Selecting a surgical approach for incurable tuberculous thoracolumbar kyphosis and analyzing its clinical efficacy

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Research Article

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Abstract

**Background:** Incurable spinal tuberculosis is extremely uncommon, its treatment is challenging and still controversial. We aimed to investigate the efficacy of posterior and combined posterior-anterior surgical approaches for incurable tuberculous thoracolumbar kyphosis.

**Materials and methods:** We retrospectively analyzed 63 cases of incurable tuberculous thoracolumbar kyphosis. The mild group was treated with posterior surgery alone, and the severe group was treated with the combined posterior-anterior surgery. The surgical efficacy was evaluated based on the clinical symptoms, Cobb angle correction rate, SVA, operative time, intraoperative bleeding, and surgical complications. Symptoms and function were assessed using the American Spinal Injury Association (ASIA) spinal cord injury classification, the visual analogue scale (VAS), the Oswestry dysfunction index (ODI), and the Kirkaldy-Willis functional score. The degree of implant fusion was evaluated according to the Eck fusion grading scale.

**Results:** The preoperative Cobb angles were 59.4°±12.6° and 102.9°±16.6°, and the improved postoperative Cobb angles were 19.9°±6.2° and 28.5°±9.6° for the mild and severe groups, with correction rates of 65.5%±12.0% and 72.0%±9.5%, respectively. The Cobb angle losses were 3.1°±1.4° and 4.2°±1.7° at the last follow-up for the mild and severe groups, respectively. The preoperative SVA were 27.6±10.7 mm and 39.1±18.6 mm, which postoperatively improved to 20.6±9.0 mm and 26.4±12.1 mm in the mild and severe groups, respectively. All patients had an ASIA classification of E, except two patients in the severe group with a classification of D at the time of the final follow-up. All patients with bone grafting achieved grade I fusion. The Kirkaldy-Willis functional scores were 89.7% and 85.3% for the mild and severe groups, respectively, except for two case (1 mild and 1 severe group) with broken rods. no tuberculosis recurrence, internal fixation loosening, breakage, and obvious loss of correction were found during the follow-up period.

**Conclusion:** Simple posterior surgery can achieve the desired clinical outcomes in patients with mild non-curative tuberculous thoracolumbar kyphosis. However, in severe patients with accumulated multiple segments, combined posterior-anterior surgery is required for satisfactory deformity correction, complete lesion removal, and significant bone grafting support, making it a safe and reliable treatment method.

**Level of evidence:** IV

1. Introduction

Tuberculosis of the spine is the most common form of bone tuberculosis and a common cause of spinal deformities[1]. It has a severe long-term impact on the patients’ physical and mental health, leading to high rates of disabilities. The development of kyphosis includes stages I and II of spinal tuberculosis[2]. In approximately 90% of stage I patients, the nodules erode and destroy the structure of the anterior column and collapse the vertebral structure[3]. Rajasekaran et al[4] reported that tuberculosis involving thoracic or thoracolumbar segment disrupts and collapses a single segment of the lumbar spine, leading to kyphosis of 35°-40° compared to 20°. Most patients with stage I spinal tuberculosis develop localized rigid bony fusions after anti-TB treatment and enter stage II, which signifies cured spinal tuberculosis[5]. Patients with a long history of anti-TB treatment suffer recurring episodes of incurable spinal tuberculosis. However, despite long-term anti-TB treatment spinal tuberculosis is incurable because of severe destruction of the vertebral structure, bone defects in the anterior column, and formation of dead bones and cavities. It frequently manifests in varying degrees of low-grade fever, night sweats, low back pain, bilateral lower limb weakness, and sinus tract formation in the back. They also manifest imaging features, such as local osseous fusion, paravertebral or prevertebral cold abscesses with surrounding tissue softening, abscesses of the psoas major muscle, and increased erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP).
recurrent tuberculosis attacks and an increase in the number of destroyed segments lead to a tilt or topple near the parietal vertebrae or several adjacent segments\cite{4, 6, 7}. protrusion of the central vertebral mass and proliferation of fibrous tissues in the spinal canal, and overstretching of the spinal cord into a kyphosis cause chronic ischemia of the spinal cord. Delayed paraplegia occurs as growth and development progressively worsen\cite{8}. Therefore, the treatment should consider the correction of the deformity, complete removal of the lesion, adequate bone graft support for healing the nodule, and improved fusion rates for the bone grafts.

