Childs Nerv Syst (2016) 32:1495–1502
DOI 10.1007/s00381-016-3152-9

ORIGINAL PAPER

One-stage posterior focus debridement, interbody grafts, and posterior instrumentation and fusion in the surgical treatment of thoracolumbar spinal tuberculosis with kyphosis in children: a preliminary report

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Received: 16 November 2015 / Accepted: 19 June 2016 / Published online: 8 July 2016

Abstract
Purpose The purpose of this study was to determine the efficacy and feasibility of surgical management of children with thoracolumbar spine tuberculosis with kyphosis by using one-stage posterior focus debridement, interbody grafts, and posterior instrumentation and fusion.
Methods From October 2010 to September 2013, 21 children with thoracolumbar spinal tuberculosis accompanied by kyphosis were treated with one-stage posterior decompression, interbody grafts, and posterior instrumentation and fusion. There were 13 males and 8 females, aged from 7 to 13 years old (average age 9.9 years). The mean follow-up was 34 months (range26–48 months). Patients were evaluated before and after surgery in terms of ESR, neurologic status, pain, and kyphotic angle.
Results Spinal tuberculosis was completely cured, and the grafted bones were fused in all 21 patients. There was no recurrent tuberculous infection. ESR got normal within 3 months in all patients. The ASIA neurologic classification improved in all cases. Pain relief was obtained in all patients. The average preoperative kyphosis was 29.7° (range 12–42°) and decreased to 5.5° (range 2–10°), postoperatively. There was no significant loss of the correction at the latest follow-up.
Conclusions Our results show that one-stage posterior decompression, interbody grafts, and posterior instrumentation and fusion were an effective treatment for children with thoracolumbar spinal tuberculosis. It is characterized as minimum surgical trauma, good neurologic recovery, good correction of kyphosis, and prevention of progressive kyphosis.

Keywords Thoracolumbar · Spine tuberculosi · Kyphosis · Children · Posterior approach

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Introduction

Children who are predisposed to tuberculosis have suffered an increased incidence of bone and joint tuberculosis over the past decade. Severe kyphosis is more often a complication in childhood spinal tuberculosis than that in adult disease [1]. Severe kyphosis is a major cosmetic and psychological disturbance in a growing child and can result in secondary late-onset paraplegia [1]. So much attention should be attached to early diagnosis and therapy for children with spinal tuberculosis to prevent the spinal tuberculosis from severe kyphosis. Effective antituberculous chemotherapy has largely made uncomplicated spinal tuberculosis a medical disease, but it has been found to be ineffective in preventing the progression of the deformity [2, 3]. It is believed that surgical treatment should be adopted in the management of children with spinal tuberculosis [4, 5]. Various methods have been applied for children with thoracolumbar spine tuberculosis including anterior approach, single-stage anterior and posterior approach, or staged anterior and posterior approach [6–8]. However, few studies have been reported on the treatment of children with spinal tuberculous accompanied by kyphosis by using one-stage posterior decompression, interbody grafts, and posterior transpedicular instrumentation and fusion. The purpose of this study is to evaluate the effectiveness and safety of one-stage posterior focal debridement and spinal canal decompression, instrumentation, and bone graft fusion for children with thoracolumbar spinal tuberculosis accompanied by kyphosis. This is the preliminary report of our study.

