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Original Article

Spinal osteotomy for thoracolumbar tuberculosis complicated with kyphosis does not further shorten existing shortened spinal cord

Chang-Ying Sun[1], Shi-Jin Lu[1], Chao-Feng Guo[2], Dong Wei[1], Wei-Wei Pei[1], Bin Shi[1], Gao-lin Li[1], Yan-Jun Che[1]

[1]*Department of Orthopedics, Peace Hospital Affiliated to Changzhi Medical College, Changzhi 046000, Shanxi, China;* [2]*Department of Spine Surgery, Xiangya Hospital of Central South University, Changsha 410008, China*

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Abstract: Objective: This study aims to observe the efficacy of single posterior vertebral osteotomy and the debridement treatment of the active stage of thoracolumbar tuberculosis complicated with kyphosis deformity, and to determine whether the current shortened spinal cord would be further shortened after osteotomy. Methods: A retrospective analysis was conducted on 32 patients who were treated from 2009 to 2012. Patients were treated with single posterior vertebral osteotomy, debridement and internal fixation. VAS and ODI were used to evaluate lower back pain and nerve function. The TraumaCad™ system was used to detect local kyphotic angle and spinal height changes. Results: VAS and ODI scores were improved from preoperative 5.81±1.15 and 47.47±9.813 to postoperative 1.75±0.67 and 89.80±3.59%, respectively (*P*<0.01). Preoperative local kyphotic angle was 38.38°±13.60°, and was 7.47°±2.9° upon followed-up (*P*<0.01). Furthermore, the rate of shrinkage of the height of the spinal cord increased from preoperative 49.48±17.67% to 88.32±20.74%, with an increase of 37.32±12.77%. Correlations of the newly increased postoperative shrinkage rate between the preoperative shrinkage rate and local kyphotic angle were not remarkable, and R values were 0.535 and 0.512, respectively. Conclusion: Under the control of normative anti-tuberculosis drugs, single posterior debridement and spinal shortened osteotomic internal fixation can effectively treat patients with active thoracic and lumbar spinal tuberculosis complicated with kyphosis. Furthermore, the spinal cord was able to tolerate further vertebral shrinkage, and its length was not affected by the existing spinal cord shrinkage and kyphotic angle.

Keywords: Spine, spinal tuberculosis, posterior spinal osteotomy

Introduction

Spinal tuberculosis is the most common form of extrapulmonary tuberculosis. If the active spinal tuberculosis is not effectively controlled, the progression of this disease can lead to the collapse of the vertebral body and the rachiocyphosis [1]. Deformities and lesions cause spinal cord dysfunction in the active stage, and deformities can be progressively aggravated even though the lesions had been healed, which result in delayed neurological dysfunction [2]. Most active spinal tuberculosis can be cured by conservative treatment, but complicated kyphosis deformities have been one of the main indications for surgical intervention [3]. Common surgical approaches include debridement, intervertebral bone graft and instrument; and these can be implemented through one stage or staged surgery through anterior, posterior, combined anterior and posterior, and posterior-anterior-posterior approaches [4-6]. In the recent years, vertebral osteotomy has been gradually emphasized, because it can complete the debridement and deformity correction through a single posterior approach, contact for both ends of the transected bone can be directly attained by shortening, and no bone grafting in the lesions is required [7]. However, it remains need to be elucidated whether existing spinal cord shrinkage would have an effect on the further shortening of the spinal cord. These results are reported in this paper.