A simple posterior approach to the deformity can achieve satisfactory results in cases of mild kyphosis. However, there is no consensus regarding adequate lesion removal, support for bone grafting, and reestablishing the spinal stability in severe kyphotic deformities involving multiple segments, where a purely posterior approach is taken\cite{9, 10}.

2. Materials And Methods

2.1 General information

The study was approved by the Affiliated Tumor Hospital of Xinjiang Medical University review board, and written informed consent was obtained from all the participants included in the study. We included patients surgically treated for incurable spinal tuberculosis with focal involvement of the thoracic and lumbar spine (T2 to L4) and who had a complete clinical profile. We excluded patients with non-tuberculous spinal deformity, combined tumors, frailty, cardiopulmonary function, malnutrition, and poor cooperation and adherence.

we grouped 63 patients with incurable tuberculous thoracolumbar kyphosis admitted from March 2010 to July 2021 based on their Cobb angle. Several segments were involved in the destruction and complete loss of vertebrae. The mild group was defined as follows: Cobb \( \leq 80^\circ \); segments involved \( \leq 3 \); vertebral bodies damaged \( \leq 6 \); vertebral bodies completely lost \( \leq 3 \). The severe group was defined as follows: Cobb \( > 80^\circ \); segments involved \( > 3 \); vertebral bodies destroyed \( > 6 \); vertebral bodies completely lost \( > 3 \).

There were 29 patients (13 males and 16 females) in the mild group. Twelve patients underwent transforaminal access lesion removal and internal fixation with interbody fusion. Seventeen underwent one-stage transforaminal lesion removal and Smith-Petersen osteotomy with compression fusion. The mean age, duration of tuberculosis, and history of anti-TB treatment were 23.0 ± 13.2 y, 4.2 ± 3.4 y, and 7.1 ± 3.3 months, respectively. Fourteen (48.3%) patients showed various degrees of TB toxicity (hypothermia, night sweats) before surgery, five (17.2%) formed sinus tracts, and 25 were classified as ASIA grade D and four as grade E. Their VAS and ODI scores were 3.0 ± 0.9 and 16.7%±7.0%, respectively. The Cobb angle was measured using Surgimap software(Version 2.0.8). The preoperative SVA was 27.6 ± 4.7 mm; lesions accumulated were 1.7 ± 0.6 segments; the number of destroyed vertebrae was 2.8 ± 1.0; the number of completely lost vertebrae was 1.5 ± 0.8. We found increased ESR and CRP in 24 (82.3%) and 19 (65.5%) cases, respectively.

Thirty-four patients (14 males and 20 females) in the severe group were treated with posterior column osteotomy, cantilever beam technique, and traction correction combined with anterior bone graft fusion. The mean age, duration of tuberculosis, and history of anti-TB treatment were 20.9 ± 12.5 y, 11.6 ± 6.6 y, and 11.4 ± 3.1 months. Twenty-one (61.8%) patients showed preoperative symptoms of tuberculosis toxicity of varying degrees, five (14.7%) formed sinus tracts, and three were graded ASIA B, five C, 25 D, and one E. The VAS and ODI scores were 3.0 ± 1.7 and 20.4%±10.7%, respectively. The preoperative SVA was 39.1 ± 18.6 mm; lesions accumulated were 3.7 ± 0.9 segments; the number of destroyed vertebrae was 5.2 ± 1.9; the number of completely lost vertebrae was 3.8 ± 1.9. The ESR and CRP were increased in 27 (79.4%) and 20 (58.8%) cases, respectively.

All patients had complete clinical data, including natural standing, full frontal, and lateral spine x-rays, taken at consultation. visual analogue scale (VAS) and Oswestry dysfunction index (ODI) were completed. All patients were given
regular quadruple anti-tuberculosis treatment in the perioperative period, with lung function exercises, arousal test training, surgical posture training, and dietary instructions. For those undergoing second stage surgery, the interval between surgeries was 1 to 2 weeks, during which they were given aggressive blood volume supplementation and immune-boosting and nutritional support therapy.

2.2 Surgical methods

All patients were put under general anesthesia using tracheal intubation. The somatosensory evoked potential (SEP) and motor evoked potential (MEP) were intraoperatively monitored throughout the surgery.

