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Smith–Petersen osteotomy combined with anterior debridement and allografting for active thoracic and lumbar spinal tuberculosis with kyphotic deformity in young children

A prospective study and literature review

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Abstract

The purpose of this study is to determine the efficacy and safety of Smith–Petersen osteotomy combined with anterior debridement and allogenic strut bone grafting for the treatment of active thoracic and lumbar spinal tuberculosis with kyphotic deformity in young children.

Spinal tuberculosis is more destructive in young children and often causes severe kyphosis and paraplegia. Despite much progress has been made, surgical treatment is still controversial and technically challenging.

From October 2010 to August 2014, 25 children (11 males, 14 females; aged under 6 years) with active thoracic and lumbar spinal tuberculosis treated by Smith–Petersen osteotomy combined with anterior debridement and allogenic strut bone grafting were enrolled in this study. The pre- and postoperative data, follow-up medical records, imaging studies, and laboratory data were collected prospectively. Clinical outcomes were evaluated on the basis of kyphotic angle and the Frankel motor score system. The changes in C-reactive protein (CRP) levels, erythrocyte sedimentation rate (ESR), clinical symptoms, and complications were investigated. Graft fusion was evaluated using the Bridwell grading criteria.

The mean age was 3.5 ± 1.76 years (range, 1–6 years). All patients were followed up for 25 to 45 months (average, 34.3 ± 5.86 months). The average kyphotic angle was changed significantly from a preoperative value of $44.1 \pm 10.8^{\circ}$ to a postoperative value of $11.4 \pm 3.9^{\circ}$, with an average correction rate of 74% (P < .05). According to the Frankle motor score system, neurological deficits were significantly improved by the time of the last follow-up, with an average improvement of 1.7 grades (P < .05). There were 2 cases of rod breakage and 1 case of graft bone displacement. No patients experienced a recurrence of tuberculosis. According to Bridwell criteria, the degree of fusion was grade I in 23 patients and grade II in 2 patients with a fusion rate of 92%.

For young children with active thoracic and lumbar spinal tuberculosis, Smith-Petersen osteotomy combined with anterior debridement and allogenic strut bone grafting is a safe and simple procedure to achieve sufficient kyphosis correction, good neurological recovery, and reliable anterior column reconstruction.

Abbreviations: CRP = C-reactive protein, CT = computed tomography, ESR = erythrocyte sedimentation rate, MRI = magnetic resonance imaging, SPO = Smith–Petersen osteotomy, VBL = vertebral body loss, WHO = World Health Organization.

Keywords: allogenic strut bone grafting, anterior debridement, children, Smith-Petersen osteotomy, spinal tuberculosis

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1. Introduction

Tuberculosis (TB) has existed for millennia and remains one of the leading causes of death. According to the World Health Organization (WHO), there were 10.4 million new cases of TB worldwide in 2015, of which 1.0 million (10%) were children.^[1] Spinal TB is the most common type of extrapulmonary TB, accounting for approximately half of the skeletal TB involvement.^[2] It is well-known that spinal TB frequently causes kyphotic deformity, neurological deficit, and even paralysis.^[3,4] In children, the disease is more severe and destructive due to its unique anatomical characteristics.^[5,6]

Chemotherapy remains the cornerstone for the treatment of spinal TB in children, and most patients can be cured by conservative treatment (Figs. 1 and 2). However, kyphosis is inevitable in children during both the active and healing phase of the disease and may exacerbate to develop a kyphotic angle greater than 60° among 3% to 5% of patients.^[7,8] Gross kyphotic deformities in the thoracic and thoracolumbar region can result in severe cardiorespiratory compromise and neurological deficits.



Figure 1. A 2-year-old boy. (A–F) Preoperative radiological examinations showed destructive segments located at L1-L2 vertebrae, with a 32° kyphosis. Both epidural and paravertebral abscess formation. (G) Postoperative X-ray showed good kyphosis correction. (H) Thirty-two months postoperative X-ray demonstrated solid bony fusion and good correction maintenance. (I) Clinical picture showed the improvement in physiological spine curvatures during growth.

