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# The outcome of intervertebral surgery in the treatment of lumbar tuberculosis in children

## A case series and long-term follow-up

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**Abstract**

During the operation of treating lumbar tuberculosis in children, a long-segment or short-segment fixation, and fusion method were usually applied, which would adversely affect the function of normal motion unit. And so, we have been focusing on how we can shorten the range of fixation and fusion using intervertebral surgery. The objective of this retrospective study is to investigate the clinical outcome of intervertebral surgery, in the treatment of lumbar tuberculosis in children.

From June 2003 to June 2013, 18 children with lumbar tuberculosis underwent intervertebral surgery, using a combined posterior and anterior approach, in our hospital. The surgical treatments included posterior pedicle screw fixation of affected vertebrae and posterolateral bone grafting, anterior debridement, compression, and strut bone grafting. Indicators such as preoperative and postoperative erythrocyte sedimentation rate (ESR), C-reactive protein (CRP) levels, neurological function, visual analog scale (VAS) score, kyphotic Cobb angle, complications, healing of lesions, bone graft healing, and recurrence were statistically analyzed.

The mean follow-up time was 86.5 months (range, 62–120 months). Three months after the operation, all patients' ESR and CRP levels decreased to normal, and both the American Spinal Injury Association neurological function scores and VAS scores improved. Successful bone graft healing was achieved, with lesions completely healed at 6 months after surgery, and no recurrence occurred. The preoperative kyphotic was 24.00°±13.15° (range −10°–39°), which decreased to −4.61°±7.31° (range −19°–10°) postoperative ($Z=-4.34$, $P<.01$); the mean deformity correction angle was 28.61°±8.43° (range 9°–43°). There was no significant difference between the kyphotic angle measured immediately after surgery at (−4.61°±7.31°) and the kyphotic angle measured at 5-year follow-up at (−3.11°±7.56°). The mean loss of correction was 1.50°±0.90°.

Intervertebral surgery using a combined posterior and anterior approach is an effective and safe method for the treatment of lumbar tuberculosis in children. It can also preserve the function of normal motor segments to the maximum extent.

**Abbreviations:** ASIA = American Spinal Injury Association, CRP = C-reactive protein, CT = computed tomography, ESR = erythrocyte sedimentation rate, HRZS = isoniazid (H), rifampicin (R), pyrazinamide (Z), streptomycin (S), MRI = magnetic resonance imaging, VAS = visual analog scale.

**Keywords:** children, combined posterior and anterior approach, intervertebral surgery, lumbar spinal tuberculosis

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*QL, YP, and QW contributed equally to this work.*

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## 1. Introduction

The surgical method of treating lumbar tuberculosis (TB) in children is similar to that used to treat lumbar TB in adults. The combined posterior and anterior procedure is most commonly used. During bone grafting and internal fixation, a long-segment (involving 2 or more normal motor units, superior to the affected vertebrae, and 2 or more normal units inferior to it) or short-segment (involving 1 normal motor unit superior to the affected vertebrae, and 1 motor unit inferior to it) fixation and fusion method are usually applied.[1–4] Extending the fixation and fusion segments, not only stiffens the fixation segments by stabilizing the normal motion units but also induces fusion of the normal motion units within the fixation segments, due to subperiosteal dissection of the lamina and joints, which affects spinal motor function. Especially for lumbar TB in children, the extended posterior fixation often leads to an unbalanced development of the anterior and posterior columns.

In order to prevent the occurrence of these undesirable complications and to treat the loss of spinal motor function, (as well as the unbalanced development of the anterior and posterior columns caused by extension of internal fixation segments), we have proposed an intervertebral surgery that is restricted to the motion units invaded by TB, in which a series of surgical procedures were performed. This procedure includes the posterior dissection of lamina, pedicle screw fixation, deformity