**Posterior surgery:** After the onset of anesthesia, the patient was placed in a prone position. A longitudinal incision was made along the spinous process with another C-arm x-ray-assisted longitudinal incision on the posterior side extending 3–4 vertebrae upwards and downwards with the parietal vertebrae as the center. The area was completely exposed, and the paravertebral muscles were stripped with a periosteal stripper, revealing the spinous process, bilateral laminae to the lateral edge of the lesser articular process, and the transverse process roots. Pedicle screws were placed symmetrically in at least 2–4 vertebrae above and below the lesion. For patients with lesions in the thoracolumbar segment (T10-L2), the lesion was temporarily fixed on one side before removal to avoid intersegmental displacement leading to spinal cord injury. The superior and inferior articular processes were removed on the other side, and part of the lamina was removed to visualize the surgical field. The nerve roots and the lateral edge of the dural sac were carefully exposed with a nerve stripper and separated along the paravertebral area. The proximal ribs might be removed if the lesion involves the thoracic spine and the exposure is problematic. The segmental nerve and vascular bundles might be cut and ligated if necessary. The necrotic disc, granulation tissue, dead bone, dead cavity, and abscess were entirely removed at the end of the visualization, and the contralateral lesion was similarly removed (Fig. 1A-C). In patients without lesions in the thoracolumbar segment, the bilateral articular tuberosity, lamina, spinous process, and ligaments were removed at the intervertebral space level using an ultrasonic bone knife or a lance-like bite forceps. The lesion was temporarily immobilized by placing a connecting rod on the front side. After clear visualization, the necrotic disc, granulation tissue, dead bone, dead cavity, and pus were entirely removed. The upper and lower vertebral surfaces were smoothed with an ultrasonic bone knife or bone file for Smith-Petersen osteotomy (SPO) osteotomy. The temporary fixation bar was repositioned on the contralateral and opposite sides, with the final orthopedic fixation performed by connecting the nail and bar (Fig. 1D-F).

**Combined posterior-anterior surgery:** After the onset of anesthesia, the patient is routinely exposed and temporarily fixed with a pre-curved short rod on one side after insertion of the pedicle screw. The supraspinous and interspinous ligaments were resected posterior to the contralateral osteotomy segment. Parts of the bilateral articular tuberosity, spinous process, and laminae were removed using an ultrasonic bone knife or laminae bite forceps (Fig. 2A). After replacing the temporary fixation bar, the osteotomy was similarly released. On both sides of the top posterior convexity, pus aspirated anteriorly through the intertransverse process and intervertebral foramen. Some of the necrotic disc tissues and dead bones were removed. Two pairs of long rods were installed alternately. The temporary fixation rods were released, and the deformity was corrected using the cantilever beam technique + longitudinal traction (bilateral axillary and ankle traction) (Fig. 2B). After confirming the accuracy of SEP and MEP monitoring, the pre-bent connecting rods were replaced and secured in turns (Fig. 2C).

After correcting the deformity, the remaining lesions were removed completely using a thoracic or extraperitoneal approach, either simultaneously or during the second stage, depending on the extent and scope of the nodule destruction and the surgical tolerance. An appropriately sized bone graft was implanted in the vertebral bone defect (Fig. 2D). All patients underwent a wake-up test to check the movement of both lower limbs after orthosis. Fluoroscopy was performed using the C-arm x-ray to ensure that the osteotomy area and internal fixation of the lesion were free of abnormalities. A drainage tube was placed, and the field was flushed with saline. An autologous + allogeneic bone graft was performed.
between the posterior laminae, 2–4 g of streptomycin was placed in the lesion area, and the incision was closed with sutures layer by layer. Pus was intraoperatively collected from Mycobacterium tuberculosis cultures. Drug sensitivity testing was performed, and tissues were intraoperatively removed for pathological examinations. The patients were bedridden for 1 to 3 d after surgery, with prophylactic antibiotics for 2 to 3 d. They were monitored closely for mental, sensory, motor, drainage, diet, and functional exercises. The patients continued to take the quadruple dosage of antituberculosis drugs and supplemented with liver and kidney-protective drugs. Pyrazinamide was stopped three months after surgery and ethambutol after six months. Isoniazid and rifampicin continued until 12 to 18 months after surgery. The liver and kidney functions were reviewed once a month after surgery, and chemotherapy drugs were promptly adjusted accordingly.

