Lumbar Tuberculosis Treatment with Cortical Bone Trajectory Screw Fixation

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Abstract

Objective: This study aimed to investigate the clinical efficacy of a cortical bone trajectory (CBT) screw technique combined with an anterior small incision lesion removal and bone grafting for the treatment of single-segment lumbar spinal tuberculosis.

Methods: A retrospective analysis of 42 patients with lumbar tuberculosis was performed. The patients were divided into two groups: intervertebral CBT screw fixation group (CBT group) and posterior pedicle screw fixation group (traditional group). Then the surgery time, bleeding volume, postoperative drainage volume, postoperative hospital stay, visual analogue scale (VAS) score, Cobb angle, neurological function (Frankel grading), and bone graft fusion time were compared between the two groups.

Results: There were no significant differences between the two groups in terms of the operation times, bleeding volumes, drainage volumes, hospital stays, VAS scores, and Frankel grading. VAS scores, Cobb angles, and Frankel grading improved significantly after surgeries, without a significant difference between the two groups. At the final follow-up, no significant loss of the Cobb angle was found. All of the patients were followed up for 14 to 30 months, with a mean time of 20.8 months. The bone graft fusion time ranged from 3 to 8 months, with a mean time of 5.1 months. There were no serious complications.

Conclusions: The CBT screw technique combined with an anterior small incision lesion removal and bone grafting is an effective and safe method for the treatment of lumbar tuberculosis.

Introduction

The incidence of tuberculosis has increased significantly in recent years due to the increased population mobility, increased number of human immunodeficiency virus infections, tubercle bacillus mutations, increased resistance to resistant strains, and the
irregular use of anti-tuberculosis drugs [1, 2]. Spinal tuberculosis is a common type of extrapulmonary tuberculosis, and it is one of the most common diseases with severe teratogenicity and disability that is seen in the clinic [2, 3]. Although anti-tuberculosis drug therapy is the most basic and critical treatment for spinal tuberculosis, surgery is an important method to treat chest and lumbar tuberculosis with severe complications, such as spinal instability and spinal nerve compression [4, 5].

For lumbar tuberculosis patients requiring surgical intervention, one-stage anterior debridement, bone graft fusion, and posterior internal fixation is currently the most commonly used surgical procedure [6]. A pedicle screw fixation performed only in the diseased vertebrae has many drawbacks, including a larger exposure of bony marks, greater possibility of screw loosening, and higher risk of infection [7] [8]. Santoni et al. [9] first proposed the cortical bone trajectory (CBT) screw fixation technique in 2009. For this technique, the CBT screw was inserted through the pedicle, and its length was shorter than that of a traditional pedicle screw. The screw trajectory did not penetrate into the anterior middle column of the vertebral body. It was mainly located in the cortical bone, with its biomechanical strength being enhanced when compared with the traditional pedicle screw [8]. As reported, the application of a CBT screw combined with a traditional pedicle screw has achieved ideal clinical results in treating lumbar tuberculosis [10, 11]. However, the above application does not fully exploit the advantages of CBT screws used for an intervertebral fixation.

In this retrospective study, the value of the CBT screw fixation technique for the treatment of lumbar tuberculosis was analyzed by comparing the effects of these two surgical procedures for the treatment of single-segment lumbar tuberculosis.

Materials And Methods

Clinical information
All procedures performed in this study were in accordance with the ethical standards of the Ethics Committee of Hangzhou Red Cross Hospital, China (Ethical approval number [2018 Clinical Review No. 009]) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

A total of 42 patients with lumbar tuberculosis receiving surgery in our hospital from February 2013 to December 2017 were enrolled in this study, including 23 males and 19 females. The patients were divided into two groups based on their surgical procedures: an intervertebral CBT screw fixation combined with anterior small incision lesion removal support bone grafting (CBT group) and a posterior pedicle screw fixation combined with anterior small incision lesion removal support bone grafting (traditional group). At the time of admission, the erythrocyte sedimentation rate, kyphosis Cobb angle, Frankel classification [1], and visual analogue scale (VAS) pain values were obtained.

**Inclusion criteria**

The inclusion criteria were as follows: adult patients with clear clinical diagnoses (diagnosed by clinical symptoms, imaging, and biochemical immunological examinations) accompanied by lumbar instability-caused lower back pain; patients whose lumbar tuberculosis lesions were limited to a single segment, including one intervertebral disc and an adjacent vertebral body, without attachment being involved; patients with progressively aggravated neurological damage; patients who were not cured by conservative medical management, with the lesion being enlarged or the clinical symptoms being aggravated; and patients whose residual height of the diseased vertebra could be subjected to an anterior support bone graft.