Compounding to this issue, the crisis of multidrug-resistant TB has recently emerged in many developing countries, including China.^[1] Unregular or prolonged chemotherapy from a young age may increase the risk of multidrug-resistance.^[9] Also, conservative treatment alone is considered unsatisfactory for some cases in recovering neurological function. Therefore, surgical treatment still plays an important role in the management of children with spinal TB, especially in patients with severe or progressive neurological dysfunction, spinal instability, kyphotic deformity, and abscess formation.^[10,11]

Various methods of surgical procedures have been described for the treatment of spinal TB in children, including anterior, posterior, and combined approaches.^[12,13] Although each procedure can be effective in decompression of spinal cord, the issues of radical debridement, spinal stability and segmental reconstruction, deformity correction, maintenance of correction, and complications are still a focus of debate. Furthermore, considering the immaturity of the spine and its ongoing growth as well as the disease characteristics in young children, surgical treatment on these subjects with spinal TB is technically challenging, and the optimal treatment strategy remains controversial.^[14] To our knowledge, there are few articles reporting the surgical treatment of younger children (≤ 6 years old) with active spinal TB in literature. The purpose of this study was to determine the clinical efficacy and safety of the Smith–Petersen osteotomy (SPO) combined with anterior debridement and structural allografting for active thoracic and lumbar spinal TB in young children with kyphotic deformity.

2. Methods

2.1. General information

This study was approved by the ethical committee of the First Affiliated Hospital of Xinjiang Medical University and conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all patients. From October 2010 to August 2014, 25 cases of pediatric patients younger than 6 years of age diagnosed with active thoracic or lumbar spinal TB complicated with kyphotic deformity and treated by SPO combined with anterior debridement and allogenic strut bone grafting were enrolled in this study. The indications for surgery included active spinal TB of the thoracic or lumbar spine, persisting pain due to spinal instability, which is caused by vertebral destruction, severe or progressive neurological dysfunction, severe kyphosis or a predisposition for kyphosis progression, and extensive paravertebral abscess or obvious spinal cord compression due to epidural abscess formation. There were 11 males and 14 females. The mean age was 3.5 ± 1.76 years (range, 1-6 years). Involved levels were observed in the thoracic



Figure 2. A 6-year-old girl. (A,B) Preoperative X-ray showed local kyphosis and paravertebral abscess formation (arrow). (C,D) CT demonstrated destruction of T9-T10, with a 48° kyphosis. (E,F) Sagittal T1 and T2-weighted MRI images showed epidural, paravertebral abscesss formation, and spinal cord compression. (G) Postoperative X-ray showed good kyphosis correction. (H) Forty-five months postoperative 3-dimensional CT reconstruction demonstrated that solid fusion of resection site was achieved.

spine in 17 cases, the lumbar spine in 5 cases, and the thoracolumbar region in 3 cases. There were 11 cases with multilevel involvement. The patient characteristics are summarized in Table 1.

All cases presented with back pain and constitutional symptoms such as weakness, malaise, night sweats, fever, and weight loss. Nineteen cases had visible local kyphosis and 2 cases had sinus formation. Neurological function was classified by the Frankel motor score system.^[15] Eighteen cases suffered from neurological deficits (Frankel Grade A to D). Among them, 4 cases demonstrated complete motor loss (Grade A: 1 case; Grade B: 3 cases). The remaining 14 cases were presented with incomplete motor loss (Grade C: 6 cases; Grade D: 8 cases).

Preoperative routine plain radiography, computed tomography (CT), and magnetic resonance imaging (MRI) were performed. Lateral X-ray of the spine showed variable degree of deformity angles in all cases. The local kyphotic angle (the angle between the upper and lower endplates of the collapsed vertebral levels) was measured; if there was uncertainty on X-ray observation, kyphotic angle was measured on CT scans. The mean kyphosis of all patients was $44.1 \pm 10.8^{\circ}$ (range, $21^{\circ}-68^{\circ}$).