Materials and methods

Basic information

The Hospital Ethical Committee approved the study. From October 2010 to September 2013, 21 consecutive children with spinal tuberculosis on thoracolumbar (T10-L2) spine were enrolled in our hospital. Inclusion criteria was below (1) vertebral body collapse and unstable vertebra caused by bone destruction; (2) spinal cord compressed by the abscess, caseous necrosis material, progressively exacerbated clinical neurologic symptoms; (3) obvious kyphosis (SI>15°) or ongoing deformities becoming more serious; (4) larger porosis and dead bone, especially around the intervertebral. One-stage posterior decompression, interbody grafts, and posterior transpedicular instrumentation and fusion were performed on them. All patients were admitted due to severe back pain and paraparesis, with mean symptom duration of 8.2 months (range 6 to 11 months). There were 13 males and 8 females, aged from 7 to 13 years old (average age 9.9 years). Diagnosis was based on clinical and hematological criteria. All patients had the symptoms of tuberculosis, such as weight loss, low fever, and fatigue. All patients were evaluated by anteroposterior and lateral radiography for vertebral collapse or angular deformity, by computerized tomography (CT) or by magnetic resonance imaging (MRI) for detection of granulation tissue and its spreading, degrees of spinal compression for bony destruction, and canal compromise. Radiographic findings of tuberculous spondylitis included the following: intraosseous and paraspinal abscess formation with disk preservation, subligamentous spreading of infection, vertebral body destruction and collapse, and extension in the spinal epidural space. As outlined in Table 2, involved levels were observed at T11-T12 in 6 cases, T12-L1 in 5 cases, L1-L2 in 6 cases, T10-T12 in 1 case, and T11-L1 in 3 cases. Erythrocyte sedimentation rate (ESR) was used to evaluate whether the lesion was "active" or not and whether the disease was healed. The angle of the kyphosis was measured on lateral radiographs by drawing a line on the upper surface of the first normal vertebra above the lesion and one through the lower surface of the first normal vertebra below the lesion, measured with an average of 29.7° (range 12–42°). The classification of the American Spinal Injury Association (ASIA) Classification (Table 1) was used to assess the neurologic compromise function, resulting in two patients with grade B, four patients with grade C, nine patients with grade D, and six patients with grade E.

Preoperative procedure

Three to five weeks prior to the operation, the patients were administrated anti-tuberculosis drug with isoniazid (5~10 mg/kg/day with no more than 300 mg/day), rifampicin (5 to 10 mg/kg/day with no more than 300 mg/day), and ethambutol (15 mg/kg/day with no more than 500 mg/day). Preoperative halo traction plays an important role in partial correction of kyphosis deformity. The surgical plan was made on the basis of anteroposterior and lateral radiography, CT, and MRI. The operation was not performed until anemia and hypoproteinemia recovered and ESR returned to the normal level or had significant decrease.

Operative procedure

All patients were operated under general anesthesia in prone position. Through posterior midline approach, the lamina, facet joints, and transverse processes costotransverse articulations and medial ribs were exposed. Exposing the vertebral laminae of involved segments, the posterior pedicle screws were installed. The Vertex Reconstruction System (Sofamor Danek, Medtronic, USA) and Legacy Reconstruction System (Sofamor Danek, Medtronic, USA) were, respectively, used in these patients. Longer segmental fixation was preferred in the thoracolumbar junction, where flexion moment or a tendency to kyphosis was noticed, at least two above and one below the lesion. Transpedicular screws were also placed in the affected vertebrae if the upper part of the vertebrae is not destroyed by infection. A temporary rod on the mild side of the focus was stabilized to avoid spinal cord injury induced by instability of the spine during decompression and focal debridement. After removing spinous process of the affected vertebrae, unilateral costotransversectomy and resection of partial medial ribs (about 2 cm) at the more severe lesion or more abscess side of the affected vertebrae were to drain prevertebral abscess and expose diseased vertebral bodies. Unilateral partial laminectomy or hemilaminectomy according to the extent of spinal canal stenosis was performed preceded debridement of the affected intervertebral disks and vertebrae. If necessary, unilateral partial or total facetectomy or pediculectomy was also performed. To obtain a broader view, one spinal nerve on the focal side may be sacrificed in the thoracic levels. Then, corpectomy and discectomy were performed, and abscesses were evacuated. To achieve improved debridement, compression wash and negative pressure suction were alternatively performed by incubating the urethral catheter in the abscess cavity. Following completion of the corpectomy and debridement, correction of the deformity was accomplished by installing permanent rods with compression maneuvers under vision. Spinal cord monitoring, including motor-evoked and spinal cord-evoked potential, was also used. Posterior interbody grafts were applied after making sure that there