**Exclusion criteria**

The exclusion criteria were as follows: patients whose conditions were complicated by basic diseases and they could not tolerate surgery; patients with a history of lumbar
surgery or lumbar spine tumors; and patients with severe lumbar kyphosis and a greater risk of height loss after a single-segment internal fixation.

**Treatment methods**

**Antispasmodic treatment**

Conventional anti-tuberculosis chemotherapy with isoniazid, rifampicin, pyrazinamide, and ethambutol was administered for 2 to 4 weeks. Individual anti-tuberculosis treatment was required if the patient was elderly, the liver function was abnormal, or an allergic reaction occurred. The systemic nutritional support treatment was strengthened, and, if necessary, a transfusion was applied to improve anemia. The tuberculosis poisoning symptoms and erythrocyte sedimentation rate were monitored. When the poisoning symptoms were reduced, the body temperature was ≤ 37.5°C, the hemoglobin was > 100 g/l, and the erythrocyte sedimentation rate was below 60 mm/h, it was the best time for surgery.

**Preoperative preparation**

First, we performed an X-ray, a plain computed tomography (CT) scan and two-dimensional reconstruction, and an MRI examination of the spine. Next, the posterior approach was used to fix the intervertebral CBT screw. Then, the lesion removal path was chosen according to the extent of vertebral destruction and the location of the abscess.

**Surgical methods**

In the CBT group, after undergoing general anesthesia, the patient was placed in the prone position, and the abdominal space was separated. After the localization of the surgical segment was confirmed, the patient was routinely disinfected. A median incision was made in the posterior lumbar spine, and the segment was exposed layer by layer down to the spinous process. The paraspinal muscles on both sides of the spinous process were removed under the periosteum. The CBT screw placement only required the exposure of the lateral part of the lamina and the medial edge of the facet joint. According to the
preoperative planning, the CBT screw was placed.

The CBT screw placement method was as follows. The lamina located downwardly and inwardly 2 mm from the lower inner edge of the superior articular process was the entry point. The nail entry point was drilled by grinding, and the needle insertion direction was an extraversion of approximately 10~20°. The head tilt was approximately 25~30°, and the screw diameter was approximately 3.5~5.0 mm. The length of the screw was as follows: the front end of the screw passed through the pedicle.

After confirming that the screw position was good using a C-arm X-ray machine, we selected and pre-bent a titanium rod of the appropriate length. We put the end of the screw into the pre-bent rod and fixed the nut. An effective negative pressure drainage device was placed and sutured to the skin layer by layer [10]. The patient was then placed in a semi-recumbent position. A small incision of 6~8 cm centered on the diseased vertebrae was created and separated into the diseased vertebrae along the extraperitoneal space to complete the anterior debridement and autologous iliac bone grafting [12].

The patients in the traditional group were placed in the prone position, and the posterior median incision was made with the diseased vertebral body as the center. The paravertebral muscle approach revealed bilateral articular processes. Individualized pedicle screws were implanted according to the degree of the vertebral destruction of the preoperative lesions. The length of the implanted screws was between 30 and 45 mm, and the pedicle screws were placed in the upper and lower 1~2 normal vertebral bodies through the internal fixation system. The kyphosis was corrected by the internal fixation system. The anterior operation was the same as that performed in the CBT group.

Postoperative treatment

Based on the drainage situation, the drainage tube was generally removed 24 to 48 hours
after the surgery. Antibiotics were used for 2 to 3 days. After 1 week, the patients could perform normal walking activities with a brace. The principle of “multiple beds and fewer activities” was to be adopted for the first 3 months [13]. The anti-tuberculosis treatments and nutritional support were continued after the surgery.

**Observation indicators**

The observation indicators included the general information (including the surgery time, bleeding volume, postoperative drainage volume, and hospitalization days), clinical symptoms, imaging measurements, and laboratory tests (including the VAS scores before the operation, 1 week after the operation, and at the last follow-up, the Cobb angle, and the erythrocyte sedimentation rate), and the neurological function grading (Frankel grading).

**Statistical analysis**

The statistical analysis was performed using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA). A chi-squared test was performed on the gender and lesion segments of the two groups. The two independent samples t-test was used for the age, disease course, operative time, bleeding volume, drainage volume, postoperative hospital stay, VAS score, Cobb angle, and erythrocyte sedimentation rate. The two independent samples Wilcoxon signed-rank test was used for the neurological function classification (Frankel grading). *P* values less than 0.05 were considered as statistically significant.