CT was performed to evaluate bone destruction and measure the vertebral body loss (VBL). The mean VBL was 1.3 ± 0.38 . All cases were presented with abscess formation, according to MRI. Five cases were afflicted epidurally, while 3 cases were presented with paraspinal abscess formation. The abscess was located in both sites in the remaining 17 cases.

2.2. Preoperative procedure

All cases received combined HREZ chemotherapy by oral administration 5 mg/kg/day of isoniazid, 10 mg/kg/day of rifampicin, 15 mg/kg/day of ethambutol, and 35 mg/kg/day of pyrazinamide for 2 to 4 weeks, with an addition of 15 mg/kg/day intravenously administered streptomycin for 1 week before surgery.

2.3. Surgical procedure

In the first procedure, the patients were placed in a prone position after administration of general anesthesia. A midline longitudinal incision was made over the spinous process of the infected

 Table 1

 Basic information of all patients

Case no.	Age, y	Gender	Involved level	Total VBL	Area of abscess formation	Instrumentation level	Follow-up, mo
1	1	М	T12-L1	1.3	Ep, Para	T11-L2	32
2	2	Μ	T9-T10	1.6	Ер	T7-T8, T11-T12	38
3	5	Μ	T5-T7	1.1	Ep, Para	T3-T4, T7-T8	26
4	6	F	T10-T12	1.6	Para	T8-T10, L1L-2	40
5	6	F	T12-L1	1.0	Ep	T10-T11, L2-L3	36
6	4	F	T10-T11	1.4	Ep, Para	T8-T9, T12-L1	30
7	4	F	T6-T8	1.6	Ep, Para	T3-T5, T8-T10	38
8	1	F	T9-T10	0.9	Ep	T8-T11	35
9	2	F	L3-L4	0.7	Ep, Para	L2-L4	45
10	6	Μ	T4-T10	2.1	Ep, Para	T2-T4, T10-T12	30
11	5	F	T2-T4	1.3	Ер	T1-T2, T5-T6	34
12	2	Μ	L1-L2	1.1	Ep, Para	T12-L3	32
13	3	F	T5-T6	1.4	Ep, Para	T3-T4, T7-T8	36
14	6	F	T8-T10	0.8	Ep, Para	T6, T8, T10, T12	45
15	3	F	T4-T6	1.8	Ep, Para	T2-T3, T7-T8	28
16	1	Μ	T7-T8	1.0	Para	T5-T6, T8-T9	42
17	4	F	T5-T8	1.9	Ep, Para	T2-T4, T8-T10	36
18	2	Μ	L2-L3	1.2	Ep, Para	L1-L2, L4-L5	40
19	1	Μ	T11-T12	0.9	Ер	T9-T10, T12-L1	29
20	2	Μ	T12-L2	1.1	Ep, Para	T10-T11, L1-L2	30
21	5	Μ	T10-T12	1.2	Ep, Para	T9-T10, L1-L2	25
22	3	F	T5-T6	1.4	Para	T3-T4, T7-T8	28
23	5	Μ	L2-L3	0.9	Ep, Para	T12-L1, L3-L4	36
24	5	F	T7-T10	1.6	Ep, Para	T5-T7, T10-T12	40
25	4	F	L1-L2	0.6	Ep, Para	T12-L1, L3-L4	26
Mean	3.5 ± 1.76			1.3 ± 0.38			34.3 ± 5.86

Ep = epidural abscess formation, F = female, M = male, Para = paraspinal abscess formation.

vertebra. The posterior spinal construction including lamina, facet joints, and transverse processes were exposed. Pedicle screws were placed into 1 to 3 segments superior and inferior to the involved levels. In some cases, short pedicle screws were placed at the involved segments without touching the infected anterior sites. According to the severity of kyphosis, 1 to 4 SPOs were performed at the apex of the deformity to increase flexibility and effectiveness of correction. In order to avoid spinal cord injury during the process of kyphosis correction, limited decompression was carried out through the operating space obtained by the facet joint resection. Thorough drainage of epidural abscess was performed to avoid TB spread and to decrease the mechanical pressure on spinal cord. Then, the dura was separated from the granulation tissues by gently using nerve dissectors through both sides of each osteotomy space. After limited decompression and complete spinal cord untethering, correction of the deformity was performed. At this point, the initial length of anterior column was restored by intraoperative traction. In the meantime, closure of the resection area was accomplished by installing contoured permanent rods with compression maneuvers. The mixture of autogenous bone and allogeneic bone was used for posterior fusion, and drainage was performed at the end of posterior approach.