Materials and methods

Thirty-two patients treated in the Department of Orthopedics in our hospital from April 2009 to April 2012 were retrospective analyzed, in which 13 patients were male and 19 patients were female. Age range of patients was 17-55 years old, with an average age of 42 years old. The course of disease lasted from four months to six years. Furthermore, four patients were T_{10-11}, eight patients were T_{11-12}, nine patients were T_{12}-L_1, 10 patients were L_{1-2}, and one patient was T_{11}-L_2. Preoperative normative anti-tuberculosis treatment was carried out for more than two weeks; then, spine shortening osteotomy, debridement and pedicle fixation were implemented by single posterior approach. All patients had symptoms of active thoraco-lumbar tuberculosis such as lower back pain, fatigue, night sweats, afternoon fever, positive C-reactive protein and fast blood sedimentation rate. The defined diagnosis was made before the operation according to X-ray, CT and MRI results; and was confirmed by pathological examination during intraoperative excision. Mycobacterium tuberculosis in six patients were cultured using a common method, and were found to be all sensitive to ethambutol. All lesions were complicated with obvious dead bone and paravertebral abscess or psoas abscess. Three patients were complicated with gravity abscess, including two patients with chest wall abscess and one patient with lumbar triangle abscess. Furthermore, 27 patients underwent initial treatment, and a recurrent case of T_{12} tuberculosis occurred in one patient, in which paravertebral abscess relapsed one year after the implementation of one stage of posterior fixation, anterior radical debridement, and bone grafting. The time interval from normative anti-tuberculosis treatment to the operation was two weeks to six months, with an average time interval of 1.3 months. In addition, triple anti-tuberculosis drugs were preliminary given to patients, and quadruple anti-tuberculosis drugs were used for recurrent cases.

Indication selection

(1) Acute thoracolumbar spinal tuberculosis, and lesions were localized in 1-2 segments, with lower back pain, dead bone and abscess formation complicated with kyphosis deformity, or accompanied with the performance of spinal cord or nerve root compression; (2) normative anti-tuberculosis treatment for more than two weeks; (3) no surgical contraindication. The operation was performed by the same surgeon.

Surgical technique

After successful anesthesia, patients were taken the prone position, the position of the waist bridge was adjusted, and an incision was made at the posterior midline. The length of the incision depended on the length proposed to be fixed, which is usually in the levels of 2-3 vertebral bodies above and below the vertebral lession, which was proposed to perform the osteotomy, respectively; routinely disinfected, draped, the skin was cut open, the subcutaneous tissue, fascia and paraspinal muscle were cut open using an electric scalpel, with the two sides reaching the roots of the transverse process. Subsequently, the pedicle that was proposed to be fixed were routinely localized, the hole was enlarged if it was considered to be satisfactory, the transpedicle screws were implanted, and the *in situ* temporary fix rod was placed. The proposed osteotomic processus spinosus was resected, and the adjacent processus spinosus at the head end was partially resected. At the proximal gap of the vertebral lamina proposed to be resected, the yellow ligament and intervertebral foramen posterior bony structures (including the inferior articular process, and part of the lower lamina) were transversely bit off with a narrow mouth laminectomy rongeur; at the remote, along the direction of the facet joint the yellow ligament and inferior articular process were bit off with a V shape (at this stage, the corresponding nerve root should be visible and protected), and stanched the bleeding with a gelatin sponge. Next, the bone groove was prepared by the removal of the bony structure with the tip of the rongeur or drilled longitudinally along the connecting lines of the superior and inferior articular process, the vertebral lamina was held up by a towel clamp to prevent rebound, the adhesion between the dura and lamina was separated with a nerve stripper, and the lamina was performed with *en block* resection. The superior articular process of the vertebral body proposed to be osteotomic must be kept intact, which was the main indicator of exposure and osteotomy. However, the inferior articular process of the proximal vertebra and the vertebra proposed to be osteotomic was completely resected. The root of the transverse process was brokenoff with a bone chisel, and stripped to the place where it was connected with the vertebral body using a wide periosteal stripper along the pedicle axial. As a result, the superior articular process and the surroundings of the pedicle were freed. Bleeding was stanched with a gelatin sponge, bone wax was used for bone surface bleeding, and prepared for pedicle osteotomy. At this step, special retractors can be used for hemostasis, or hemostasis by filling in the cotton sheet and gelatin sponge. The superior articular process was bit away, the upper and lower edge of the pedicle were exposed, the upper and inner edge of the pedicle was indicated with a neural stripper but could not be stretched; along the axial upper edge of the pedicle and parallel to the upper end plate, the bone was cut with a straight bone scalpel that had the same width as the pedicle, osteotomy was implemented with the same method on the lower pedicle margin and on the ipsilateral posterior vertebral body margin, osteotomy was implemented with the special curved bone scalpel, scraped off the osteotomic bone of the vertebral pedicle, sucked the pus, and further scraped off the caseous tissue, dead bone, necrotic intervertebral disc and the granulation tissue in the tuberculose focus. Subsequently, the focus adjacent to the front of dura was separated with a nerve stripper and scraped, the osteotomy was completed consecutively on one side. The psoas abscess could be drained by blunt separation of the abscess cavity with fingers after osteotomy. Left and right transposition was carried out to place the temporary fixing rod *in situ*. The surgeon swapped position with the first assistant, and the osteotomy on the opposite side was completed with the same method. The middle of the two sides should be completely communicated when the osteotomy is finished. The spatial conformation and depth of the osteotomy can be detected by the nerve stripper. Loosed the temporary fixing device, made the leg straight, attention was given to the lumbar lordosis, tried to make the osteotomy surface involutorial with soft manipulation, and the pre-bent orthopedic stick was placed when no dura was compressed by the projecting bone tissue in the front and rear of the dura; then, further determined whether dural compression was present, as well as the involutorial condition of the osteotomy surface. The screw was tightened from up to down or from down to up one by one. According to the involutorial condition of the osteotomy, the gap of the bone was made to be further involutorial with the pressure device of the instrument, if necessary. Then, the lamina was repaired, which was implemented by the *en block* resection; then, implanted to the original place to be sure that there was no dural compression, made the lamina placed *in situ* stable by setting a horizontal chain, and the gelatin sponge was placed into the exposed dura. In general circumstances, no remarkable dural sac swelling occurred in grade 4 of the osteotomy; dural sac would be swelled in grade 5 and 6 of osteotomy, and expanded resection scope of the lamina would be required in this circumstance. The drainage tube was placed, and the incision was sutured layer by layer.