Table 1 American Spinal Injury Assosiation Impairment Scale

A	Complete: no motor or sensory function is preserved in the sacral segments S4-S5.
B	Incomplete: sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-S5.
C	Incomplete: motor function is preserved below the neurologic level, and the majority of key muscles below the neurological level have a muscle grade less than 3.
D	Incomplete: motor function is preserved below the neurologic level, and the majority of key muscles below the neurologic level have a muscle grade of 3 or more.
E	Normal: motor and sensory function is normal.

was no compression of the spinal cord. For all patients, autogenous bone or an allograft of the proper size was selected for posterior fusion on the segments that underwent decompression and focal debridement. Treatment with 1.0 g streptomycin and 0.2 g isoniazid was locally administered; drainage and incision sutures were performed postoperatively. The biopsy specimens were sent for pathologic study. The average operative time was 236 min (range 192–312 min). The average blood loss was 320 ml (range 220–530 ml) which increased with the operative time.

Postoperative procedure

The drain was usually removed when drainage flow was less than 50 ml/24h. After surgery, patients were allowed to ambulate after remaining supine for 14 to 20 days postoperatively. All patients were treated with antituberculous chemotherapy regimen mentioned above for 12–18 months postoperatively. The braces were continually used for 6 to 8 months postoperatively. The mean period of follow-up was 34 months (range 26–48 months).

Follow-up index and statistical analysis

For all cases, the following indexes were recorded preoperatively, postoperatively, and during the follow-up: (1) localized spinal deformity was measured as the angle between the upper and lower endplates of the collapsed vertebral levels; (2) neurologic status; (3) ESR. Using SPSS 13.0 software, kyphosis angle and ESR were statistically analyzed by paired *t* test pre operatively, postoperatively, and during the follow-up. Discrepancy of the normal distribution was analyzed by a rank-sum test with a significance level of 0.05.

Results

Basic condition

Wounds were healed without chronic infection or sinus formation. No complications related to instrumentation occurred. One patient showed symptoms of pleural effusion postoperatively. These symptoms disappeared after the patients were performed anti-inflammatory and symptomatic supportive treatment for 2 weeks.

Neurologic function and pain

Neurologic deficits in all patients were improved at final follow-up examination. The results were evaluated by ASIA classification: five cases improved by two grades and ten cases improved by one grade (Table 2). All patients had pain relief. All patients achieved bone fusion.

Kyphosis deformity

The kyphosis angle was 12–42° with mean kyphosis angle of 29.72° preoperatively; it significantly decreased to 2–10° with mean kyphosis angle of 5.5° postoperatively ($P < 0.001$) (Fig. 1; Table 2). The kyphosis angle was 4–12° with mean kyphosis angle of 6.7° at final follow-up, whose loss of correction was only 1.2°. It still significantly improved in comparison to the preoperative measurements ($P < 0.001$) (Table 2). The average of correction of kyphosis deformity was 66.7 %.

Erythrocyte sedimentation rate

The average pretreatment ESR was 57.2 mm/h (42 to 78 mm/h), which got normal within 3 months in all patients. There was statistically significant difference between preoperative ESR and 3-month follow-up ESR ($P < 0.001$) (Table 2).