### 2.3 Observed indicators

The efficacy of the procedures was evaluated according to clinical symptoms, operative time, intraoperative bleeding, surgical complications, recurrence rate, degree of fusion of the implant, correction rate of the Cobb angle of the posterior convexity deformity, SVA, and pre-operative and post-operative height difference. Symptoms and functional evaluation indicators include visual analogue scale (VAS), American Spinal Injury Association (ASIA), Oswestry dysfunction index (ODI), and Kirkaldy-Willis functional score. Laboratory tests included the erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP). The degree of implant fusion was assessed using the Eck fusion grading scale.

### 2.4 Statistical methods

We used the SPSS22.0 statistical software. Age, duration of disease, number of segments involved, number of completely destroyed vertebrae, duration of surgery, intraoperative bleeding, preoperative and postoperative height differences, Cobb angles and correction rate, SVA, VAS score, ODI score, and other measures are expressed as mean ± standard deviation (x ± s). The preoperative, postoperative, and final follow-up results were compared using the t-test. ASIA spinal cord injury classification and Kirkaldy-Willis functional evaluation results were tested using the Wilcoxon rank-sum test during the last follow-up and compared to the preoperative period. The statistical significance was set at p < 0.05.

### 3. Results

All patients completed the surgical treatment, and incisions healed eventually, except for one case (7-year-old girl, 5 months after operation) in the mild group and one case (6-year-old girl, 37 months after operation) in the severe group. Broken rods, tuberculosis recurrence, internal fixation loosening, breakage, and loss of correction were not found during the follow-up period. All patients with bone grafting achieved grade I fusion by the final follow-up, with a fusion rate of 100%.

**Mild group:** The surgery time, intraoperative bleeding, postoperative Cobb angle, and correction rate were 231.4±56.2 min, 544.8±364.8 ml, 21.2±7.0°, and 63.5%±14.8%, respectively. The mean at the final follow-up was 19.9°±6.2°, with a Cobb angle loss rate of 3.1°±1.4°. The postoperative SVA was 27.6±10.7 mm (Table 1). The difference in height before and after surgery was 26.2±9.4 mm. The postoperative VAS improvement rate was 76.5%. The differences between preoperative, postoperative, and final follow-up VAS scores were significant (t<sub>postoperative</sub> = 11.2, t<sub>final follow-up</sub> = 16.0, p < 0.05). The postoperative ODI improvement rate was 65.3%. The differences between preoperative, postoperative, and final follow-up ODI scores were significant (t<sub>postoperative</sub> = 9.9, t<sub>final follow-up</sub> = 12.3, p < 0.05) (Table 2). The follow-up period was 18.6±5.8 months. All patients had an ASIA classification of E at the final follow-up (Table 3). According to the Kirkaldy-Willis functional scale, there were 24 excellent, three good, and two moderate cases, giving an overall excellent rate of 82.8% (Figure 3A-F).
**Severe group:** The operative time, intraoperative bleeding, postoperative Cobb angle, and correction rate were 337.1±66.4 min, 1111.8±565.8 ml, 28.5°±9.6°, and 72.0%±9.5%, respectively. The mean at the final follow-up was 32.7°±9.9°, with a Cobb angle loss rate of 4.2°±1.7°. The postoperative SVA was 26.4±12.1 mm (Table 1). The difference in height before and after surgery was 61.4±37.6 mm. Postoperative VAS improvement rate was 87.2%. The differences between the preoperative, postoperative, and final follow-up VAS scores were significant ($t_{\text{postoperative}} = 8.0$, $t_{\text{final follow-up}} = 9.3$, $p < 0.05$). The postoperative ODI improvement rate was 68.8%. The differences between preoperative, postoperative, and final follow-up ODI scores were significant ($t_{\text{postoperative}} = 9.8$, $t_{\text{final follow-up}} = 11.0$, $p < 0.05$) (Table 2) (Figure 4A-H). The follow-up time was 19.4±6.6 months. All patients improved to grade E by final follow-up, except for one case with a former ASIA classification of B, which improved only to grade D (Table 4). According to the Kirkaldy-Willis functional scale, there were 29 excellent, four good, and one moderate case, with an overall excellent rate of 85.3% (Figure 5A-F).