Postoperative treatment: Routine preventive antibiotics were used, anti-tuberculosis drug treatment was same with preoperation treatment, and anti-tuberculosis drugs were adjusted according drug sensitivity. The total course was 12 months for initially treated cases, and 18-24 months for recurrent cases. The drainage tube was removed after 24-72 hours. The first X-ray was taken before discharge. The patients should take proper ambulation by wearing a brace after four weeks in bed, but should mainly stay in bed and wear the brace for 3-6 months.

Curative effect observation: Followed-up once after operation in three, six, nine and 12 months, respectively; then, followed-up once every year, and review at any time for special circumstances. Follow-up mainly include: clinical manifestations, ESR, CRP, liver function, anteroposterior and lateral spinal X-ray, and CT examination at 12 months postoperation. Evaluation of lower back pain with VAS score; Lumbar function was evaluated with the Oswestry disability index (ODI) [8]. The formula for ODI scores improvement rate: improvement rate = (preoperative score - follow-up score)/ preoperative score × 100%. Sagittal deformity assessment: intersection angle of the extended lines of the normal proximal and distal endplates of the lesion vertelral body was measured with the Cobb method on a series of X-rays, and the lordosis was recorded as negative. Spinal shrinkage rate calculation (**Figure 1**): varied value of the middle column height of the local pathological segment and the related segment were measured with TraumaCAD software on the X-ray film. The spinal shrinkage rate of the pathological segment was calculated

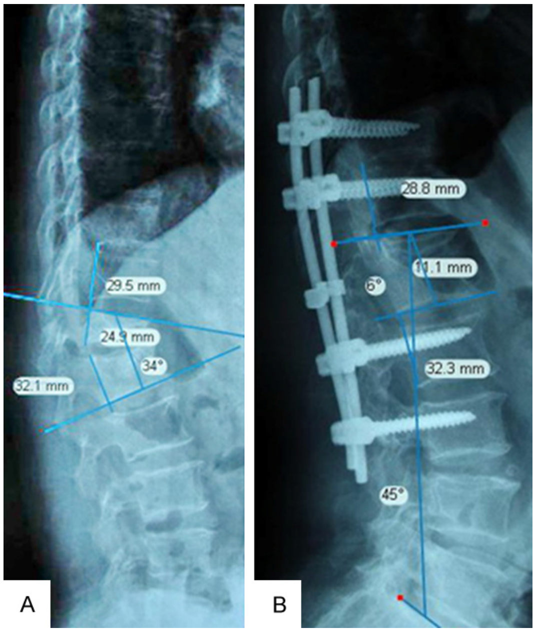

Figure 1. A: The preoperation measurement of shorted height of grade 4 osteotomy; B: The postoperation measurement of grade 4 osteotomy.

using the following method: (1) normal vertebral body and intervertebral disc height of the proximal end of the lesions; (2) normal vertebral body and intervertebral disc height of the distal end of the lesions; (3) height of pathological vertebral body and the corresponding intervertebral disc; (4) the theoretical height of the pathological segment before pathological changes was ([1] + [2])/2. Pathological segment shrinkage rate = ([4] - [3])/[4] × 100%, that is, [(theoretical value - actual value)/theoretical value] × 100%. Spinal fusion was evaluated by the Bridwell standard [9].