In the second procedure, the patients were placed in a lateral decubitus position, leaving the severely involved side upward. The extrapleural or extraperitoneal anterior-lateral approach was taken through a minimal incision. The tuberculous lesion, including paravertebral or psoas abscesses, collapsed vertebrae, intervertebral discs, and granulation tissues was thoroughly debrided. Slots were made in healthy bleeding bone of the vertebral bodies above and below the affected levels, and the spinal defect was measured. A suitable-length structural

allogeneic bone was placed into the resultant gap for intervertebral fusion. Before incision sutures, pleural or peritoneum was observed carefully, and local antibiotic therapy with 15 mg/kg streptomycin was routinely administered.

2.4. Postoperative management

The drainage tube was usually removed when the volume was less than 30 mL/day. Intravenous antibiotics were administered for 3 days postoperatively to prevent infection. Patients continued with the oral HREZ chemotherapy for 6 months and received another 6 to 12 months of the HRE chemotherapy. X-ray examination was performed 7 to 10 days after operation to evaluate the correction of kyphosis and location of the graft bone and instrumentation. Patients without severe neurological deficits (Frankel D to E) were mobilized under the effective brace protection after 2 weeks post-op.

2.5. Follow-up evaluation and statistical analysis

Patients were followed-up at 1, 3, and 6 months and then annually. The activity of infection was monitored with erythrocyte sedimentation rates (ESRs) and C-reactive protein (CRP) levels. The kyphotic angle was measured and analyzed during the preoperative, postoperative, and last follow-up periods. During the preoperative, 3 months postoperative, and last follow-up periods, neurological function was evaluated and compared on the basis of Frankel motor score system. The Bridwell grading system was used to evaluate the grade of bony fusion.^[16]

All statistical analyses were performed with SPSS 20.0 statistical software (International Business Machines, Armonk, NY). The Student t test was used to evaluate preoperative and

final follow-up changes in laboratory testing (ESR, CRP) and kyphotic angle. The Wilcoxon signed-rank test was used to compare the Frankel grade. Any discrepancy in normal distribution was analyzed using the rank sum test. Statistical significance was set at P < .05.

3. Results

Table 2

There were no intraoperative neurological complications noted in any of the patients. Pleural injury was observed in 3 cases during the anterior surgery. The mean operation time was 240 minutes (168 minutes for posterior surgery; 72 minutes for anterior surgery). The mean blood loss was 235 mL (166 mL for posterior surgery; 69 mL for anterior surgery). All patients were followedup for at least 24 months, with an average of 34.3 ± 5.86 months (range, 25-45 months). There were 2 cases with rod breakage and 1 case of graft bone displacement. These patients received revision surgery for their complications. The wounds healed without chronic infection or sinus formation. All patients had a significant improvement in constitutional symptoms by the time of the first follow-up visit (1 month after discharge). ESR and CRP returned to normal levels within 3 months in all patients. The average ESR levels declined to 8.7 ± 4.9 from preoperative levels of 41.2 ± 16.5 , and CRP levels declined to 4.3 ± 2.7 from 27.4 ± 19.3 at 3 months postoperatively (*P* < .05). There was no recurrence of the disease in any of the patients during the followup period.

According to the Frankel motor score system, preoperative neurological deficits were significantly improved by the 3 months follow-up (Table 2). At the last follow-up, neurological functions of 15 cases out of 18 cases with preoperative neurological deficits recovered to normal. The other 3 cases of complete preoperative motor loss were recovered to Frankel Grade D, with an improvement of 2 to 3 grades. In total, there were 2 cases improved by 3 grades, 8 cases improved by 2 grades, and 8 cases improved by 1 grade. The average improvement of neurological deficits was 1.7 grades. There was a significant difference in Frankel grades between postoperative 3-month follow-up and last follow-up (P < .05).