**Complications:** On day two after surgery, a case presented with severe non-curative tuberculous thoracolumbar kyphosis with progressive lower limb muscle strength loss, which was identified as spinal cord ischemia in conjunction with imaging data. An emergency neuro-probes spinal decompression was performed. On the day of surgery, two suspended red blood cells units were infused and hormones and lower limb rehabilitation were given. Nine patients developed postoperative cerebrospinal fluid leakage (three mild, six severe), and fourteen patients developed pleural effusion (six mild, eight severe), which were relieved after a lumbar puncture placement thoracentesis drainage. Two patients (one mild, one severe) required anti-inflammatory and nutritional support treatment for internal fixation fracture during postoperative follow-up.

**4. Discussion**

The presentation of incurable spinal tuberculosis is similar to stage I spinal tuberculosis. Although most stage I spinal tuberculosis are treated with regular anti-TB therapy, localized rigid bony fusions manifest as curative spinal tuberculosis\[5, 11\]. Despite long-term regular anti-TB treatment, incurable spinal tuberculosis has recurrent clinical manifestations of varying degrees, including low-grade fever, night sweats, low back pain, weakness in both lower limbs, and sinus tract formation in the back. They also present local imaging manifestations, such as failure to form a bony fusion, paravertebral or prevertebral cold abscesses with surrounding tissue softening, abscesses in the major lumbar muscles, and increased ESR and CRP. Therefore, the treatment of this disease involves the complete surgical removal of the dead bone, dead cavity, and caseous lesions in the lesion area. The combination of perioperative and postoperative regular anti-TB treatment is the key to its cure\[12–14\]. There are many reports in the literature on the treatment of old tuberculous kyphosis through a posterior approach\[15–19\], which have achieved good results. Lee et al\[20\] suggested that posterior surgery alone can treat early spinal tuberculosis with limited vertebral destruction. Chang et al\[21\] suggested that posterior orthopedic surgery combined with anterior focal debridement and fusion is effective when tuberculosis accumulates in multiple segments and the kyphosis is significant. Therefore, we chose posterior surgery alone for the mild group and combined posterior-anterior surgery for the severe group after combining the case characteristics, such as the number of segments involved, the number of vertebral destruction, and Cobb’s angle.

In the treatment of spinal tuberculosis with lesions limited to the thoracolumbar segment (T10-L2), we found that posterior transforaminal access for lesion removal and interbody fusion with internal fixation was less invasive, convenient, and less complicated. It also achieved complete lesion removal and correction of moderate to severe kyphosis. For the treatment of spinal tuberculosis in other segments, the use of posterior lesion removal and Smith-Petersen osteotomy\[22, 23\] with compression fusion resulted in complete lesion removal, adequate spinal cord decompression, and correction of the retroflexion deformity under direct vision, and reducing severe complications, such as spinal cord injury. The posterior structures at the lesion level were directly compressed after transverse osteotomy. Moreover, the intersegmental closure was completed without the need for anterior bone defect fusion or support implants, which achieves bone healing, good deformity correction, and spinal stability.
In contrast, we used posterior lesion removal and Smith-Petersen osteotomy with compression fusion for lesions located in the remaining segments. The operating time, intraoperative bleeding, postoperative Cobb angle, posterior convexity correction rate, Cobb angle loss rate, postoperative VAS improvement rate, postoperative ODI improvement rate, and neurological recovery were similar to previously reported literature[3, 6, 23, 24]. No recurrence of tuberculosis, pseudarthrosis, loosening of internal fixation, or fracture occurred in the remaining patients except one. Therefore, this surgical method can achieve satisfactory deformity correction and complete lesion removal for the treatment of mild incurable tuberculous thoracolumbar kyphosis, making it an ideal surgical treatment.