Statistical processing: data were statistically processed using SPSS 19 statistical software. Parameters before and after the operation were compared by paired *t*-test, changes of correlated parameters were implemented by Pearson's correlativity analysis. Inspection level a = 0.05.

Results

According to the vertebral osteotomy classification raised by Schwab [10], 21 cases were grade 4 (**Figure 1**), seven cases were grade 5 (**Figure 2**), and four cases were grade 6 osteotomy (**Figure 3**). Operation time was 248±29.78 minutes (200-320 minutes), the amount of intraoperation and postoperation blood transfusion was 1,226±113.19 ml (800-2,600 ml), and followed-up duration was 2.6±0.76 years (2-3.5 years). There was one case of intraoperative dural injury, which was repaired timely; in which postoperative cerebrospinal fluid leakage appeared, drained for 10 days, and then healed. One case had pleural injury, in which thoracic drainage was closed for three days and recovered. Five cases underwent local small incision drainage or puncture drainage for gravity abscess. There were no incision infection cases, and no nerve injury cases. The general conditions of all the cases improved gradually during the follow-up period, and clinical symptoms and signs disappeared. Blood sedimentation returned to normal after 4.31±1.19 months (3-6 months) postoperative. The total course of anti-tuberculosis drugs were 17.3±2.53 (15-18 months).

Lumbar function and lower back pain score

VAS pain and ODI scores gradually improved at postoperation, and during followed-up for half a year and two years, respectively; and the difference was statistically significant at each observation time point compared with that of preoperation ($P<0.05$) (**Tables 1** and **2**).

Local kyphotic angle changes

Local kyphotic angle remarkably improved when patients were followed-up at postoperation, half a year and two years, compared with that of preoperation; and the difference was significant ($P<0.05$). There were non-significant losses in pairwise comparisons when followed-up at postoperation, half a year and two years; and the difference were not significant ($P>0.05$) (**Tables 1** and **2**).

Spinal shrinkage rate changes

Calculated based on the pathological seg-ment theoretical value, preoperative spinal shrinkage rate was 49.48±17.67% (23-95%). Postoperative shrinkage rate at the time of last followed-up was (88.32±20.74%) (55.18%-146.01%), and the newly increased shrinkage rate was 37.32±12.77% (12%-65%). Among these, the preoperative spinal shrinkage rate in the patients underwent grade 4 osteotomy was 42.23±9.76% (32-56%). At the time of the last followed-up, shrinkage rate was 61.28±5.29%