**Table 1**

**Diagnostic basis of patients.**

| Case no | Clinical manifestations | Radiological findings | Histopathologic diagnosis | Mycobacterium culture |
|---|---|---|---|---|
| 1 | Local pain, sinus tract, | + | + | − |
| 2 | Local pain, cold abscess, weight loss | + | + | − |
| 3 | Local pain, anorexia, lower fever | + | + | − |
| 4 | Local pain, night sweats | + | − | + |
| 5 | Local pain, cold abscess, night sweats | + | + | − |
| 6 | Local pain, sinus tract, lower fever | + | + | + |
| 7 | Local pain, cold abscess | + | + | + |
| 8 | Local pain, cold abscess, night sweats | + | + | − |
| 9 | Local pain, sinus tract, lower fever | − | + | − |
| 10 | Local pain, cold abscess, anorexia | + | + | − |
| 11 | Local pain, night sweats, lower fever | + | + | − |
| 12 | Local pain, lower fever, weight loss | + | − | + |
| 13 | Local pain, lower fever | + | + | − |
| 14 | Local pain, cold abscess | − | + | + |
| 15 | Local pain, night crying, weight loss | + | + | − |
| 16 | Local pain, sinus tract, night sweats | + | + | − |
| 17 | Local pain, night crying | + | + | + |
| 18 | Local pain, sinus tract, cold abscess | + | + | + |

"+" = diagnosed with lumbar tuberculosis, "−" = not diagnosed with lumbar tuberculosis.

correction, posterolateral bone grafting and fusion, anterior radical debridement, decompression, and autologous iliac bone grafting and related procedures.[5,6] All those above-mentioned surgical procedures were performed within the affected motor units while the normal motor units were not involved. No reports about the intervertebral surgery in the treatment of lumbar spine in children have been published. The present study aimed to review the clinical data and investigate the feasibility and clinical efficacy of intervertebral surgery, in the treatment of lumbar TB in children.

## 2. Methods

### 2.1. General patient data

The present study was approved by the Ethics Committee of the General Hospital of Ningxia Medical University. Informed consent was obtained from the guardian of each patient. This study included 18 children (8 males and 10 females; mean age, 10.61 years; range, 7–14 years) with lumbar TB in L1–S1, who underwent an intervertebral surgery using a combined posterior and anterior approach in our hospital, from June 2003 to June 2013. Patients were selected when the 3 dimensional computer tomography (CT) showed the upper and lower endplates of the affected vertebrae are intact, so as to provide a reliable host bed for the strut bone graft. Patients were excluded if they had severe kyphosis deformity (>60°) and could not be corrected by changing the patient's position, using manual techniques and instrument application, or the pedicle of vertebra had invaded by TB. The diagnosis of spinal TB was based on clinical manifestations, imaging examinations, laboratory tests, and etiologic and histopathological examinations (Table 1). One motion unit was involved in 15 cases, and 2 motion units were involved in 3 cases.

Clinical manifestations among the patients were as follows: 16 cases had systemic symptoms such as night sweats, low-grade fever, anorexia, weight loss, and night crying; 18 cases had local pain; and 9 cases had decreased sensation in the lower extremity and muscle weakness. The preoperative American Spinal Injury Association (ASIA) grade scale (A: Complete. No sensory or motor function is preserved. B: Sensory incomplete. C: Motor incomplete, have a muscle grade less than 3. D: Motor incomplete, have a muscle grade of 3 or greater. E: Normal.) was Grade C in 3 patients, grade D in 5 patients, and grade E in 10 patients. The mean preoperative kyphotic angle (the krypotic angle was measured by drawing lines along the upper-most and lower-most endplate of the affected segment) was $24.00° \pm 13.15°$ (range, −10°–39°). The preoperative erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) levels were $43.33 \pm 23.01$ mm/h (range, 13–96 mm/h) and $15.07 \pm 8.34$ mg/L (range, 2.61–32.40 mg/L). X-ray examination showed varying degrees of wedge-shaped vertebral deformation, intervertebral space destruction, and narrowing or disappearance of the intervertebral space. CT reconstruction showed the destruction of the vertebral body in all patients; magnetic resonance imaging (MRI) showed lesions of vertebral bone destruction and bone marrow edema. Detailed general information for all patients is given in Tables 2 and 3.

Surgical indications were as follows:

(1) patients with neurological dysfunction caused by spinal cord or cauda equina compression;
(2) patients with spinal instability and kyphosis;
(3) patients with a relatively large abscess, sequestrum, or prolonged healing of a sinus tract;
(4) patients cannot tolerate the pain caused by the lesions of lumbar TB.