Based on our results of the severe group, when using a purely posterior VCR technique, it is necessary to expand the resection of the normal posterior structures or take a six-level osteotomy to achieve complete lesion removal and adequate support for bone grafting; however, this increases the surgery time and intraoperative bleeding. Moreover, it is difficult to avoid serious neurological complications, such as spinal cord crepitations and ischemia, when completing the orthosis by pressurizing the posterior column. Zeng et al[24] and Lu et al[25] used a cantilever beam during the technique to rectify severe, old kyphotic deformities. Both achieved satisfactory orthosis and avoided spinal cord injury caused by spinal cord folds. In this study, we chose to combine posterior column osteotomy, cantilever beam technique, and traction orthopedics with anterior bone grafting and fusion surgery because of good spinal flexibility, traction effects, and a cumulative number of damaged segments, which made it difficult to achieve complete lesion removal and adequate bulk support bone grafting through the posterior approach. The advantages of this surgical approach include complete lesion removal, adequate bone graft support[26], preserved integrity of the posterior longitudinal ligament, reduced resection problems in the normal posterior structures, prolonged surgery time because of arterial rupture bleeding in the posterior segment[27], reduced risk of spinal cord injury, delayed healing because of displacement, and ruptured support during correction of severe kyphosis[28]. Its surgery time, intraoperative bleeding, and complication rates were significantly lower compared to previously reported literature[24, 25]. The postoperative posterior convex Cobb angle, posterior convexity correction rate, Cobb angle loss rate, postoperative VAS improvement rate, postoperative ODI improvement rate, and neurological function recovery were similar to previously reported literature[29–32]. Similarly, no recurrence of tuberculosis, pseudarthrosis, loosening of internal fixation, or fracture occurred in the rest of the patients except for one. this surgical method can achieve satisfactory deformity correction, complete lesion removal, and adequate support for bone graft in severe non-curative tuberculous kyphosis. the reduced operative time, intraoperative bleeding, and serious complication rate make it a safe and reliable surgical treatment modality. However, the disadvantages are that the surgery is very traumatic and unsuitable for weak, malnourished patients with abnormal cardiopulmonary function and an intraoperative position change is required, which increases the probability of medically induced injury and infection.

the limitations of our study were the relatively small sample size, a retrospective study design, and lack of long-term follow-up data. Therefore, future prospective randomized studies with a follow-up period of at least five years are needed to elucidate the benefits of the treatment of incurable tuberculous thoracolumbar kyphosis via posterior and combined posterior-anterior surgical approaches.

5. Conclusion

In summary, complete removal of dead bone, dead space and caseous lesions in the lesion area combined with regular anti-TB treatment during the perioperative and postoperative periods is crucial for treating noncurative tuberculous thoracolumbar kyphosis. Secondly, careful preoperative evaluation, adequate perioperative management under the premise of strict indications, meticulous intraoperative management, maintaining stable intraoperative blood pressure, continuous neurophysiological monitoring and intraoperative and postoperative arousal tests to check the movement of both lower extremities can help improve the safety of surgery.
ASIA: American spinal injury association; CRP: C-reactive protein; CT: Computerized tomography; ESR: Erythrocyte sedimentation rate; MEP: Motor evoked potential; MRI: Magnetic resonance imaging; ODI: Oswestry dysfunction index; SVA: Sagittal vertical axis; SEP: Somatosensory evoked potential; SPO: Smith-Petersen osteotomy; TB: Tuberculosis; VAS: Visual analogue scale.

Declarations

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Author Contributions

MM & ZD: Conceptualization, Methodology, Validation, Investigation, Supervision, Software, Visualization, Writing - original draft, Writing- Reviewing and Editing. YS, AM: Validation, Supervision, Visualization, Investigation. MMT, WY, JW, MK, AY and RJ participated in the coordination of data acquisition and data analysis and reviewed the manuscript.

Funding

This study was not funded by anybody.

Data Availability Statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics Statement

All experiments were performed in accordance with relevant guidelines and regulations. We confirm that all methods were carried out in accordance with relevant guidelines and regulations. The studies involving human participants were reviewed and approved by The Ethics Committee of Affiliated Tumor Hospital of Xinjiang Medical University and First Affiliated Hospital of Xinjiang Medical University (Ethical approval number: 20180223-157). We have uploaded the medical ethics committee approval report in the additional file. The patients/participants provided their written informed consent to participate in this study and for minor patients informed consent was obtained from their guardians.

Consent for publication

Not Applicable

Conflict of Interest

The authors declare no conflicts of interest.