Discussion

Children with spinal tuberculosis is predisposed to infect the vertebral body. Infection of the vertebral body causes destruction and collapse of the vertebra leading to kyphosis and sagittal imbalance [9]. Thoracolumbar lesions are the junction region of thoracic lesions and lumbar lesions. It had the highest propensity to develop morphological changes that predispose to deformity progression in children with spinal tuberculosis [10]. So, early therapy becomes very important in the treatment of children with thoracolumbar spinal tuberculosis. In general, antituberculosis chemotherapy is the mainstay in

Table 2 Clinical data on all patients

Case no.	Age (year)/Gender	Level	Kyphosis angle(°)			ASIA		ESR(mm/h)	
			Preop	Postop	Final follow-up	Preop	Final follow-up	Preop	Three months postop
1	7/M	T11-T12	41	9	10	B	D	46	7
2	9/F	T12-L1	21	6	7	C	E	60	12
3	11/M	T11-T12	34	7	8	D	E	56	8
4	10/F	T12-L1	15	2	4	D	E	42	6
5	8/M	T11-T12	23	2	5	E		62	10
6	12/M	T12-L1	35	7	8	C	D	72	12
7	12/F	L1-L2	24	3	5	D	E	75	13
8	9/M	T11-T12	42	10	12	B	D	78	14
9	13/M	T11-L1	40	9	10	C	E	49	9
10	10/F	T11-T12	32	7	9	E		45	8
11	7/F	T12-L1	27	5	8	C	E	67	10
12	8/M	L1-L2	37	6	9	D	E	65	9
13	10/M	T12-L1	34	5	6	E		54	8
14	9/M	L1-L2	12	2	2	D	E	70	12
15	13/M	T11-T12	29	3	3	D	E	58	9
16	7/F	T11-L1	39	6	7	D	E	73	12
17	9/F	L1-L2	40	9	9	E		47	9
18	11/F	T10-T12	28	6	7	D	E	66	10
19	12/M	L1-L2	38	7	8	E		71	14
20	10/M	L1-L2	14	2	2	E		69	12
21	12/M	T11-L1	18	3	3	D	E	59	10

the management of spinal tuberculosis. Although antituberculosis chemotherapy effectively inactivates the tuberculosis, vertebral collapse may continue. So, kyphosis which will require extensive reconstructive procedures is a common complication of the spine tuberculous in patients treated by chemotherapy alone [11, 12]. Surgery in tuberculosis spondylitis is generally considered to be an adjuvant of effective chemotherapy. Indications for surgery are neurologic deficits, spinal instability, severe and/or progressive kyphosis, no response to chemotherapy treatment, and non-diagnostic and large paraspinal abscess [4, 5].

Various surgical methods have been applied to treat spinal tuberculosis, but few literatures on the use of one-stage posterior decompression, interbody grafts, and transpedicular instrumentation and fusion in the treatment of children with thoracolumbar spinal tuberculosis have been reported. Combined with standard chemotherapy, early reconstruction of spinal stability plays an important role in surgical management of spinal tuberculosis. Regular chemotherapy and spinal stability maintenance are the prime strategy for treatment of any spinal tuberculosis, and they cannot be separated from each other. Because the inflammation is usually located in the anterior aspect, anterior debridement and strut grafts were often recommended by some surgeons [13]. This method can be direct access to the disease focus and have effective debridement of the lesion and decompression of the spinal cord. Hodgson and Stock [14, 15] used an anterior approach with chemotherapy and reported a 93 % fusion rate, with only 1 relapse among 48 patients. The anterior surgical approach permits direct debridement and strut grafting in compression. Progressive kyphosis from posterior element overgrowth was an initial concern regarding children with spinal tuberculosis treated with anterior fusion [16]. However, Baker et al. [17] suggested that the posterior elements fuse 3 to 8 months after anterior fusion. They thought that another posterior fusion should be supplemented in children with spinal tuberculosis to prevent progressive kyphosis following anterior fusion. Altman et al. [18] believed that timing of the anterior decompression and fusion followed by posterior fusion within 3 months is important in preventing postoperative progression of the kyphosis. Good results have been shown in this study with treatment of severe spinal tuberculosis in children by anterior and posterior spinal fusion without instrumentation. However, this procedure sometimes hasn't been successful in preventing the progression of kyphosis and can't correct the preexisting severe kyphosis [13, 16]. In view of these complications of this method, additional posterior instrumentation which is applied to reduce kyphotic deformities and to prevent