### 2.2. Preoperative preparation

Anemia, hypoproteinemia, and similar conditions were corrected, while nutrition support was given before surgery. A quadruple anti-TB regimen including rifampicin, (R, 10 mg/kg/d), isoniazid (H, 10 mg/kg/d), pyrazinamide (Z, 25 mg/kg/d), and streptomycin (S, 20 mg/kg/d) was administered for 2 to 4 weeks (mean, 2.3 weeks). Each patient underwent surgery when his or her symptoms of TB and general condition had improved. Preoperative images obtained by CT, MRI, and ultrasound examinations were used to develop a reasonable and feasible surgical procedure.

### 2.3. Surgical procedure

An intervertebral surgery using a combined posterior and anterior approach was used for all 18 children, and fixation of

**Table 2**

**Clinical data of patients and outcome.**

| Case no | Age | Sex | Levels involved | Operative time, min | Blood loss, ml | Post-ophospitalization, d | ESR, mm/h | | CRP, mg/L | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Pre-op | TMP | Pre-op | TMP |
| 1 | 9 | F | L2-3 | 95 | 400 | 7 | 67 | 13 | 21.20 | 1.54 |
| 2 | 12 | F | L1-2 | 120 | 520 | 9 | 46 | 5 | 12.95 | 1.24 |
| 3 | 8 | M | L4-5 | 75 | 450 | 12 | 33 | 9 | 8.78 | 0.56 |
| 4 | 11 | M | L2-4 | 80 | 380 | 9 | 19 | 11 | 17.32 | 2.74 |
| 5 | 11 | F | L4-S1 | 95 | 350 | 8 | 31 | 7 | 31.19 | 2.48 |
| 6 | 13 | M | L4-5 | 100 | 470 | 10 | 15 | 2 | 15.70 | 1.43 |
| 7 | 10 | F | T12-L2 | 110 | 380 | 14 | 45 | 5 | 4.56 | 0.65 |
| 8 | 13 | M | L3-4 | 90 | 480 | 6 | 26 | 7 | 2.61 | 0.71 |
| 9 | 9 | M | L4-5 | 85 | 360 | 8 | 96 | 13 | 9.66 | 1.83 |
| 10 | 14 | F | L3-4 | 120 | 440 | 10 | 31 | 4 | 3.90 | 0.42 |
| 11 | 12 | F | L3-4 | 105 | 470 | 11 | 13 | 3 | 13.54 | 1.19 |
| 12 | 8 | M | L1-2 | 80 | 520 | 7 | 49 | 12 | 14.79 | 1.60 |
| 13 | 11 | M | L4-5 | 97 | 490 | 9 | 28 | 7 | 12.85 | 1.97 |
| 14 | 14 | F | L2-3 | 95 | 360 | 11 | 36 | 5 | 26.81 | 2.70 |
| 15 | 7 | F | L4-5 | 90 | 430 | 13 | 55 | 12 | 15.35 | 2.36 |
| 16 | 9 | F | L4-S1 | 95 | 370 | 9 | 32 | 8 | 32.40 | 1.57 |
| 17 | 8 | M | L1-2 | 85 | 490 | 10 | 83 | 11 | 18.11 | 1.75 |
| 18 | 12 | F | L3-4 | 100 | 460 | 8 | 75 | 7 | 9.46 | 0.89 |
| Mean | 10.61 | | | 95.39 | 434 | 9.50 | 43.33 | 7.83 | 15.07 | 1.54 |

CRP = C-reactive protein, ESR = erythrocyte sedimentation rate, Post-ophospitalization = post operation hospitalization duration, Pre-op = pre-operation, TMP = 3 months after the operation.

affected vertebrae was used during surgery. Posterior deformity correction, pedicle screw fixation of affected vertebrae, and posterolateral bone grafting were performed first, and then anterior debridement, decompression, and strut grafting were carried out.

During the posterior procedure, the patient was placed in a prone position. A posterior midline incision was made, and the affected segments were exposed. Pedicle screw fixation of affected vertebrae was carried out, connecting rods were placed, and transverse connectors were attached to the rods to increase stability. For patients with kyphosis, the apex vertebra was pressed manually for reduction; then internal fixation devices were used to correct the deformity; and finally the devices were locked to complete the correction and fixation.

