A Novel Surgical Strategy For Correcting Severe Angular Kyphosis Due To Pott’s Disease: Three Column Osteotomy In Non-lesioned Areas

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Abstract

Severe sharp angular kyphosis due to Pott’s disease usually need surgical correction. Three column osteotomy performed in lesion area as well as apex area has been demonstrated useful to correct angular kyphosis. But the residual kyphosis may conspicuous and there is usually high rate of perioperative risk. To improve the correction effect and avoid high rate of risk, we designed a novel strategy that osteotomy in the non-lesioned vertebrae to correct severe angular kyphosis due to Pott’s disease. We retrospectively reviewed 16 patients who underwent the new surgical strategy that osteotomy in non-lesioned vertebra instead of lesioned areas in our hospital from 2016 to 2018. Radiographic parameters including angle of kyphosis and sagittal vertical axis (SVA) were recorded respectively at admission and final follow-up. Neurological improvement was measured according to the American Spine Injury Association (ASIA) classification. Operative time, blood loss, perioperative complications were also recorded. There were 6 male and 10 female patients. Their mean age was 30.7±11.41 years. The duration of follow-up ranged from 24 to 42 months. The mean operative time and blood loss were 492±127.3min and 1791±788.8 ml, respectively. Kyphosis angle was corrected from 97.6±14.6° to 28.8±18.70°. In two cases with lumbar lesions (L1-L5 and L2-S1 respectively), the lumbar lordosis was restored. The mean SVA was 6.7±3.58cm at admission, and 3.3±1.57cm at final follow-up. Neurological function improved in 6 cases, while it remained the same as before surgery in other 10 patients. The rate of complications including wound infection (1 case) and rod fracture (1 case at the 12 months after surgery) was approximately 11.8%. The new surgical strategy was effective and safe to correct severe angular kyphosis due to Pott’s disease. However, the surgical team should be experienced.

Introduction

Spinal tuberculosis, also known as Pott’s disease, was first described by Percival Pott in 1779 [1]. It accounts for less than 2% of patients with tuberculosis, but its incidence is increasing [2]. Most spinal lesions are located in the anterior column of the vertebral body, resulting in collapse of the anterior column and kyphosis. It has been reported in the literature that patients with conservatively treated spinal tuberculosis eventually develop kyphosis with an average angle of 15°, and in 3–5% of patients the angle is > 60° [3]. The occurrence and severity of kyphosis are particularly pronounced in individuals who develop spinal tuberculosis in childhood [4]. Severe kyphosis is often associated with low back pain, impaired lung function, and spinal cord injury. Studies have shown that the incidence of spinal cord injury in patients with severe kyphosis is 10–43% [5, 6].

Surgical treatments for angular kyphosis due to spinal tuberculosis aim to correct the kyphosis and relieve spinal cord compression, thereby improving pulmonary and spinal nerve function and the patient’s daily activities[7]. Posterior 3-column osteotomies are the most commonly used and effective treatment to correct kyphosis due to spinal tuberculosis [7]. However, the adhesion around the spinal cord at the tuberculous lesion can be pronounced, which can affect the blood supply of the spinal cord and compress the spinal nerve roots together, resulting in a high risk of major bleeding, nerve injury, failure of anterior column fusion, and internal fixation failure in the long term [8]. Therefore, our team designed a
new osteotomy strategy for severe angular kyphosis [9] (Figure 1), which has achieved satisfactory results in the treatment of severe scoliosis in patients with neurofibromatosis.

In this study, we used the same strategy to treat a group of patients with angular kyphosis due to spinal tuberculosis and selected non-lesioned areas for corrective osteotomy. Because of multiple vertebra collapsed due to Pott’s disease, severe angular kyphosis and two compensatory curves replace the normal physiological curve. So the osteotomy level we chose was the normal vertebra adjacent to the lesion areas. This study summarizes the therapeutic efficacy and clinical data of the patients treated with this strategy to explore a more effective corrective osteotomy plan for angular kyphosis due to spinal tuberculosis.