The average kyphotic angle was corrected to $11.4 \pm 3.9^{\circ}$ from $44.1 \pm 10.8^{\circ}$ preoperative values, with a mean correction of 32.7° (74%). Kyphosis fell to $14.6 \pm 4.3^{\circ}$ (range, $7^{\circ}-25^{\circ}$) values at the last follow-up, with a mean loss of 3.2° (range, $1^{\circ}-6^{\circ}$). The final correction of kyphosis was 29.5° (67%). Preoperative and postoperative changes in degree of local deformity were statistically significant (P < .05). All patients achieved bony fusion. According to the Bridwell criteria, the degree of fusion was grade I in 23 patients and grade II in the remaining 2 patients with an overall fusion rate of 92%.

4. Discussion

In children younger than 7 years of age, spinal TB is more likely to affect adjacent multi-segments and usually causes more severe destruction of vertebral bodies during the active phase of the disease, which often results in severe kyphotic deformity.^[6] Rajasekaran^[6] reported that after ambulatory therapy and chemotherapy, the initial kyphosis increased by 10° in children aged under 5 years during the active phase, while the increase was only 4° in children over 10 years old. Furthermore, unlike adults,

Case no.	OT, min		BL, mL		Kyphotic angle			Frankle grade			
	PA	AA	PA	AA	PRE	POST	LFU	Pre	Post 3 mo	LFU	Complications
1	120	70	130	50	42	11	13	D	E	Е	
2	150	80	150	60	55	15	18	С	D	E	
3	180	60	250	60	41	10	12	D	Е	E	
4	210	80	280	80	54	16	17	В	С	D	
5	180	70	230	50	37	9	12	D	Е	E	
6	200	60	180	60	47	13	15	С	D	E	
7	210	90	210	100	54	17	21	В	С	D	Rod breakage
8	120	50	90	40	45	12	15	D	E	E	Ũ
9	100	60	80	60	32	8	13	E	E	E	
10	240	80	270	150	68	20	25	В	С	E	Pleural injury
11	150	50	150	50	52	12	15	D	E	E	
12	120	80	100	40	32	9	9	E	E	E	
13	150	80	200	70	58	19	22	С	D	E	Pleural injury
14	240	70	210	90	48	13	19	D	E	E	
15	210	80	200	60	47	14	17	С	E	E	Rod breakage
16	120	60	120	80	35	9	13	E	E	Е	
17	210	90	160	70	59	12	16	С	D	E	
18	120	50	100	50	38	8	12	E	E	E	Graft slippage
19	110	60	70	40	34	6	8	E	E	E	
20	180	90	90	80	41	9	13	D	E	E	
21	150	120	120	110	34	8	14	С	D	E	
22	210	80	180	60	38	7	10	D	E	E	
23	180	70	200	50	36	11	13	E	E	E	
24	240	80	300	120	54	12	15	А	В	D	Pleural injury
25	100	50	80	40	21	4	7	Е	E	E	
Mean	168	72	166	69	44.1	11.4	14.6				
Total	240		2	35							

AA = anterior approach, BL = blood loss, LFU = last follow-up, OT = operation time, PA = posterior approach.

spinal deformity in children usually deteriorates with growth even after the disease is cured. Rajasekaran^[8,17] also reported 39% of 61 children with spinal TB showed deterioration in kyphosis during the healing or growth phase. Even more pressing is the issue of neurological deficits, the most dreaded complication of spinal TB in children, which often requires an early active treatment.^[5] However, the clinical managements of spinal TB in very young children are rarely reported in the literature, and surgical management is technically challenging. In our study, the average age of the patients was 3.5 ± 1.76 years, which was even younger than the patients who were previously reported.