**Results**

The ages of the 42 patients ranged from 30 to 73 years old, with a mean age of 50.7 ± 12.3 years old. The course of the disease was 2 to 16 months, with a mean time of 7.7 ± 3.4 months. The clinical manifestations were as follows: the patients had different degrees of lumbar pain and stiffness, and their flexion and extension rotational activities were limited. Nine of the patients (CBT group/traditional group: 4/5) exhibited neurological
symptoms, such as numbness, weakness, and lower extremity dysfunction, while 13 of the patients (CBT group/traditional group: 6/7) exhibited typical tuberculosis symptoms, such as hypothermia, night sweats, and fatigue.

The imaging examinations showed vertebral body and intervertebral disc destruction and paraspinal abscesses. The T2-weighted magnetic resonance imaging (MRI) showed vertebral compression deformation with a non-uniform high signal, and a flow-like high signal could be seen in the soft tissue space (Fig. 1). All of the patients exhibited a single gap, and the specific vertebral lesion distribution is shown in Table 1. Three cases (CBT group/traditional group: 1/2) had sinus formations.

No significant differences were found in the genders, ages, disease durations, or diseased segments between the CBT group and traditional group ($P > 0.05$), which were comparable (Table 1). In addition, there were no significant differences in operation times and hospitalization times between the two groups. The amount of bleeding and postoperative drainage decreased, but the differences were not statistically significant (Table 2).

The changes in the VAS scores, Cobb angles, and erythrocyte sedimentation rates after the operation are shown in Table 3. When compared to the preoperative values, the VAS scores and Cobb angles of the two groups were significantly improved after 1 week ($P < 0.05$), but the erythrocyte sedimentation rates were not improved ($P > 0.05$). The VAS scores, Cobb angles, and erythrocyte sedimentation rates were all significantly improved at the final follow-up when compared to the preoperative values ($P < 0.01$), and there were no statistically significant differences between the two groups.

All of the patients exhibited improved neurological symptoms after the surgery (Table 4). According to the Frankel grading, the neurological functions were significantly recovered in the two groups at the follow-ups when compared with the preoperative values ($P < 0.05$). There was no statistically significant difference between the two groups ($P > 0.05$).
All of the patients in this study were followed up for a period of 14 months to 30 months, with a mean time of 20.8 months. At the 3-month follow-up, the lateral psoas muscle abscesses had increased in 2 patients in the CBT group and 2 patients in the traditional group who were treated using the anterior approach, which disappeared after a secondary surgery. The remaining 39 cases were cured in one stage without complications. The tuberculosis poisoning symptoms disappeared in all of the patients. The bone graft fusion time ranged from 3 to 8 months, with a mean fusion time of 5.1 months. Seven of the patients (CBT group/traditional group: 3/4) developed drug-induced liver damage after taking anti-tuberculosis drugs, which improved after adjusting the anti-tuberculosis program and strengthening the liver protection treatment.

Discussion

In this work, the retrospective analysis showed no significant differences in operation times, bleeding volumes, drainage volumes, postoperative hospital stays, VAS scores, and neurological function grading between the CBT screw fixation combined with anterior small incision lesion removal support bone grafting group and the posterior pedicle screw fixation combined with anterior small incision lesion removal support bone grafting group. VAS scores, Cobb angles, and neurological function scores were all significantly improved when compared with preoperative values. At the last follow-up, there was no significant loss of the Cobb angle in either the CBT screw fixation group or the conventional pedicle screw fixation group, with no significant difference between the two groups.

After the complete removal of spinal tuberculosis, bone graft fusion and internal fixation are essential for reconstructing the stability of the spine [1, 14]. Two internal fixation methods for reconstructive surgery are currently reported [15, 16]. The first is a long-segment fixation method for two or more normal motion units on the upper and lower sides of a fixed diseased vertebra [17]. Although it has obvious advantages for restoring
the normal sequence of the spine and maintaining the spinal orthopedic effect, extending the fixed segment not only makes the fixed segment stiff but also affects the motor function of the spine. In addition, it can also accelerate the occurrence of adjacent spondylosis. The second is a short-segment fixation method for one normal motion unit on the upper and lower sides of a fixed diseased vertebra [12]. The short segmental pedicle internal fixation has become an important trend in spinal orthopedic surgery. The internal fixation of the vertebral pedicle can reduce the internal fixation of the normal vertebral body. Under the premise of shortening the fixed range as much as possible, the reliability of the internal fixation is ensured, and the biomechanical change in the spine caused by the excessive internal fixation is reduced. Besides, there is a fixation method for fixing the diseased vertebrae only [18, 19]. The number of fixed/fused segments is equal to the number of lesion segments. This operation does not involve normal motion units, and the spinal motor function is preserved to the utmost extent.