Materials and Methods

General patient information

Institutional Review Board approval was obtained prior to the initiation of this study. An approved informed consent was signed by each patient before any tests were performed. Patients with angular kyphosis due to spinal tuberculosis who were treated in our hospital and underwent osteotomy in non-lesioned areas, fusion with bone graft, and pedicle-screw internal fixation during orthopedic surgery from 2016 to 2018 were analyzed in this study. The inclusion criteria included: (1) healed spinal tuberculosis accompanied with angular kyphosis; (2) presence of neurological impairment, or severe femoroacetabular impingement syndrome; (3) ≥ 5 damaged vertebral bodies; and (4) ≥ 24-months of follow up. The exclusion criteria included: (1) active tuberculosis in other systems or organs; (2) pulmonary disease; and (3) did not undergo posterior 3-column osteotomy.

Surgical methods

All patients were placed in the prone position under general anesthesia and endotracheal intubation. A posterior midline incision was made spanning the lesion and the planned osteotomy area. The lowest instrumented vertebra (LIV) was determined to be at least 3 vertebral bodies below the osteotomy site and the upper instrumented vertebra (UIV) was determined based on the overall sagittal imbalance in the patient and the vertebrae involved in the lesion. Actually because of the multiple vertebra collapsed, the thoracic and lumbar sagittal alignment became one angular kyphosis and two compensatory lordosis. And the UIV was usually T1. After exposing both sides of the lamina to the lateral side of the facet joints, pedicle screws were implanted above and below the lesion areas and the osteotomy areas, according to the preoperative plan. After using fluoroscopy to confirm the correct position, a pre-bent titanium rod was applied from the right side (opposite side of the surgeon) over the apex areas to connect the upper and lower pedicle screws for temporary fixation. The lamina of the vertebral body to be cut and most of the lamina adjacent to the superior and inferior adjacent vertebral bodies were removed using an ultrasonic osteotome. If the vertebral body to be sectioned was a lumbar vertebra, the bilateral transverse processes were severed at the root. If the vertebral body to be sectioned was a thoracic vertebra, the transverse process, medial rib, and rib head were resected to facilitate the complete separation of the bone structure.
from the surrounding soft tissues on the side of the vertebral body. After separation of one side, cotton gauze was used to pack the space and stop bleeding, followed by separation of the other side. An ultrasonic osteotome was used to make a V-shaped osteotomy through the pedicle from the opposite side of the temporary fixation side to the anterior wall of the vertebral body. The removed area of the vertebral body was expanded superiorly and inferiorly with the ultrasonic osteotome until the superior and inferior discs were removed. A rod was inserted for temporary fixation, and the residual bone on the opposite side of the vertebral body was removed in the same manner to complete the osteotomy. The surgical assistant inflated the oxygen cushion for the patient until the lower limbs were elevated higher than the body position. A pre-bent titanium rod was placed on the left pedicle screw, then the right temporary fixation rod was loosened and the elasticity of the left titanium rod was used to partially correct the kyphotic spinal deformity until partial improvement of kyphosis was observed. The titanium rod for the right-hand side was pre-bent to an angle smaller than that of the kyphotic spine. After insertion of the pre-bent titanium rod for the right side, the titanium rod on the left side was released until the kyphosis was further corrected. This procedure was repeated with alternate bending of the titanium rods on the left and right sides until adequate correction of the kyphosis was achieved. The correction was performed gradually. After each correction step, the tightness of the dural sac was checked, and the extent of decompression was increased if necessary. Intraoperative elevation of the lower limbs and pelvis was performed by a surgical assistant when necessary to achieve a distal posterior rotation effect and further achieve sagittal reconstruction (Fig. 2). Neuromonitoring of somatosensory evoked potentials (SEP) and motor-evoked potentials (MEP) was performed throughout the procedure.

Postoperative follow up and data collection

Whole spine radiography was taken before discharge and at the postoperative 3-month, 6-month, 1-year, 2-year, and final follow ups. Measurements data included the extent of lesion destruction, the pre- and post-operative kyphosis angles (we measured the kyphosis with the same upper and lower vertebra without apex region before and after surgery), the pre- and post-operative sagittal vertical axis (SVA) values, and failure of the internal fixation after surgery.

Statistical analysis

The SPSS 20.0 software package (IBM, Armonk, NY) was used for statistical analysis. The preoperative and postoperative imaging measurement data are presented as mean ± standard deviation and were used for paired t test analysis. P < 0.05 was considered statistically significant.