After internal fixation, posterolateral bone grafting and fusion were carried out between the upper and lower affected vertebrae. The cortical bone of the articular processes, lamina, isthmus, and the transverse processes of the affected vertebrae was removed, and then an autogenous bone grafting and fusion was applied. No matter whether the lesion involved a single segment or multiple segments, fixation and fusion was carried out only for the affected vertebrae. The internal fixation devices were SIN0, UPASS, or LEGACY pedicle screw systems, and the diameters and lengths of the pedicle screws were 3.0 to 4.5 mm and 20 to 30 mm, respectively.

**Table 3**

**Radiological examination and neurological function of patients.**

| Case no | Cobb angle (°) | | | | | ASIA | | | VAS | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-op | Post-op | FFU | Correction | Lost | Pre-op | Post-op | FFU | Pre-op | FFU |
| 1 | 32 | 2 | 3 | 30 | 1 | D | E | E | 7 | 1 |
| 2 | 23 | −6 | −3 | 29 | 3 | C | C | D | 6 | 2 |
| 3 | 21 | −3 | −1 | 24 | 2 | E | E | E | 8 | 2 |
| 4 | 33 | 3 | 4 | 35 | 1 | E | E | E | 5 | 0 |
| 5 | −6 | −18 | −17 | 12 | 1 | E | E | E | 8 | 1 |
| 6 | 36 | 4 | 6 | 32 | 2 | D | D | E | 4 | 0 |
| 7 | 23 | −7 | −6 | 30 | 1 | E | E | E | 5 | 1 |
| 8 | 10 | −11 | −10 | 21 | 1 | C | D | E | 7 | 1 |
| 9 | 26 | 4 | 5 | 22 | 1 | D | E | E | 6 | 2 |
| 10 | 39 | 10 | 12 | 29 | 2 | C | D | D | 6 | 0 |
| 11 | 24 | −5 | −5 | 29 | 0 | E | E | E | 8 | 1 |
| 12 | 35 | −1 | 3 | 36 | 4 | D | E | E | 5 | 0 |
| 13 | 35 | −8 | −7 | 43 | 1 | E | E | E | 7 | 2 |
| 14 | 31 | −7 | −5 | 38 | 2 | E | E | E | 6 | 1 |
| 15 | 29 | −6 | −5 | 35 | 1 | D | D | E | 8 | 0 |
| 16 | −10 | −19 | −18 | 9 | 1 | E | E | E | 5 | 0 |
| 17 | 23 | −5 | −4 | 28 | 1 | E | E | E | 4 | 0 |
| 18 | 28 | −10 | −8 | 38 | 2 | E | E | E | 6 | 2 |
| Mean | 24.00 | −4.61 | −3.11 | 28.61 | 1.50 | | | | 6.17 | 0.89 |

ASIA = American Spinal Injury Association, FFU = final follow-up, Pre-op = pre-operation, Post-op = post-operative, VAS = visual analog scale.
Cobb angle: kyphosis are recorded as positive; lordosis are recorded as negative.