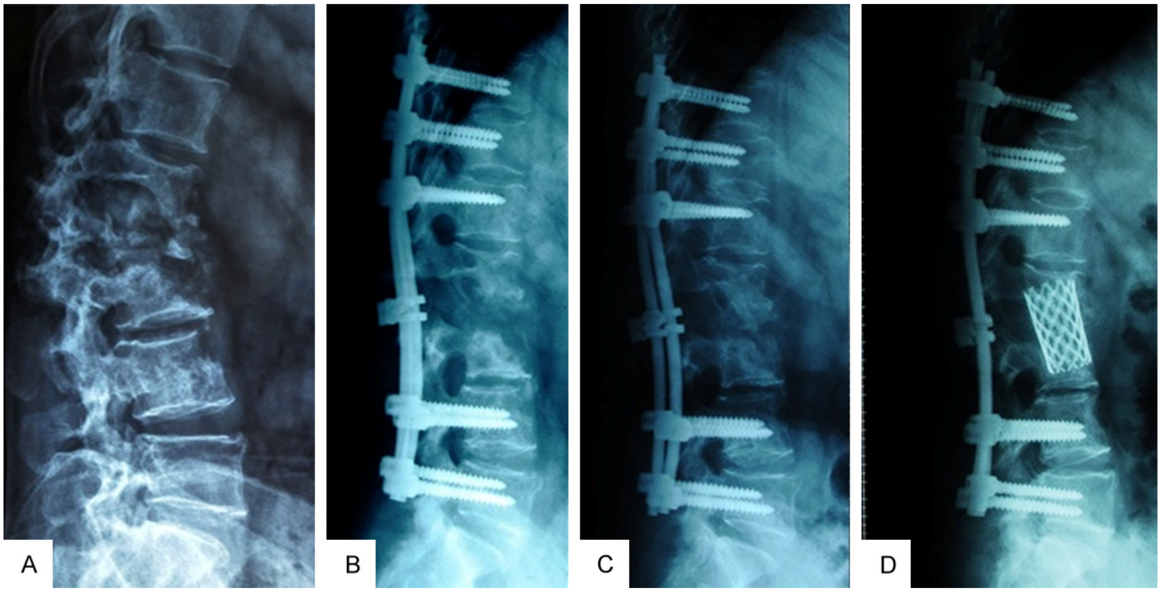

Figure 2. (A-D) were X-ray images of a case underwent grade 5 osteotomy at preoperation, postoperation, 12 months follow-up and the second stage of anterior approach reconstruction, Respectively. Compared to (B), the bone quality of (C) improved significantly.

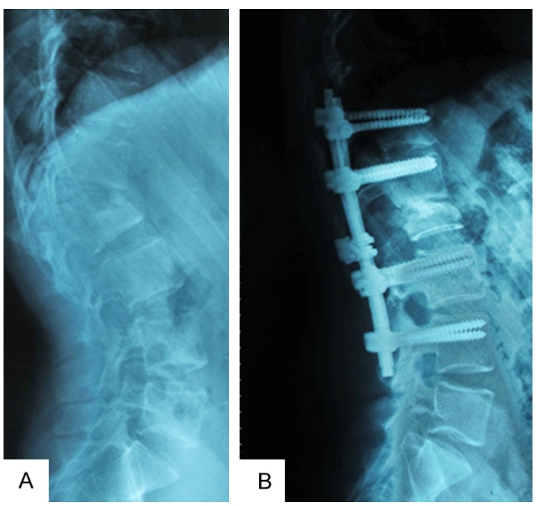

Figure 3. A. Grade 6 of osteotomy; B. 2 years after the grade 6 osteotomy.

(55-67%), and the newly increased shrinkage rate was 27.31±5.65% (22%-35%). The preoperative spinal shrinkage rate in the patients underwent grade 5 osteotomy was 60.93± 12.58% (38-83%). At the time of last followed-up, shrinkage rate was 91.84±14.34% (65-91%), and the newly increased shrinkage rate was 4.052±11.33% (26-65%). The preoperative spinal shrinkage rate in the patients underwent grade 6 osteotomy was 75.70±8.86% (67-98%). At the time of the last follow-up, shrinkage rate was 121.16±19.95% (94-147%), and the newly increased shrinkage rate was 36.67±18.18% (12-65%) (**Table 3**).

Correlation analysis on the newly increased spinal cord shrinkage rate versus preoperative existing shrinkage rate and local kyphotic angle

For the correlation test between the postoperative newly increased spinal cord shrinkage rate and the spinal cord shrinkage caused by the destruction of preoperative spinal tuberculosis lesions, F = 12.028, P = 0.002, correlation coefficient R = 0.535, R^2 = 0.286, and the correlation equation was: Y = 14.310 + 0.535X. The correlation was not remarkable. For the correlation test between the postoperative newly increased spinal cord shrinkage rate and local kyphotic angle of preoperation, F = 10.679, P = 0.003, correlation coefficient R = 0.512, R^2 = 0.263, and the correlation equation was: Y = 14.035 + 0.512X. The correlation was not remarkable (**Table 3**).