Results

16 patients, including 6 males and 10 females, met the inclusion criteria for this study. The mean age was 30.7 ± 11.41 years (range from 21 to 61 years), and all had developed spinal tuberculosis in childhood. The tuberculosis lesion involved both thoracic and lumbar vertebrae in 14 cases and only lumbar vertebrae in 2 cases. The mean number of vertebrae affected was 7.3 ± 2.11 (range, 5–10). Halo-pelvic traction was performed in 11 cases to reduce the kyphosis, but effect on angular kyphosis was
poor after a mean of 6 months of traction. The average preoperative angle of kyphosis was $97.6 \pm 14.6^\circ$ (ranging from 76 to 121°). The mean preoperative sagittal vertical axis (SVA) was $6.7 \pm 3.58\text{cm}$ (range, 2.7–11.6cm) (Table 1).

<table>
<thead>
<tr>
<th>Lesion area</th>
<th>cases</th>
<th>Number of vertebrae involved</th>
<th>SVA</th>
<th>Angle of kyphosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pre-op  Post-op</td>
<td>Pre-op  Post-op</td>
</tr>
<tr>
<td>Thoracic and lumbar spine</td>
<td>14</td>
<td>7.8 ± 1.8</td>
<td>6.7 ± 3.58cm</td>
<td>3.3 ± 1.57cm</td>
</tr>
<tr>
<td>Lumbar spine</td>
<td>2</td>
<td>5</td>
<td>Pre-op  Post-op</td>
<td>80.5 ± 4.5 ± 1.5</td>
</tr>
</tbody>
</table>

SVA, sagittal vertical axis; P < 0.05 was considered statistically significant.

Neurological function was assessed using American Spinal Injury Association (ASIA) Impairment Scale. There were 9 ASIA D cases and 7 ASIA E cases (Table 2).
Table 2

Pre- and Post-operative ASIA Grade

<table>
<thead>
<tr>
<th>Pre-op ASIA Grade</th>
<th>Cases</th>
<th>Post-op ASIA Grade</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>A</td>
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<tr>
<td>D</td>
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<td>3</td>
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<tr>
<td>E</td>
<td>7</td>
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ASIA, American Spinal Injury Association;

The mean operation time was 492 ± 127.3 minutes (270–600 minutes), the mean blood loss was 1791 ± 788.8 ml (800–3000 ml), and the mean follow-up duration was 31.2 ± 5.49 months (24–42 months). The man kyphosis angle decreased significantly from 97.6 ± 14.6° (76–121°) preoperatively to 28.8 ± 18.70° (−13° to 46°) postoperatively, with a correction rate of 65%. Two patients had lesions concentrated in the lumbar spine (lesions ranged from L1 to L5 in one patient and from L2 to S1 in the other patient). The preoperative kyphosis angles of these 2 patients were 85° and 61° and the postoperative lordosis angles were 13° and 10°, respectively (Time scale analysis: −13 and −10). The SVA to assess the sagittal balance of the patients was restored from 6.7 ± 3.58 cm (2.7–11.6 cm) in the preoperative sagittal position to 3.3 ± 1.57 cm (1.5–6 cm) postoperatively, achieving the overall sagittal balance of the spine (Table 1). Neurological function improved in 6 cases, and the remaining 10 cases had no significant change at final follow-up (Table 2).

Intraoperative neuromonitoring showed that one patient had a significant decrease in SEP signal and short-term neurological impairment after surgery. After rehabilitation with exercise, this patient’s neurological function returned to normal at final follow-up. One patient had a postoperative incisional infection which was resolved after incision debridement. 1 patient had a fracture of the internal fixation rod at 12 months after surgery that was caused by poor fusion of the anterior column. And the patient underwent revision surgery.