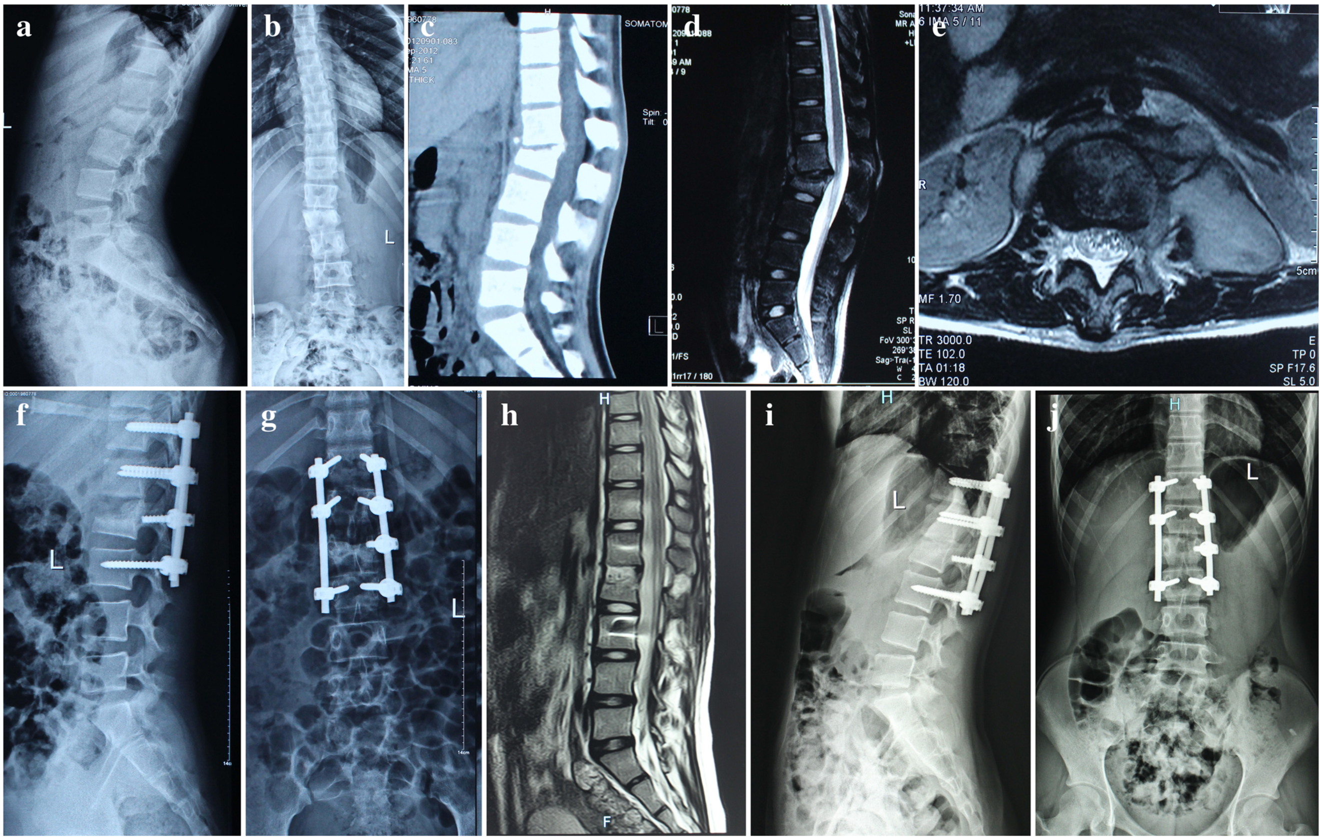

Fig. 1 **a–e** A 12-year-old girl who had tuberculosis in L1-L2. Preoperative X-ray showed that kyphosis was 24° and the vertebral body collapse on L1-L2. MRI and CT showed that lesion around vertebral body of L1-L2 developed a great abscess with marked bony destruction. **f–g** Postoperative X-ray showed that kyphosis was 3°. **h** Follow-up MRI showed complete resolution of epidural abscess. **i–j** Final follow-up radiographs showed good bone fusion and maintenance of the correction

correction loss and graft failure was applied by some surgeons [6]. But, this combined procedure has a longer operation time, longer healing duration, and higher surgical trauma.