Observation of spinal fusion

With the extension of the postoperative time, it was found that the bony structure of the lesion was gradually cleared up in the films of X-ray and CT three-dimensional reconstruction, dur-

Table 1. Observing indexes at different time points

Project	Preoperative	After the operation	Follow up for 6 months	Follow up for 2 years
VAS pain score	5.81±1.15	3.84±1.05	2.41±0.87	1.75±0.67
Cobb angle	38.38±13.60	6.59±2.66	7.16±2.71	7.47±2.98
ODI score	47.47±9.813	11.78±3.94	6.78±1.74	3.97±0.97
Follow up ODI improvement rate	-	74.38±6.02	83.91±5.40	89.80±3.59

Table 2. Statistical analysis at different time points

Project comparison		Cobb angel		ODI score		VAS	
		MD	*P*	MD	*P*	MD	*P*
Preoperative	After the operation	39.781	0.000	35.688	0.000	1.968±0.238	0.000
	Followed up for 6 months	37.219	0.000	40.688	0.000	3.406±0.238	0.000
	Follow up for 2 years	33.906	0.000	43.500	0.000	4.063±0.237	0.000
After operation	Followed up for 6 months	-0.563	0.756	5.000	0.000	1.438±0.236	0.000
	Follow up for 2 years	-0.875	0.629	7.812	0.000	2.094±0.225	0.000
Follow up 6 months	Follow up for 2 years	-0.313	0.863	2.512	0.039	0.656±0.229	0.007

ing followed-up, and the bony density improved. The difference in bony fusion rates between these different osteotomy grade at half a year and two years of follow-up was not statistically significant ($P>0.05$). At follow-up for half a year, enlargement of the nail hole at the fixed distal pedicle was found in one patient (no bone graft in the gap of osteotomy during the surgery). The radiolucent zone was approximately 8 mm between the vertebral body, and bony density improved at both ends and diagnosed as grade IV fusion. Once again, the pathological vertebral body was exposed *via* the anterior approach, the fibrous tissue was found in the vertebral body during operation, the fibrous tissue was dissected, titanium mesh bone graft was implemented after the healthy bone above and below the pathological vertebral body was exposed, grade I bony fusion was achieved at follow-up after half a year (**Figure 2B-D**). The column posterior of all the patients achieved bony fusion at two years of follow-up. The bony fusion rates at grade I and II between vertebral body reached 87.50%. Grade III fusion rate was 12.5%, and a transparent gap of approximately 1-3 mm existed between the upper and lower fused vertebral body, which was the fibrous fusion. No grade IV fusion was found.

Discussion

The correction of spinal tuberculosis in the active stage complicated with kyphosis deformity is one of the main goals of surgical treatment [3, 6]. Before the advent of anti-tuberculosis drugs, the aim of spinal tuberculosis treatment was to make tuberculosis focus quiescent; and is usually dependent on the patient's own immune status. The development of anti-tuberculosis drugs makes it possible to heal tuberculosis, but these are often left with varying degrees of spinal deformity. With the advances in diagnostic methods, anesthesia, surgical techniques and equipment, instruments, it is possible to cure tuberculosis lesions with less or without spinal deformity [11]. At present, surgical methods include debridement, intervertebral bone graft and internal fixation; whcih can be completed in one or multiple stages of implementation through the approaches of anterior, posterior, and combinations of anterior and posterior, and posterior-anterior- posterior. Due to differences in the degree of deformity, the stage of the disease and age of patients, appropriate surgical methods should be selected according to specific circumstances [4, 5, 12].

The severity of spinal kyphosis deformity depends on the degree of damage of the vertebral body, the spinal segment involved and the age of patient. Severe deformities are more prone to occur in the thoracic vertebra, thoracolumbar spine, and child patient. Since there are physiological kyphosis and lordosis in the thoracic and lumbar spine individually, the tho-

Table 3. Correlation analysis on the newly increased spinal cord shrinkage rate versus preoperative existing shrinkage rate and local kyphotic angle

Project	Preoperative shortening rate (%)	The new short rate (%)	The cumulative shortening rate (%)	Cobb angle change (%)	
				Preoperative	After the operation
4 stage osteotomy	42.23±9.76 (32-56)	27.31±5.65 (22-35)	61.28±5.29 (55-67)	44.00±11.93 (28-62)	8.50±3.08 (5-14)
5 stage osteotomy	60.93±12.58 (38-83)	40.52±11.33 (26-65)	91.84±14.34 (65-91)	47.17±15.09 (30-65)	6.20±2.35 (2-10)
6 stage osteotomy	75.70±8.86 (67-98)	36.67±18.18 (12-65)	121.16±19.95 (94-147)	53.25±13.40 (33-75)	6.00±2.83 (3-11)
The average short rate	49.48±17.67 (23-95)	37.32±12.77 (12-65)	88.32±20.74 (55.18-146.01)	50.38±13.60 (28-75)	6.59±2.66 (2-14)