Discussion

With the application of anti-tuberculosis drugs, the incidence of spinal tuberculosis is better controlled in areas with good medical conditions. However, the incidence of spinal tuberculosis remains higher in areas of poor medical conditions [10]. Because of its distinct site of infection, spinal tuberculosis that is not treated in time can lead to serious consequences including spinal deformity, impaired respiratory function, and neurological damage [5, 6, 11]. The development of kyphosis in patients with spinal tuberculosis is mainly divided into two independent stages: the active tuberculosis stage and the cured tuberculosis stage. Under normal circumstances, kyphosis in adult patients with spinal tuberculosis
develops mainly in the active stage of tuberculosis. After the tuberculosis is cured, the kyphosis do not get worse. However, in pediatric patients, kyphosis progresses in both stages, which is why children with spinal tuberculosis have more severe kyphosis [4, 12]. A previous study showed that patients with the disease onset at less than seven years and spinal infection that involving more than three thoracic or thoracolumbar vertebrae have an extremely high possibility of progressive kyphosis, which requires early surgical intervention [13]. In order to stabilize the entire spine, the vertebral bodies above and below the lesions change their sequence direction, forming two long-arc compensatory (lordotic) curves of the spine. In addition, the spinal cord is extremely stretched at the apex of the kyphosis, leading to neurological damage [14]. Neurological damage is one of the three major complications of spinal tuberculosis, occurring not only in the active stage of tuberculosis, but also in cured spinal tuberculosis, especially when kyphosis develops. Kyphosis, bone bridges, and fibrotic scarring may compress the spinal cord and cause neurological damage or paraplegia [15, 16]. In this study, all patients had childhood spinal tuberculosis, which manifested as destruction and fusion of multiple vertebral bodies. Thus, the severity of kyphosis was relatively pronounced and the risks associated with surgical treatment of these patients were high, making treatment challenging. The proportion of patients with preoperative neurological impairment in this study was 56.2%.

Three-column osteotomy is considered the best choice for correcting severe kyphosis due to spinal tuberculosis. There are currently three approaches to this surgery including the anterior approach, a combination of anterior and posterior approaches, and the posterior approach [7, 17]. The difficulty of the anterior surgical approach is greatly increased when the angle of kyphosis is > 60°. The complication rate of the anterior approach increased due to fibrosis and adhesions in the lesion area. If the lesion is resected directly through the anterior surgical approach, transient overstretching of the spinal cord may occur, leading to serious neurological complications. In addition, bony fusion of the posterior column often requires a combination of anterior and posterior approaches to achieve satisfactory postoperative clinical outcomes. In summary, the posterior surgical approach has been mainly used to correct severe kyphosis due to old spinal tuberculosis rather than the anterior surgical approach or the combination of anterior and posterior approaches [7, 18].

A previous study showed that posterior 3-column osteotomies could achieve a correction angle of 39.2° to 88.4°, decompress the spinal cord with 33–100% improvement of neurological function, and have an 8–20% surgical complication rate [19]. Currently, the commonly used posterior 3-column osteotomy includes pedicle subtraction osteotomy (PSO), vertebral column resection (VCR), and vertebral column decancellation (VCD). Single-segment PSO has achieved a kyphosis angle correction of 30–50° in non-tuberculous kyphosis [20]. Some scholars consider the lesion area of angular kyphosis due to cured spinal tuberculosis as a vertebral body, and therefore spinal decompression and spinal correction can be performed in the lesion area, similar to PSO, can be performed to achieve good correction [21, 22]. PSO removes bone through the middle and posterior columns and uses the anterior wall of the vertebral body as a hinge, making PSO similar to closing wedge osteotomies. However, PSO can lead to further shrinkage of the spinal cord and increases the risk of spinal cord injury in patients with angular kyphosis due to old spinal tuberculosis [7]. Although VCR has higher surgical requirements, it decompresses the
front of the spinal cord under direct vision, corrects kyphosis, and may avoid the risk of excessive spinal cord shrinkage caused by PSO surgery. Therefore, VCR has been widely used in the orthopedic treatment of kyphosis due to anterior column collapse[7, 19]. Numerous studies have reported the use of VCR to correct angular kyphosis due to old spinal tuberculosis with good clinical results[23–26]. VCD has been used to correct kyphosis due to old spinal tuberculosis and researchers believe that this surgical approach is less difficult compared to VCR, with greater correction and no need for the supporting materials for the anterior column, further reducing the risk of surgical complications [27].