Anterior, posterior, and combined approaches including anterior-posterior (A-P) and posterior-anterior (P-A) have been described for the surgical treatment of spinal TB in children. During the past decades, the anterior approach has become the gold standard for surgical treatment of active spinal TB.^[18,19] Although the anterior approach allows for adequate debridement, effective decompression, and the ability to place a large strut graft under a direct line of vision, it has the disadvantage of insufficient kyphosis correction for mild to severe kyphosis.^[20] Furthermore, in young children, progressively severe kyphosis can develop with ongoing spinal growth even after TB is cured by anterior debridement. Therefore, the anterior approach alone is considered to be unsatisfactory for young children in terms of postoperative correction loss. Bailey et al^[21] reported 100 children with spinal TB who were treated by anterior debridement and anterior arthrodesis. In their 1 to 15 years follow-up, there was an average of a 22.2° (ranging 2°-106°) increase in kyphosis in 75 children. Afterwards, Rajasekaran et al^[22] further demonstrated that the poor results of anterior approach alone were associated with more extensive vertebral involvement and a larger bony defect due to aggressive debridement. Unfortunately, young children with spinal TB carry a higher risk of poor results, as the disease often involves adjacent multi-segments. In our study, there were 11 cases with multilevel involvement. Severe vertebrae destruction was observed in all cases with a mean VBL of 1.3 ± 0.38 .

With the introduction of the screw and rod fixation systems, many surgeons attempted to address the problem of correction loss via combined posterior instrumentation. Sundararaj et al^[23] achieved significant less correction loss (mean 4.8° for thoracic spine; mean 3.5° for lumbar spine) using posterior instrumentation followed by radical debridement and anterior fusion. To demonstrate the efficacy of this procedure on children, Huang et al^[24] reported 15 children with spinal TB aged between 5 and 16 years. As expected, a minimal correction loss (mean 4°) was observed in their 30 months follow-up study.^[24] In addition, reconstruction of spinal stability by posterior instrumentation is more beneficial to bony fusion and healing of the lesion.^[25,26] However, if anterior debridement and strut bone grafting is carried out first, the posterior instrumentation is forced to undergo in situ fixation without further correction of the kyphosis, resulting in a similar degree of kyphosis correction as the anterior approach alone. Also, this procedure may carry a potential risk of graft slippage when changing the position of surgery, which in turn may increase further neurological insult to the spinal cord.

To achieve sufficient kyphosis correction, some surgeons advocated P-A approach as an alternative surgical method. Wang et al^[27] achieved good correction through posterior instrumentation combined with anterior debridement and bone grafting. Compared with the results of previously reported A-P approaches, Wang et al^[27] accomplished a greater correction

rate (78.5%) and less correction loss (1.6°). In order to minimize the risk of TB spread, they emphasized that kyphosis correction should be undertaken without exposure of the lesion.^[27] However, posterior-only correction without prior debridement and decompression may increase the mechanical pressure on the spinal cord and worsen the neurological deficit. In our study, the MRI examinations showed that all of the patients were presented with spinal cord compression. Among them, 18 cases suffered from neurological deficit.

In recent years, the posterior-only approach has become an option for surgical treatment of active spinal TB in adults and elders, and it is also applied in some selective cases of children. Zhang et al^[28] reported 10 children with cervicothoracic TB treated by 1-stage posterior focus debridement, fusion, and instrumentation. All cases showed good clinical outcomes without wound-related complications in their study.^[28] However, posterior-only approaches have been blamed to be inadequate in achieving satisfactory debridement and reconstruction of anterior column defects and is considered not suitable for some cases with multiple-level involvement and extensive abscess. Especially in young children, posterior strut bone grafting is more challenging and unreliable.

In our series, we carried out a SPO with limited decompression, and kyphosis correction combined with anterior debridement and strut bone grafting for young children with active thoracic and thoracolumbar spinal TB. The posterior approach was performed primarily to obtain maximum kyphosis correction on the premise of not insulting the spinal cord. Following, anterior debridement and strut bone grafting were accomplished through a lateral exposure. Considering the degree of kyphosis correction, neurological complications, reconstruction of anterior column, and maintenance of correction, we believe this is safer and more effective surgical procedure for young children. In our study, we achieved a mean kyphosis correction of 32.7° without any intraoperative neurological complications. All cases obtained bony fusion, and no patient experienced recurrence of the disease during the follow-up. Furthermore, correction was satisfactorily preserved with a slight correction loss of 3.2°. According to the Frankel grade, neurological deficit was significantly improved in all patients.