Note: Analysis of the correlation between postoperative newly increased shrinkage rate and preoperative shrinkage rate, F = 12.028, P = 0.002, correlation coefficient R = 0.535, R^2 = 0.286; Analysis of the correlation between postoperative newly increased shortening rate and preoperative Cobb angles, F = 10.679, P = 0.003, the correlation coefficient R = 0.512, R^2 = 0.263.

racolumbar connection lies between them, pathological segments have not been distinguished in most clinical studies, which makes the understanding and definition of severe spinal deformity not the same, and the range could be varied from more than 50 degrees to more than 75 degrees. According to the size of the kyphotic angle, some scholars have divided the kyphosis into: mild degree, with an angle of <30 degrees; moderate degree, with an angle of 30-60 degrees; severe degree, with an angle of >60 degrees [13]. Masini *et al.* [14] observed through an experimental model that when the kyphotic angle reached 50 degrees, the anteroposterior spinal stenosis appeared, and the dura got contact with the spinal cord. When the kyphotic angle reached 90 degrees, the spinal cord was extruded, and pressure in the spinal cord was exponentially increased.

For mild kyphosis deformity with no neurologic complications, the main reason for surgical treatment is that the deformity would be progressively aggravated during conservative treatment, and operative risk and the difficulty would be increased. The purpose of the operation is to prevent deformity progression by internal fixation, regardless the implementation of the approaches of single anterior, posterior, or one stage of anterior and posterior; the satisfactory results are achieved. Guven *et al.* [15] only performed the posterior fused fixation and drug treatment for anti-tuberculosis, and no meaningful foci debridement was performed for the patients. During the 10 years of followed up, 98% of the 87 patients were cured. Malhar [16] *et al.* attained similar results.

Although the adult vertebral body of the thoracolumbar tuberculosis was severely damaged sometimes, it does not produce severe kyphosis deformity, but moderate deformity was common, due to anatomical and biomechanical reasons and the surgical treatment through the approaches of anterior, posterior and anterior-posterior or posterior-anterior have been reported with disputes [3, 4]. Spontaneous fusion in the facet joint, osteoporosis and bone defect were common in patients with longer disease courses. There was difficulty in the correction of kyphosis deformity through the anterior approach and placement of the internal fixture. However, the foci debridement, anterior reconstruction and kyphosis correction can be performed by one stage of posterior-anterior or anterior-posterior surgery with satisfactory results; but, the operative trauma was great, and intraoperative posture changes prolonged operation time and increased the chance of contamination. Therefore, osteotomy, debridement and internal fixation through the simple posterior approach have been gradually recognized [16] for its unique characteristics, such as: residual bone does not require any form of dressing after debridement, vertebral osteotomic end was directly fitted accompanied with kyphosis correction, and there was no intralesional graft retention.

The most osteotomy cases were 1.5 vertebra and two discs (grade 6 osteotomy). In majority of cases, the osteotomy involved parts of the vertebral plus one intervertebral disc (grade 4 osteotomy), the average newly increased shrinkage was 36.67±18.18% based on the original spinal shrinkage. One case had T_{11} to L_4 multi-segment lesions, bone defection at $L_{1\text{-}3}$ was more serious, kyphosis deformity was 33 degrees. After resection of L_2 vertebrae, kyphosis correction (5 grade osteotomy), a huge bone defect still remained and anterior titanium mesh bone graft reconstruction was performed at one year post operation. The author considers that if a posterior-anterior surgery in one stage was performed in such patients, after anterior foci debridement, bone defects left by residual cavity dressing would be more than two vertebral segments, and the reconstruction of the graft bone would be very difficult. However, when patients underwent posterior shortening osteotomy and foci debridement, systemic conditions would be improved significantly. When the bone was reconstructed in the second stage of anterior titanium mesh bone graft, bone defects were shortened, bony quality was improved and reconstruction surgery became easier (**Figure 2**). In addition, among these cases, the newly increased shrinkage rate of the grade 5 osteotomy was more than in grade 6 osteotomy. The reason was that existing shrinkage before the operation of grade 5 was less, and intraoperative osteotomy was relatively more. However, it was double segmental osteotomy in grade 6 osteotomy, and one of the vertebral bodies had been serious shortened due to the absorption of the destroyed bone.

