach could achieve radical debridement, sufficient decompression, robust bone grafting, and favorable deformity correction.

Whether the implant should be removed after bony fusion is another issue of debate. Ruf et al.[21] reported that implants had no significant adverse effect on further growth of the vertebrae and would not lead to neurologic deficits or spinal stenosis. Spinal tuberculosis is preferentially involved in the anterior and middle columns of the spine, with the posterior column rarely involved. Therefore, resection of the lesions in the anterior and middle columns may result in a kyphosis deformity. Literatures have reported that the kyphosis deformity may exacerbate even though spinal tuberculosis is cured, especially in children less than 7 years with 3 or more vertebrae [9, 16]. Posterior instrumentation might act as a tension band, which could restrict the growth of the posterior column and help prevent the development of kyphotic deformity. The implant was removed in two cases owing to strong requests from their patients. Although no adverse effects have been observed in two-year follow-ups, we tend to preserve the implants. Given the long-term effects of long fusion on the growth potential of spine remain unclear, the patients are still under closely follow-up.

Limitations in this study should be pointed out. First, the length of follow-up was short. As all the patients were young children with spinal growth potential, they should be frequently monitored until skeletal maturity to investigate the

effects. Second, the sample size of this study was relatively small, even though patients were enrolled over eight years. Third, the children were too young to have language competence, and the frequently used functional scales could not be applied to them.

Conclusions

Posterior fixation, combined with one- or two-stage anterior debridement and bone grafting, is a safe and effective surgical strategy for treating young children with thoracic and lumbar tuberculosis.

Abbreviations ESR: Erythrocyte sedimentation rate; CRP: C-reactive protein; T-SPOT: T-cell spot test; CT: Computed tomography; MRI: Magnetic resonance imaging

Authors' contributions WS contributed to the study conception and design. SG, YA, FM, MM, WL, HG performed material preparation, data collection and data analysis. SG and YA drafted the manuscript. FM and CX revised the manuscript. All authors read and approved the final manuscript.

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Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate The study was approved by the ethics committee of our hospital.

Conflict of interest The authors declared no competing interests.

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