When compared with current clinical practices in reported literatures, we are convinced that this procedure is more applicable for active spinal TB with kyphotic deformity in young children. Firstly, simultaneous posterior column osteotomy and posterior decompression allows for good spinal cord protection during the process of correction, minimizing the risk of neurological complications. Second, in the active stage of spinal TB, the anterior column is often released by infection. Furthermore, due to the good flexibility of spine in young children, SPOs of posterior column followed by intraoperative traction not only facilitate sufficient kyphosis correction but can also restore the length of anterior column. In addition, with the use of posterior instrumentation, immediate stabilization after correction can be accomplished at the first stage. Subsequently, the patient can change positions for anterior debridement with less threat to the spinal cord. Compounding to this, posterior instrumentation can decrease the risk of graft-related complications and improve fusion. Third, as we know, structural bone graft plays a significant role in anterior column reconstruction.^[29] However, unlike adults, young children provide limited recipient site for structural bone grafts. Therefore, strut bone grafting can be more reliable through an anterior approach under direct vision. Furthermore, an anterior approach allows for easy extrapleural or extraperitoneal access to the lesion, and exposure

can be much simpler in young children due to the relatively thicker pleura and peritoneum. Fourth, this combined approach provides a 3-column spinal fusion that can prevent the imbalanced spinal growth of children, which is important for long-term maintenance of the correction and reduction of instrumentation failure during growth.

5. Conclusion

For young children with active thoracic and thoracolumbar spinal TB with kyphotic deformity, the SPO combined with anterior debridement and allogenic strut bone grafting is an effective and safe surgical technique that can achieve sufficient kyphosis correction with less risk of spinal cord injury. Compared with other approaches, it is a simple procedure that allows for easy access to thorough debridement and anterior column reconstruction.

References

- World Health Organization. Global Tuberculosis Report 2016. Geneva: World Health Organization; 2016. Available at: http://www.who.int/tb/ publications/global_report/en/. Accessed 13 October 2016.
- [2] Jain AK. Tuberculosis of the spine: a fresh look at an old disease. Bone Joint Surg Br 2010;92:905–13.
- [3] Jain AK, Dhammi IK. Tuberculosis of the spine: a review. Clin Orthop Relat Res 2007;460:39–49.
- [4] Rajasekaran S. The problem of deformity in spinal tuberculosis. Clin Orthop Relat Res 2002;398:85–92.
- [5] Mushkin AY, Kovalenko KN. Neurological complications of spinal tuberculosis in children. Int Orthop 1999;23:210–2.
- [6] Rajasekaran S. Buckling collapse of the spine in childhood spinal tuberculosis. Clin Orthop Relat Res 2007;460:86–92.
- [7] Moon MS, Kim I, Woo YK, et al. Conservative treatment of tuberculosis of the thoracic and lumbar spine in adults and children. Int Orthop 1987;11:315–22.
- [8] Rajasekaran S. The natural history of post-tubercular kyphosis in children. Radiological signs which predict late increase in deformity. J Bone Joint Surg Br 2001;83:954–62.
- [9] Li L, Zhang Z, Luo F, et al. Management of drug-resistant spinal tuberculosis with a combination of surgery and individualised chemotherapy: a retrospective analysis of thirty-five patients. Int Orthop 2012;36:277–83.
- [10] Al-Sebai MW, Al-Khawashki H, Al-Arabi K, et al. Operative treatment of progressive deformity in spinal tuberculosis. Int Orthop 2001;25: 322–532.
- [11] Jain AK. Treatment of tuberculosis of the spine with neurologic complications. Clin Orthop Relat Res 2002;398:75–84.
- [12] Chen WJ, Wu CC, Jung CH, et al. Combined anterior and posterior surgeries in the treatment of spinal tuberculous spondylitis. Clin Orthop Relat Res 2002;398:50–9.
- [13] Issack PS, Boachie-Adjei O. Surgical correction of kyphotic deformity in spinal tuberculosis. Int Orthop 2012;36:353–7.