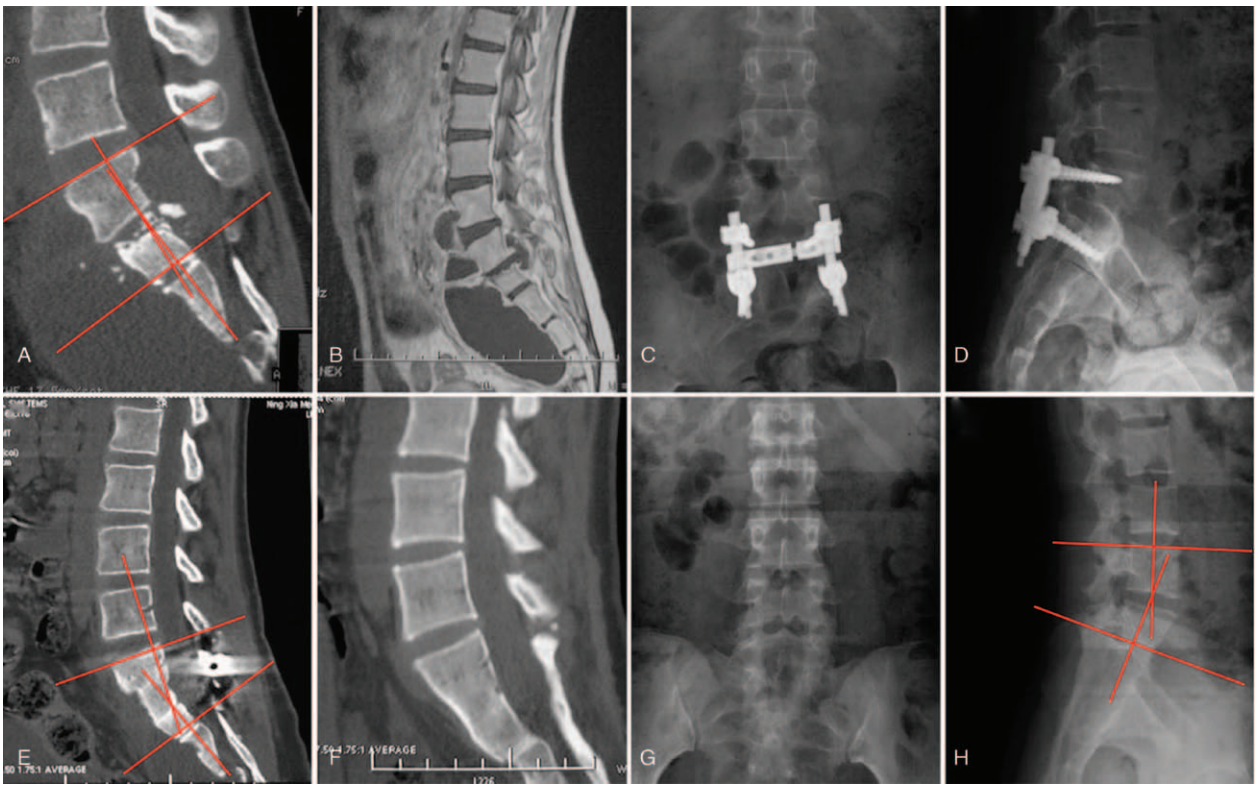


**Figure 1.** An 11-year-old female patient who had L4–S1 tuberculosis underwent combined anterior and posterior surgery using fixation of the affected vertebrae. (a) A preoperative sagittal CT reconstruction image showed vertebral destruction in L4, L5, and S1, along with intervertebral space narrowing in L5–S1. (b) A preoperative sagittal T1-weighted MR image showed vertebral destruction in L4, L5, and S1, destruction of the L5–S1 disc, and prevertebral and intraspinal abscess formation. (c and d) Anteroposterior and lateral X-ray images obtained 1 month after surgery showed that the fixation of affected vertebrae was excellent. (e) A sagittal CT reconstruction image obtained 2 months after surgery showed that L4–L5 and L5–S1 tuberculosis lesions were healed and the location of the bone graft was excellent. (f) Two years after surgery, bone fusion was achieved, and the posterior internal fixation system was removed according to the patient's individual requirements. (g and h) Five years after surgery, the anteroposterior and lateral X-ray images showed an excellent spinal curve without imbalance between the anterior and posterior columns. CT = computed tomography, MR = magnetic resonance.

During the anterior procedure, the patient was placed in the lateral decubitus position, and a renal incision was made for patients with affected vertebrae in the upper lumbar spine. While the patient was placed in the supine position, a V-shaped incision was made for patients with affected vertebrae in the lower lumbar spine. The more severely destroyed side of the affected vertebrae was selected for the surgical approach. The affected vertebrae were exposed, and radical debridement was carried out,[7] inflammatory granulation tissue and pus were removed, and strut grafting was carried out using an autologous iliac bone graft. All these procedures were performed in the affected segments without involving the normal segments (Fig. 1 and Fig. 2).

These 2 surgeries were completed in 1 stage or 2 stages according to each patient's condition. Twelve out of 18 patients underwent anterior and posterior surgeries in 1 stage, and 6 patients underwent surgeries in 2 stages.