In the kyphotic spine, the anterior and middle columns and the ventral spinal cord had been shortened, and the posterior column and the dorsal spinal cord were close to the original height. After spinal shortening and correction of deformity, the spinal cord would be distorted. The more the deformity was corrected, the more serious the dorsal spinal cord twisted. However, the extent of shrinkage that the spinal cord could tolerate remains unclear. It needs to be further elucidated whether existing spinal cord shrinkage would influence the osteotomic spine to be further shortened, and the extent of further shrinkage that the spinal cord could tolerate. The experimental study on spinal shrinkage indicate that spinal cord function would not be affected if the shrinkage was not more than 2/3 of the vertebral body height. If this danger scope needs to be exceeded, total laminectomy of the superior and inferior adjacent vertebra were required to prevent spinal cord twisting and compression [17, 18]. However, in the experiment, the resected vertebra was normal, the anterior and posterior resection of the vertebra was equal, and the shrinkage of the anterior and posterior spinal cord was same. These were different from actual clinical situations. Wang Yan *et al.* [19] corrected a severe tuberculous kyphosis by double segmental osteotomy; although, in some cases, anterior bone graft reconstruction was required. In the patients of this group, although the preoperative spinal cord has been shortened, in order to obtain an osteotomic end-to-end involutorial, further intraoperative shrinkage was implemented on the spinal cord. The newly increased shrinkage could be up to 65% of the vertebral segments, which was close to the numerical range of the above listed experimental study. The statistical analysis indicated that the newly increased shrinkage had no significant correlation with the existing shrinkage of the pathological segments and kyphotic angle. This suggests that the vertebra could still tolerate further shortening in the existing spine shrinkage, and the severe kyphosis deformity could be corrected by the spinal shrinkage [19]. The possible reason may be that when spinal tubercular kyphosis slowly occurred, the spinal cord generated a tolerance to the shrinkage through sliding and shortening mechanism [18].

After posterior spinal shortening osteotomy, the point-like bone healing or fibrous bone healing were the main forms, since there were no bone grafts between vertebral bodies. However, the stability of the fusion was confirmed by the fusions between the posterior laminas and the strong pedicle fixation. In order to perform the posterior column fusion, we bridge the upper and lower laminae spaces produced by spine shortening osteotomy with the whole vertabral lamina resected by the *en block* technique. In grade 4 osteotomy, the *in situ* re-plantation of a single complete resection of the lamina could meet these demands. When more than one vertebral lamina was resected, the lamina could not be replanted. If the gap left between the vertebral bodies could not be involutorial, an anterior column reconstruction was required, which could be performed by the implantation of autogenous bone or titanium mesh bone graft or by the second stage of anterior approach reconstruction. Although there was no breakage of internal fixation in patients in this group during the follow-up period, long-term stability of the internal fixture may be lost. Thus, followed-up observation is required, especially for cases that failed to perform laminae replantation *in situ*.

The limitations of this study are: (1) due to the limitation of a direct measurement method for spinal shrinkage, the author chose alternative methods of measuring the middle spinal column height; (2) affected by the internal fixture, no reliable evaluation standard for the fusion of lamina replantation *in situ*; (3) when operations were performed on the recurrent lesion or its adjacent segment that has healed for years, due to intraspinal conglutination, and reduced tolerance to spinal cord shrinkage, the spine was easy to be damaged in operation. In one recurrent case of this group, dural injury occurred in the laminectomy, and no adverse effects on the prognosis were found after timely repair.

Disclosure of conflict of interest

None.

Address correspondence to: Shi-Jin Lu and Chang-Ying Sun, Department of Orthopedics, Peace Hospital Affiliated to Changzhi Medical College, Changzhi 046000, China. Tel: +86 15340832961; E-mail: shijinludor@163.com (SJL); Tel: +86 13303551128; E-mail: changyingsundoc@163.com (CYS)

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