A pedicle screw fixation performed only in the diseased vertebrae still exhibits the following defects. First, it is necessary to peel the muscles away in a large range to expose the bony marks and assist the safe placement of the screws. For example, when the screws are placed into the lower lumbar vertebrae and the sacrum, the range of muscle peeling is larger. Second, the anterior column of the vertebral body has been destroyed, which affects the mechanical strength of the screw and causes the screw to loosen. Especially in osteoporosis cases, due to the reduction of the bone mass and the deterioration of the bone structure, the possibility of screw loosening after surgery is greater. Finally, the distal end of the screw enters the lesion, causing the risk of spreading the infection backward.

In 2009, Santoni et al. [9] proposed a CBT technique for a lumbar pedicle screw fixation. The screw was placed from the vertebral pedicle in the sagittal plane from the bottom to
the top and in the transverse section from inside to outside, changing the traditional way of placing the screw through the anatomical axis of the pedicle. CBT screw internal fixation technology places the screw in full contact with the cortical bone concentrated area, which can increase the bone-screw interface strength. When compared with the traditional pedicle screw, the CBT screw torque is increased by 1.7 times, and the axial pull-out stress is increased by 30% [9, 20]. The advantages of CBT screws for spinal tuberculosis are as follows [10, 21]. First, they simplify the surgical procedure, reduce back muscle exfoliation and intraoperative bleeding, and reduce soft tissue damage. Second, the CBT technology has a shallower screw insertion depth than that of conventional pedicle screws. Its insertion depth is located behind the vertebral body, which is suitable for most diseased vertebrae, and it does not affect the anterior interbody fusion. Third, in its trajectory, the screw has 4 points of cortical contact with the lumbar vertebra (the isthmus, pedicle inner wall, pedicle outer wall, and anterior lateral wall of the vertebral body), which increases the stability of the internal fixation. Finally, if necessary, two sets of screws (one conventional pedicle screw and one CBT screw) can be placed in the same pedicle area to improve the osteoporotic bone-screw holding force. It has been reported that the application of a CBT screw combined with a traditional pedicle screw for the treatment of lumbar tuberculosis has achieved ideal clinical results [10, 11]. However, the above application does not fully exploit the advantages of the CBT screws used in the intervertebral fixation. In our study, at the final follow-up, no significant loss of the Cobb angle was found. The lateral psoas muscle abscesses were increased in 2 patients in the CBT group and 2 patients in the traditional group who were treated using the anterior approach, but they disappeared after a secondary surgery. The remaining 39 cases were cured in one stage, without sinus formations, incisional hernias, cerebrospinal fluid leakages, or spinal tuberculosis recurrences.
There have been several limitations in this study as follows: small sample size, non-randomized design, and no power analysis performed, which will be taken into consideration in our future work.

In summary, the use of a CBT screw intervertebral fixation is a safe, effective, and feasible surgical method for the treatment of lumbar tuberculosis.

Conclusions

The application of CBT screw technique combined with anterior small incision lesion removal and bone grafting is a more effective and safe method for the treatment of lumbar tuberculosis.

Declarations

Ethics Approval and Consent to Participate

All procedures performed in this study were in accordance with the ethical standards of the Ethics Committee of Hangzhou Red Cross Hospital, China (Ethical approval number [2018 Clinical Review No. 009]) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study formal consent is not required.

Consent for publication

Written informed consent was obtained from all participants. Informed consent was obtained from all individual participants included in the study.

Availability of data and material

The analyzed data sets generated during the study are available from the corresponding author on reasonable request.

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Conflict of Interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers’ bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Authors’ contributions

SYS designed the study, performed the study, collected the data, analyzed the data, and drafted the manuscript. XZY conceived of the study, performed the study, collected the data, analyzed the data, and helped to draft the manuscript. QZ participated in designing the study, performed the study, collected the data, analyzed the data, and revised the manuscript. JF, JS, BZ, YHJ, SPH performed the study and collected the data. All authors read and approved the final manuscript.