### 2.4. Postoperative treatment and follow-up

A negative-pressure drainage system was used after surgery and was removed when the volume of drainage was <20 ml per 24 hours. The patient was placed on bed rest for 3 to 4 weeks after surgery. Weight-bearing ambulation was started while the patient was wearing a brace at 3 to 4 weeks after surgery, and patients returned to normal life 4 to 6 months later. A regimen of 2HRZS/4HRZ (isoniazid [H, 10 mg/kg/d], rifampicin [R, 10 mg/kg/d], pyrazinamide [Z, 25 mg/kg/d], streptomycin [S, 20 mg/kg/d]) was used after surgery. Intensive chemotherapy was applied for 2 months, and consolidation chemotherapy was used for 2 to 5 months.[8,9] The follow-up and supervision of chemotherapy were carried out by a specifically assigned person (WJ). The patients received in-hospital follow-up care each month for 6 months postoperatively; at 9 and 12 months; every year until year 5; and every other year until year 10 postoperatively. The patients received in-hospital follow-up care each month for 6 months postoperatively; at 9 and 12 months; every year until year 5; and every other year until year 10 postoperatively. X-ray, CT, MRI, and ultrasonography, ESR and CRP levels, liver and kidney functions, nerve function recovery, TB cure, and bone graft healing were recorded.

### 2.5. Statistical analysis

SPSS version 22.0 (SPSS Corporation, Chicago, IL) statistical software was used for statistical analysis. The *t* tests were used to compare ESR and CRP before and after surgery. The Wilcoxon matched-pairs test was used to compare the preoperative and postoperative Visual analog scale (VAS) scores and Cobb angles. A significance level of $\alpha = 0.05$ was used.

## 3. Results

The mean follow-up time was 86.5 months (range, 62–120 months); the mean intraoperative blood loss was 434 ml; the