Nowadays, authors have tended to emphasize the importance of tailoring the management options to the individual with spinal tuberculosis. Also, as posterior instrumentation has become popular as a technique for correction of kyphotic deformity and more effective regimens of antituberculous chemotherapy have become available [19], one-stage posterior procedure becomes an alternative treatment of spinal tuberculosis. Mehta et al. [19] and Guven et al. [20] also reported satisfactory function of stabilization and kyphosis prevention after posterior transpedicular debridement and instrumented fusion without anterior debridement. GÜzey et al. [21] and Rath et al. [22] reported good neurologic results after posterior debridement and internal fixation in patients with neurologic impairment due to tuberculosis spondylitis, which is similar to the best results obtained via anterior decompression. Chen et al. [23] extended this technique in patients with advanced spinal tuberculosis.

In our series, we adopted one-stage posterior debridement, graft fusion, and long segment instrumentation in the treatment of thoracolumbar spinal tuberculosis in children. We preferred the posterior approach because minimally invasive surgery has become the development direction of treatment for children spinal tuberculosis [24]. A mere posterior approach for debridement, fusion, and instrumentation often limits the extent of surgical intervention to a minimum [22]. This approach far away from the mediastinum and pleural cavity is characterized as the simple approach. It avoids high anesthetic risk of anterior procedure with possibility to develop postoperative severe complication. The approach described here creates enough operating space through resection of one side of the facet joint, the diapophysis, costosternal joints, and small rib portions, allowing operation on the vertebral body at a 270° angle under direct visualization of the outside of the dura mater for complete removal of the focal TB without injuring the spinal cord. Moreover, because there is no advantage of radical surgery over debridement in terms of correcting a kyphotic deformity when an extensive spinal lesion is present [25] and because anterior radical resection may destroy the anterior growth and limit the capacity for spinal remodeling [26], we only removed focal tissues and tissues in focal edges, especially the sclerotic walls, caves, dead spaces, and so on, which can result in an incurative or recurrent result for tuberculosis and reach the subnormal substance of bones between normal cancellous bones and pathologic bones, and retained the growth plate. After that, postoperative regimens of antituberculosis drugs are able to effectively enter pathologic sites to kill tuberculomyces and recover the areas of bone that are infiltrated by, but not necrotic with, tuberculous disease, and resolve possible remaining abscess which cannot be completely drained by posterior decompression [27, 28]. In our study, neurologic function of 15 patients with paraparesis was significantly improved postoperatively.

Additionally, because the thoracolumbar junction where flexion moment or a tendency to kyphosis was noticed was predisposed to the failure of grafts due to the instability associated with the transitional zone of the region [29], the long posterior transpedicular instrumentation which acts as a tension-band device can provide rigid segmental fixation along three columns of the spine and effectively corrected kyphosis deformity [30]. It is also not only to prevent loss of correction of the vertebral alignment in the long term but also to provide immediate relief of pain due to spinal instability [31]. And, indirect decompression during deformity correction and stabilization with posterior instrumentation was beneficial to improve the neurologic function [23]. Meanwhile, posterior interbody grafts and a supplementary posterior short segment fusion were performed to guarantee an equal growth of the anterior and posterior height after effective posterior correction, which prevent an increase in kyphosis during the growth period [6, 10, 26], and to provide structural support. In our study, all children obtained good correction after surgery with correction rate that was 66.7 %. And, there was no obvious correction loss during follow-up.