References


Tables

Table 1 Posterior convex Cobb's angle and SVA at preoperative, postoperative and final follow-up
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<th>Quantity</th>
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<td>Postoperative</td>
</tr>
<tr>
<td></td>
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<td>Preoperative</td>
<td>Postoperative</td>
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<td>39.1±18.6</td>
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**Table 2 VAS and ODI at preoperative, postoperative and final follow-up**

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<td>values</td>
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<tr>
<td>Preoperative</td>
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<tr>
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**Table 3 ASIA classification at preoperative and final follow-up in the mild group**

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**Table 4 ASIA classification at preoperative and final follow-up in the Severe group**
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**Figures**

**Figure 1**

**A-C.** Posterior transvertebral foramen approach for lesion removal and internal fixation by interbody fusion. **A.** excision of the superior and inferior articular processes and part of the vertebral plate to expose and protect the nerve roots. **B.** complete removal of dead bone, dead space, pus, necrotic disc, granulation tissue and caseous material through the intervertebral foramen. **C.** reconstruction of spinal stability by interbody bone grafting through the intervertebral foramen. **D-F.** Schematic diagram of the trans-posterior lesion removal and Smith-Petersen osteotomy with compression fusion. **D**. Diagram of lesion clearance and wedge osteotomy range of the diseased intervertebral space. **E.** Diagram of the
posterior osteotomy site and range of the diseased area. **F.** Diagram of the posterior convexity correction of the osteotomy surface with pressure closure after lesion clearance and wedge osteotomy.

Figure 2

Posterior column osteotomy, cantilever beam technique + traction correction combined with anterior implant fusion. **A.** Posterior multi-segment SP osteotomy to loosen the posterior column structure. **B.** Correction of deformity and restoration of normal spinal sequence by cantilever beam technique and traction. **C.** Large bone defects and multiple dead bones and cavities visible at the anterior edge of the vertebral body after correction. **D.** Reconstruction of spinal stability by anterior complete lesion removal and adequate support for bone grafting.
A 2-year-old male patient presented with kyphosis due to destructive tubercular at T7-8 with paravertebral abscess. **A.** Preoperative radiographs showed a kyphotic deformity with a Cobb angle of 53°. **B-C.** Preoperative CT scan and 3D reconstruction showed destruction and collapse of the vertebral body with multiple dead bones visible in the lesion area. **D.** MRI film showing erosion of the vertebral body by a tuberculous lesion and abscess formation at the anterior edge of the vertebral body. **E.** Postoperative radiographs showed well-corrected kyphosis with a Cobb angle of 31°. **F.** Postoperative X-ray at 18 months showed a posterior convex Cobb angle of 35 degrees and a Cobb angle loss rate of 4°, with no loosening or fracture of the internal fixation.
A 25-year-old male patient presented with kyphosis due to destructive tubercular spondylodiscitis at T9–L2 with paravertebral abscess. Cobb angle of 105°. A-C. Preoperative CT scan + 3D reconstruction and MRI showed a posterior convex apex with T9-L2 fusion, more dead bone and cold abscess formation in front of the vertebrae. D-E. Posterior osteotomy, cantilever beam technique + traction correction postoperative CT showed a large bone defect anterior to the vertebral body. F-X-ray after anterior lesion removal and bone graft fusion showed a Cobb angle of 23°, with a correction rate of 78.1%. G-H. The postoperative X-ray at 6 months and 2 years showed a Cobb angle of 28°, a Cobb angle loss rate of 5°, satisfactory implant fusion, and no loosening or fracture of the internal fixation.
A 12-year-old male patient presented with kyphosis due to destructive tubercular spondylodiscitis at T9–L3 with paravertebral abscess. **A.** Preoperative radiographs showed tuberculous kyphosis of the thoracolumbar segment with a posterior convex Cobb angle of 106°. **B-C.** Preoperative CT scan + 3D reconstruction and MRI showed a posterior convex apex with T9-L3 fusion, more dead bone and cold abscess formation in front of the vertebrae. **D.** Posterior osteotomy, cantilever beam technique + traction correction postoperative full spine sagittal x-ray showing a large anterior bone defect in the vertebral body. **E.** Postoperative radiographs after anterior lesion removal and bone graft fusion showed a Cobb angle of 27°, with a correction rate of 74.5%. **F.** The postoperative X-ray at 18 months after surgery, the whole spine X-ray showed no significant loss of orthopedic shape, satisfactory fusion of implants, and no loosening or fracture of internal fixation.
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- datasheet1.xlsx
- datasheet2.xlsx