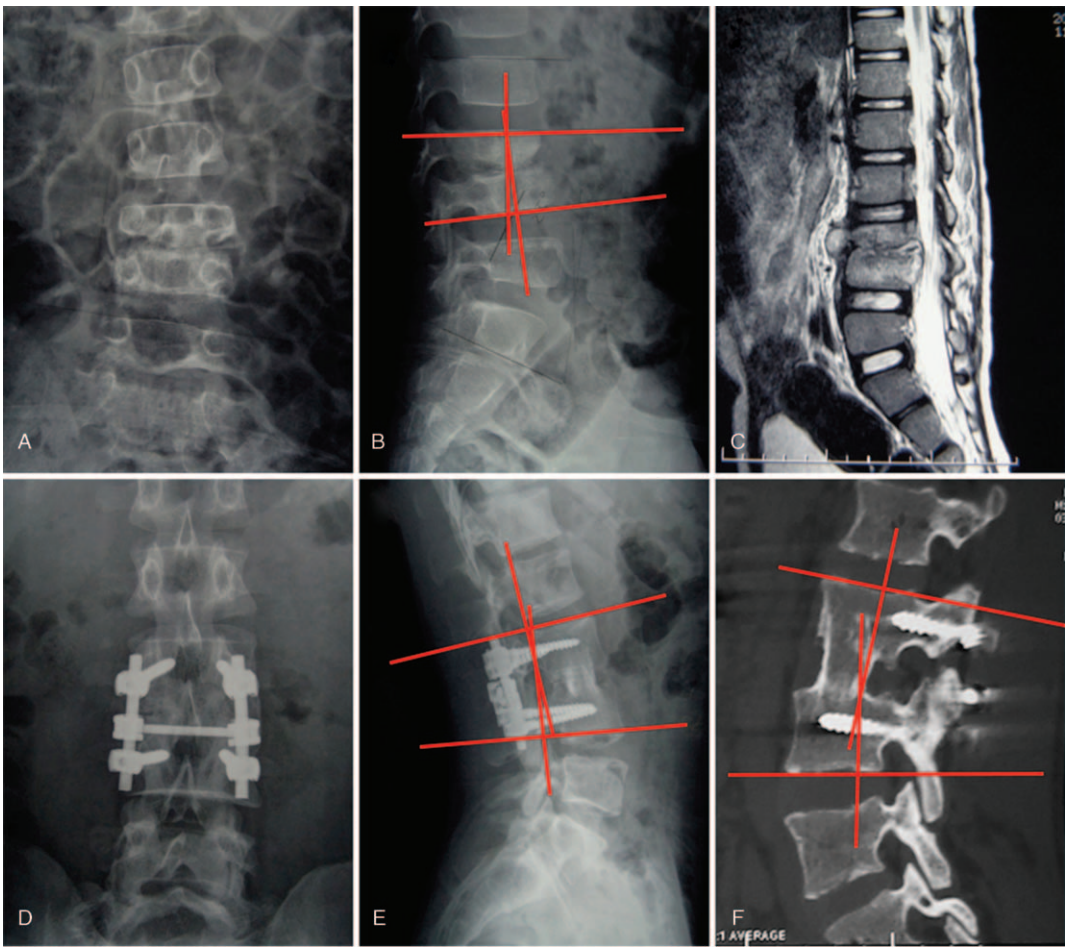


**Figure 2.** An 13-year-old male children who had L3–L4 tuberculosis underwent combined anterior and posterior surgery using affected-vertebrae fixation. (a andb) Anteroposterior and lateral X-ray images obtained before surgery showed that the L3–L4 vertebral damage with a narrowed intervertebral space and a kyphosis was formed. (c) A preoperative enhanced MR image showed vertebral destruction in L3 and L4, destruction of the L3-L4 disc, and prevertebral and intraspinal abscess formation. (d and e) Three years after surgery, the anteroposterior and lateral X-ray images show that the fixation of the affected vertebrae is excellent. (f) Eight years after surgery, the sagittal CT reconstruction shows healing of L3 and L4 tuberculosis lesions and bone graft fusion. CT = computed tomography, MR = magnetic resonance.

average postoperative hospital stay was 9.50 days; the average time of chemotherapy was 5.4 months (range, 4–7 months). All patients achieved bone graft healing, and the corresponding CT images showed the presence of bridging trabecular bone between the graft and host bone, along with enlargement of the bone graft. Healing of TB lesions was observed in all patients 6 months after surgery. All these indicators were normal at the last follow-up, and there was no evidence of non-union or recurrence. The ESR and CRP levels were reduced to normal in all patients 3 months after surgery. VAS scores were used to assess the pain degree of patients. The mean preoperative VAS score was 6.17 (range, 4–8). The mean VAS score at the last follow-up was 0.89 (range, 0–2). The neurological function was improved significantly in 8 patients who presented with neurological dysfunction before surgery. At the last follow-up, the ASIA grades were grade D in 2 children and grade E in 6 children.

In this group of patients, the number of the affected vertebrae was 39; average number of affected vertebrae was 2.17; total number of fixed vertebrae was 37; average number of fixed vertebrae was 2.06. Compared with the preoperative kyphotic angle ($24.00° \pm 13.15°$), the postoperative kyphotic angle ($-4.61° \pm 7.31°$) improved significantly ($Z = -4.34$, $P < .01$), and the average deformity correction was $28.61° \pm 8.43°$. There was no significant difference between the kyphotic angle measured immediately after surgery ($-4.61° \pm 7.31°$) and the kyphotic angle measured at the last follow-up ($-3.11° \pm 7.56°$). The average loss of correction was $1.50° \pm 0.90°$ (Table 3). No patient had injuries to nerves, blood vessels, or important organs. No patient had complications such as wound infection, sequestrum, sinus or abscess formation, failure of internal fixation, or related issues. Adverse reactions to anti-TB drugs were found in 4 cases. In 1 case, liver damage was observed 2 months after chemotherapy; this was treated with hepatoprotectors, and the transaminase level was reduced to normal 1 month later. Tinnitus and mouth numbness was observed in 3 cases after streptomycin administration; both symptoms disappeared after the drug was withdrawn.

## 4. Discussion

TB remains a common disease in developing countries, and about 9 million new cases of TB occur worldwide each year. The incidence of bone TB in TB patients ranges from 3% to 5%,[10] and more than half of these involve the spine.[11] Children are susceptible to spinal TB, most often of the central type in which the vertebral body is severely damaged and multiple vertebrae are

involved; in such instances, delayed treatment may result in serious consequences such as neurologic injury and kyphosis.[12]

Although anti-TB therapy is effective in most patients, Rajasekaran et al suggested that if spinal TB was only treated conservatively, 32% of the children would develop kyphosis >20°, and accordingly they proposed a kyphotic angle estimation formula (kyphotic angle = 5.5° + 30.5° × the number of affected vertebral bodies).[13] Therefore, surgical treatment of children with lumbar TB must not only remove the lesion and relieve spinal cord compression but also must correct the kyphotic deformity caused by the destruction or collapse of the vertebral body and prevent the aggravation of kyphosis (that may be caused by the children's subsequent growth).[14–16]