During surgical intervention to correct spinal deformities using metallic fixation, there is a risk of neurologic damage. Prevention of damage to the spinal cord is very important. Once damage has been done, it is often irreversible. Children are as much at risk of neurologic deterioration during various neurosurgical procedures as adults and benefit as much from intraoperative neurophysiological monitoring [32]. In addition, the presence of a preexisting neurologic deficit may also predispose the complex spinal surgery patient to iatrogenic neurologic deficits [32, 33]. So, intraoperative neurophysiological monitoring was used in our study. The goal of intraoperative electrophysiologic monitoring is to provide early identification of potential neurologic injury in an effort to avert postoperative deficit by assessing accurately and continually the neurologic structures placed at risk during surgery. The first electrophysiologic monitoring method used during spinal surgery was the somatosensory-evoked potential (SEP). SEP monitoring is of value in assessment of the functional integrity of sensory pathways leading from the peripheral nerve, through the dorsal column and to the sensory cortex. Reports of false-negative outcomes when using only SEP monitoring illustrated the need for additional neurologic information during surgery [34]. Monitoring of motor-evoked potentials (MEPs) is the most appropriate technique to assess the functional integrity of descending motor pathways in the spinal cord. SEPs cannot provide reliable information on the functional integrity of the motor system (for which MEPs should be used) [34]. In our study, we applied both SEP and MEP intraoperative monitoring for all patients. This combination provided higher sensitivity and positive and negative predictive values than each single modality alone [33]. It is a safe, reliable, and sensitive method to detect and reduce injury to the spinal cord. Sensory and motor pathways can be independently assessed during surgery, the number of false negative is reduced to zero, and there is probably a positive influence on the final postoperative outcome [35]. Furthermore, deterioration of SEP and MEP intraoperative monitoring is mostly incremental, giving the surgeon the opportunity to alter the surgical procedure whenever warning changes occur and before these become irreversible [36]. And, stable intraoperative neurophysiological monitoring recordings are encouraging the surgeon to proceed with spinal procedures [33]. In this study, there were no neurologic complications and no evoked potential changes. Normal evoked potential monitoring in these instances had the double function of reassuring the surgeon that spinal cord function was intact and in avoidance of the wake-up test. There were no false negatives with combined SEP and MEP monitoring.

Selecting the posterior-only approach requires the following criteria: less than two-section thoraciclumber TB, small paravertebral abscess, and a TB lesion that can be removed. One of the following situations were present in our patients: (1) vertebral body collapse and unstable vertebra caused by bone destruction; (2) spinal cord compressed by the abscess, caseous necrosis material, progressively exacerbated clinical neurologic symptoms; (3) obvious kyphosis (SI > 15°) or ongoing deformities becoming more serious; (4) larger porosis and dead bone, especially around the intervertebral.

One problem of our study is the best time for removal of the implants. Because of the plasticity of the immature spine during growth, we may risk further kyphosis, if the implants are removed too early. In view of the fact that the usage of pedicle screws is possible without adverse effects in the growing child [37, 38], we recommend at present to remove the implants after 18 years old. Of course, frequent follow-up, especially during the growth spurt, will be necessary.

In spite of the satisfactory results from our series, the authors acknowledge a few limitations. First, follow-up in our series was only good enough for short-term results, but was not long enough for the final result. The long-term follow-up for this procedure to further assess its application in the treatment of thoracolumbar spinal tuberculosis with kyphosis in children will be necessary. In addition, the small sample of patients limits the power of our conclusions, and a much larger, randomized controlled trial is required to elucidate the benefits and risks of our method. However, the data here may serve as preliminary results which can aid surgeons and patients decision-making, and in the design of future well-designed prospective studies.

Conclusions

One-stage posterior decompression, interbody grafts, and transpedicular instrumentation and fusion are an effective treatment for children with thoracolumbar spinal tuberculosis. It is characterized as minimum surgical trauma, good neurologic recovery, good correction of kyphosis, and prevention of progressive kyphosis.

Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflict of interest.

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