This study retrospectively analyzed the surgical correction of severe angular kyphosis due to spinal tuberculosis in 16 patients. The literature reports that posterior 3-column osteotomies are the preferred surgical technique for correction of kyphosis due to spinal tuberculosis [7, 14, 19, 26]. However, the 16 patients in this study all had angular kyphosis after destruction or collapse of multiple vertebral bodies (≥ 5, maximum number of vertebral body destruction of 10), with severe deformity and a wide range of lesions. These patients also had severe local scarring and adhesions and obvious spinal cord compression. In addition, there were many spinal nerve roots in the posterior column, and the surgical space was small. Osteotomy performed directly in the lesion area can greatly increase the incidence of surgical risks. In addition, the most serious surgical complications of the 3-column osteotomies are spinal cord injury and massive bleeding [28, 29]. To avoid the chronic lesions and to minimize the additional surgical risks due to the pathological characteristics of the lesions in patients with spinal tuberculosis, osteotomy was performed in non-lesioned areas in this study. Osteotomy of the whole vertebral body was performed on the normal vertebral body below (Fig. 3) or above (Fig. 4) the lesion area to correct the spinal alignment and alter the spinal canal alignment, thereby achieving the effect of spinal decompression.

The correction rate of kyphosis in our patients reached 65%. There were 9 patients with different degrees of spinal cord injury before surgery. After surgery, the improvement rate of neurological function in the patients reached 66.7%. These results indicate that this new strategy for osteotomy in non-lesioned areas achieved good correction of kyphosis and a remarkable effect on spinal decompression. Of the cases in this study, one patient experienced a worsening of transient neurological damage after surgery. This patient’s neurological function was restored after active rehabilitation and exercise. With remodeling of the spinal alignment and spinal canal alignment, stretching of the spinal nerve roots of the anterior and posterior columns may also cause stretching of the spinal cord; exercises can gradually restore the function of the spinal cord. No other worsening of neurological damage was observed in our patients.

In conclusion, osteotomy in non-lesion areas of angular kyphosis due to spinal tuberculosis avoided the complex anatomical structure of angular kyphosis and the further stimulation of the compressed spinal cord, achieving a good orthopedic effect and improving surgical safety.

Declarations

Acknowledgement
The authors caudially appreciate the assistance of the staff members from the medical record department by providing the data whenever needed.

**Author contributions**

YJL and YL designed the study, DZ and FW collected the data and wrote the manuscript. ZJH, RZ, HQH, ZZ and DXJ analysed the data. All authors approved the final manuscript.

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**Competing Interests**

The authors declare no competing interests.

**References**


Figures

Figure 1

Schematic of the procedure. a, severe sharp angular kyphosis; b, the subapical vertebra of the distal apical vertebra was selected; c, VCR was performed on the selected vertebra; d, the osteotomized distal ends were gradually shifted backwards and upwards and e, the long compensatory curve above the apical vertebral was corrected and the kyphosis was corrected. (Liang Y, et.al. Vertebral column resection
(VCR) at the subapical vertebra for correction of angular kyphosis associated with neurofibromatosis type 1 (NF1): a case report. Eur Spine J. 2022

Figure 2

21-year-old male patient with severe sharp angular kyphosis due to Pott’s disease. The tuberculosis lesion extended from T4 to T9. a, Lateral film of the whole spine; b, CT image showed that the compensatory curve was significantly corrected but the sharp angular kyphosis remained after half a year of halo-pelvic traction; c, 3D CT image of the spine showed severe sharp angular kyphosis; d,e and f, postoperative lateral film and CT images showed that satisfactory correction was achieved after osteotomy at T10 was performed, and the sharp angular lesion remained; g, the intro-operative picture for spinal cord of T10 after 3 column osteotomy was performed.
Figure 3

29-year-old female patient with severe sharp angular kyphosis due to Pott’s disease. The tuberculosis lesion extended from T4 to T12. a, lateral film of the whole spine; b and c, 3D CT image for the spine showing severe sharp angular kyphosis; d, CT image showing the compensatory curve was significantly corrected but the sharp angular kyphosis remained after half a year of halo-pelvic traction; e, postoperative lateral film showing satisfactory correction was achieved after osteotomy at L1 was performed.
Figure 4

27-year-old female patient with severe sharp angular kyphosis due to Pott’s disease. a, lateral film of the whole spine; b and c, 3D CT image of the spine showing sharp angular kyphosis of the lumbosacral spine; The tuberculosis lesion extended from L1 to S1; d, postoperative lateral film showing satisfactory correction was achieved after osteotomy at T12 was performed.