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Tables

Table 1. Detailed clinical information from the two study groups.
| Groups          | Cases | Gender (n) | Age (years) | Course of disease (months) | Focal segment |
|-----------------|-------|------------|-------------|----------------------------|--------------|
|                 |       | Male | Female |                          | L1-2 | L2-3 | L3-4 | L4-5 |
| CBT group       | 20    | 12   | 8      | 50.3±12.5                   | 7.8±3.4       | 5    | 6    | 5    | 4    |
| Traditional group | 22   | 12   | 10     | 51.2±12.3                   | 7.6±3.4       | 5    | 7    | 5    | 5    |
| Test value      | -     | χ²=0.127 | t=-0.243 | t=0.16                     | χ²=0.093     |
| ρ              | -     | >0.05  | >0.05  | >0.05                      | >0.05        |

**Table 2.** Comparisons of operation times, bleeding volumes, drainage volumes, and hospital stays between the two study groups.

| Group           | Operation time (min) | Bleeding volume (ml) | Drainage volume (ml) | Hospital stay (days) |
|-----------------|----------------------|----------------------|----------------------|----------------------|
| CBT group       | 223.3±19.4           | 631.0±139.7          | 272.8±126.9          | 14.7±4.6             |
| Traditional group | 225.2±26.5         | 674.1±144.5          | 284.6±116.9          | 15.1±4.4             |
| Test value      | t=-0.274            | t=-0.981            | t=-0.313             | t=-0.249             |
| ρ              | >0.05                | >0.05                | >0.05                | >0.05                |

**Table 3.** Preoperative, postoperative, and final follow-up monitoring of the visual analogue scale (VAS) score, Cobb angle, and erythrocyte sedimentation rate (ESR).
|                  | VAS score (points) | Cobb angle (°) | ESR (mm/h) |
|------------------|-------------------|---------------|------------|
|                  | CBT group | Traditional group | CBT group | Traditional group | CBT group | Traditional group |
| Pre-operation    | 6.7±2.2    | 6.8±2.2        | 13.1±3.1  | 13.9±3.6        | 58.3±19.3 | 56.7±18.8         |
| 1 week after the operation | 4.4±1.7    | 4.6±1.7        | 4.4±2.1  | 4.5±1.8        | 41.8±18.9 | 48.1±14.6         |
| Final follow-up  | 2.2±1.7    | 2.2±1.6        | 5.1±2.6  | 5.4±1.8        | 14.5±9.8  | 14.8±11.4         |

1 week after operation vs. pre-operation

|                  | t=3.72       | t=3.78        | t=10.49  | t=10.94        | t=2.73    | t=1.75            |
|                  | P<0.05       | P<0.01        | P<0.01  | P<0.01        | P=0.01    | P>0.05            |

Final follow-up vs. pre-operation

|                  | t=7.29       | t=8.12        | t=8.92  | t=9.92        | t=9.06    | t=9.27            |
|                  | P<0.01       | P<0.01        | P<0.01  | P<0.01        | P<0.01    | P<0.01            |

1 week after operation vs. final follow-up

|                  | t=4.01       | t=4.79        | t=-1.02 | t=-1.75       | t=5.73    | t=8.43            |
|                  | P<0.01       | P<0.01        | P>0.05  | P>0.05        | P<0.01    | P<0.01            |

Table 4. Neurological recovery based on the Frankel grading values of the two groups.

| Pre-operation | Group (CBT group/traditional group) | Frankel grading at the final follow-up in CBT group | Frankel grading at the final follow-up in Traditional group |
|---------------|-------------------------------------|-----------------------------------------------------|----------------------------------------------------------|
|               |                                     | A   | B   | C   | D   | E   | A   | B   | C   | D   | E   |
| A             | 0/0                                 |     |     |     |     |     |     |     |     |     |     |
| B             | 1/1                                 |     |     |     |     |     |     |     |     |     |     |
| C             | 3/5                                 |     |     |     |     |     |     |     |     |     |     |
| D             | 5/5                                 |     |     |     |     |     |     |     |     |     |     |
| E             | 11/12                               |     |     |     |     |     |     |     |     |     |     |

In total | 20/22 | 1   | 2   | 17  | 1   | 2   | 19  |

▲: In the CBT group, Wilcoxon signed-rank test, compared with pre-operation, Z=-2.08, P<0.05.

△: In the traditional group, Wilcoxon signed-rank test, compared with pre-operation,
Z=-2.34, P<0.05.

■: Wilcoxon signed-rank test, Traditional group compared with CBT group, Z=-0.12, P>0.05.

Figures

Figure 1

A 36-year-old female patient with lumbar 2–3 vertebral tuberculosis accompanied by incomplete paralysis. A, B, C. Preoperative computed tomography (CT) and magnetic resonance imaging scans showing lumbar 2–3 vertebral body
destruction with spinal canal occupation and spinal cord compression. D, E.

Postoperative positive lateral radiograph showing that the cortical bone trajectory screw was fixed in the lumbar 2-3 diseased vertebrae. The patient's anterior column bone destruction was still acceptable, and the ilium was placed in the anterior part of the intervertebral space. F. Postoperative CT scan indicating that the posterior dead bone of the vertebral body was removed, and the iliac bone graft was in a good position.