- [14] Eisen S, Honywood L, Shingadia D, et al. Spinal tuberculosis in children. Arch Dis Child 2012;97:724–9.
- [15] Frankel HL, Hancock DO, Hyslop G, et al. The value of postural reduction in the initial management of closed injuries of the spine with paraplegia and tetraplegia. Paraplegia 1969;7:179–92.
- [16] Bridwell KH, Lenke LG, McEnery KW, et al. Anterior fresh frozen structural allografts in the thoracic and lumbar spine. Do they work if combined with posterior fusion and instrumentation in adult patients with kyphosis or anterior column defects? Spine (Phila Pa 1976) 1995; 20:1410–8.
- [17] Rajasekaran S, Prasad Shetty A, Dheenadhayalan J. Morphological changes during growth in healed childhood spinal tuberculosis: a 15-year prospective study of 61 children treated with ambulatory chemotherapy. J Pediatr Orthop 2006;26:716–24.
- [18] Hodgson AR, Stock FE, Fang HS, et al. Anterior spinal fusion: the operative approach and pathological findings in 412 patients with Pott's disease of the spine. Br J Surg 1960;48:172–8.
- [19] Medical Research CouncilA 10-year assessment of a controlled trial comparing debridement and anterior spinal fusion in the management of tuberculosis of the spine in patients on standard chemotherapy in Hong Kong. Eighth Report of the Medical Research Council Working Party on Tuberculosis of the Spine. J Bone Joint Surg Br 1982;64:393–8.
- [20] Hassan K, Elmorshidy E. Anterior versus posterior approach in surgical treatment of tuberculous spondylodiscitis of thoracic and lumbar spine. Eur Spine J 2016;25:1056–63.
- [21] Bailey HL, Gabriel M, Hodgson AR, et al. Tuberculosis of the spine in children. Operative findings and results in one-hundred consecutive patients treated by removal of the lesion and anterior grafting. J Bone Jt Surg Am 1972;54:1633–57.
- [22] Rajasekaran S, Soundarapandian S. Progression of kyphosis in tuberculosis of the spine treated by anterior arthrodesis. J Bone Joint Surg Am 1989;71:1314–23.
- [23] Sundararaj GD, Behera S, Ravi V. Role of posterior stabilisation in the management of tuberculosis of the dorsal and lumbar spine. J Bone Joint Surg Br 2003;85:100–6.
- [24] Huang QS, Zheng C, Hu Y, et al. One-stage surgical management for children with spinal tuberculosis by anterior decompression and posterior instrumentation. Int Orthop 2009;33:1385–90.
- [25] Klockner C, Velencia R. Sagittal alignment after anterior debridement and fusion with or without additional posterior instrumention in the treatment of pyogenic and tuberculous spondylodiscitis. Spine 2003; 28:1036–42.
- [26] Talu U, Gogus A. The role of posterior instrumentation and fusion after anterior radical debridement and fusion in the surgical treatment of spinal tuberculosis: experience of 127 cases. J Spinal Disord Tech 2006;19:554–9.
- [27] Wang XB, Li J, Lü GH, et al. Single-stage posterior instrumentation and anterior debridement for active tuberculosis of the thoracic and lumbar spine with kyphotic deformity. Int Orthop 2012;36:373–80.
- [28] Zhang HQ, Wang YX, Guo CF, et al. One-stage posterior focus debridement, fusion, and instrumentation in the surgical treatment of cervicothoracic spinal tuberculosis with kyphosis in children: a preliminary report. Childs Nerv Syst 2011;275:735–42.
- [29] Ozdemir HM, Us AK, Oğün T. The role of anterior spinal instrumentation and allograft fibula for the treatment of pott disease. Spine (Phila Pa 1976) 2003;28:474–9.