In the present study, all patients achieved bone fusion at 6 months after surgery without nonunion or recurrence. The kyphotic angle, a major indicator of deformity correction and spinal stability reconstruction, was improved significantly after surgery ($-4.61° \pm 7.31°$ vs $24.00° \pm 13.15°$, $Z = -4.34$, $P < .01$); the mean deformity correction was $28.61° \pm 8.43°$, and the mean correction loss at the last follow-up was $1.50° \pm 0.90°$. Wang et al[17] and He et al[18] reported that the correction angle of lumbar TB in children treated by short-segment fixation and long-segment fixation was 24.2° and 25.2°, the correction loss was 1.2° and 1.1°, respectively; these values were similar to the results of intervertebral surgery in the present study. At the last follow-up, there was no imbalance between anterior and posterior vertebral columns in the present study. Therefore, it may be indicative that an intervertebral surgery using a combined posterior and anterior approach, is a safe and effective method in the treatment of lumbar TB in children; the procedures can reconstruct spinal stability and maintain the outcome of correction for a long time.

The combined posterior and anterior procedure cannot only achieve complete debridement, sufficient decompression, and deformity correction, but it also can obtain fusion and fixation of affected vertebrae, (including the anterior, middle, and posterior columns, to make the anterior and middle columns develop synchronously), thereby preventing the exacerbate of kyphosis. Thus, most scholars recommend the combined posterior and anterior procedure.[1–4] However, the method and range of fixation and fusion in the treatment of pediatric spinal TB have not been given sufficient attention. Some surgeons use long-segment fixation and fusion, but others apply short-segment fixation and fusion. Long-segment and short-segment fixation and fusion have the following disadvantages: Both methods sacrifice 2 or 4 normal motion units of the spine and increase the incidence of adjacent vertebral diseases postoperatively.[19] Further, the pedicle screws used for posterior fixation are placed into the normal vertebrae and affect the development of the posterior column of the normal vertebrae, resulting in an imbalance in the growth of the anterior and posterior columns.

To solve the problem of excessively long segments required for fixation and fusion during spinal TB surgery, we recommended the intervertebral surgery; that is, radical debridement is merely limited to the affected motion units, (the internal fixation screws are placed into the pedicles of affected vertebrae, the strut graft is placed in the interval of affected vertebrae), and the decompression and deformity correction are also limited to the affected segments. All surgical procedures are performed within the affected motion units during the surgical treatment of spinal TB, while the normal motion units are not involved in order to preserve the maximal motor function of the spine[20,21] and to reduce the disruption of normal spinal development in children.

Precautions at the time of applying the intervertebral surgery during the treatment of lumbar TB in children are as follows:

(1) The pedicles of affected vertebrae should be relatively intact without invasion of TB in order to provide effective anti–pull-out strength to pedicle screws.
(2) The strut graft should be an autogenous iliac bone block from the iliac crest because it not only has an excellent supporting force to share part of the stress load and prevent the collapse of the vertebral body, but the strut graft also has strong self-healing and anti-infection abilities.
(3) Because the fixation of affected vertebrae involves fewer segments, this method is not suitable for children with severe kyphosis that requires osteotomy and deformity correction. For such patient, intervertebral surgery is not suitable and short-segment or long-segment fixation should be applied.

The shortcoming of the present study is that the sample size is small. Therefore, prospective, large-sample, multicenter studies should be carried out to confirm and define optimal treatments.

## 5. Conclusion

The intervertebral surgery using a combined posterior and anterior approach can achieve excellent outcomes in the treatment of lumbar TB in children without severe kyphosis.

## Author contributions

**Data curation:** Qiang Liang, Qian Wang, Liehua Liu.
**Formal analysis:** Qiang Liang, Guangwei Sun.
**Funding acquisition:** Zili Wang, Weidong Jin.
**Methodology:** Zili Wang, Yu Pu.
**Software:** Qiang Liang, Yu Pu, Jiandang Shi.
**Writing – original draft:** Qiang Liang, Qian Wang.
**Writing – review and editing:** Zili Wang, Weidong Jin.

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