

# Efficacy, safety and prognosis of treating neurological deficits caused by spinal tuberculosis within 4 weeks' standard anti-tuberculosis treatment: A single medical center's experience

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**Abstract.** The present study aimed to retrospectively analyze the safety and efficacy of the early surgical management of thoracic tuberculosis (TB) in patients with neurological deficits. The medical data of patients with thoracic TB exhibiting neurological deficit in the Chest Hospital of Hebei Province were retrospectively reviewed. A total of 234 cases, including 123 males and 115 females, were recruited in the present study. Their pre- and postoperative neurological deficit and pain levels were assessed using the 2002 American spinal injury association (ASIA) impairment scale and visual analog scale, respectively. Patients were divided into two groups according to whether their preoperative standardized anti-TB treatment time was  $\geq 4$  weeks or  $< 4$  weeks. There was no difference in blood loss and operation time between the two groups. The erythrocyte sedimentation rate was higher in patients receiving standard anti-TB  $< 4$  weeks prior to and 1 month following surgery compared with the  $\geq 4$  weeks group, but the difference was not significant 6 months following surgery. ASIA scale scores all increased significantly 1 month following surgery in the  $< 4$  weeks group compared with the  $\geq 4$  weeks group ( $P=0.001$ ) though there was no difference between the scores prior to surgery. ASIA scale scores improved to  $4.4 \pm 0.5$  and  $4.5 \pm 0.4$  in patients with anti-TB treatment times of  $\geq 4$  weeks and  $< 4$  weeks, respectively, 24 months following surgery ( $P=0.0895$ ). The present study demonstrated that for patients with thoracic TB exhibiting neurological deficit, early surgical management following  $< 4$  weeks' standard anti-TB treatment is recommended. It may relieve spinal cord compression and

also benefit the early recovery of neurological function in these patients.

## Introduction

Tuberculosis (TB) is an ancient disease that still jeopardizes human health. The proportion and incidence of extrapulmonary TB, particularly osteoarticular TB, increases each year (1). Spinal TB is a common form of bone and joint TB and accounts for 3-5% of all types of TB. Thoracolumbar vertebrae accounts for 50% of bone TB (2,3). One of the most serious complications of spinal TB is neurological deficit (4). The majority of neurological deficits in patients with TB are caused by the posterior compression of the spinal marrow, which was primarily caused by bone ridges and tuberculous substances in the rear of the vertebral body (5). These neurological deficits seriously affect the quality of life of patients with spinal TB; it has far-reaching consequences, is the cause of a high disability rate, and may even endanger the lives of those affected (6).

At least 4 weeks of anti-TB treatment is generally recommended prior to patients with spinal TB receiving surgical treatment; the duration of which may make it possible to stabilize the disease condition, and to return the body temperature, erythrocyte sedimentation rate (ESR), C-reactive protein (CRP) level and other indexes to their acceptable ranges (7). Certain patients require an even longer period of time in order to stabilize their condition, prior to receiving surgical treatment. It has been indicated that, in order to relieve spinal cord compression, patients with spinal TB combined with neurological deficits should receive surgery as early as is feasible, which may prevent the irreversible degeneration of neurological deficits. The contradiction between the benefits and the safety of this surgery has long been the focus of substantial research (8,9).

The present study focused on whether it is necessary to undergo  $> 4$  weeks of anti-TB treatment prior to surgery, whether surgery should be performed once the ESR reaches a certain level, and whether surgery should be performed early when infections respond to treatment during the early stage of anti-TB chemotherapy. The timing of the operation, the safety and the efficacy of anti-TB surgery was investigated at different preoperative times for patients with spinal TB exhibiting neurological deficits in the present study.

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**Key words:** early surgical management, thoracic tuberculosis, neurological deficit, erythrocyte sedimentation rate, prognosis

## Materials and methods

**Patients.** The medical data of patients with thoracic TB combined with neurological deficits were retrospectively reviewed in the present study. All patients received surgery at the Department of Orthopedics of the Chest Hospital of Hebei Province (Hebei, China) between February 2013 and December 2017. The inclusion criteria were as follows: i) Thoracic tuberculosis with neurological deficit; ii) patients with complete medical data; iii) patients who continued with standardized anti tuberculosis treatment after operation; iv) patients that received follow-up of 24 months. Exclusion criteria were as follows: i) Patients with severe symptoms of tuberculosis poisoning; ii) patients with dysfunction of heart, lung, brain, liver, kidney or electrolyte abnormality; iii) patients with brain or other diseases that may affect nerve function. All patients provided written informed consent for using their medical data. The present study was ethically approved by the Ethics Committee of the Chest Hospital of Hebei Province. There were no cases lost during 24-month follow-up.

The postoperative pathological results of tuberculous granulomatous lesions or TB were positive in all cases. There were 123 male and 115 female cases were recruited successfully, aged 23-74 years, with an mean age of  $48.5 \pm 7.3$  years. TB infection cases involved single spinal segments in 45 cases, involved two segments in 124 cases, three segments in 28 cases, four segments in 18 cases and hopping multi segmental involved in 23 cases. There were 4 cases involved in the T<sub>1</sub> section, 22 cases in T<sub>2-3</sub>, 10 cases in T<sub>4-6</sub>, 32 cases in T<sub>5-8</sub>, 42 cases in T<sub>9</sub> and 128 cases in T<sub>10-12</sub>. The patients' mean preoperative Cobb angles were  $33.6 \pm 5^\circ$ . The Cobb angle is used as a standard measurement to determine and track the progression of scoliosis. Dr John Cobb invented this method in 1948 (10). Cobb suggested that the angle of curvature be measured by drawing lines parallel to the upper border of the upper vertebral body and the lower border of the lowest vertebra of the structural curve, then erecting perpendiculars from these lines to cross each other, the angle between these perpendiculars being the 'angle of curvature' (11). Their preoperative visual analogue scale was  $6.9 \pm 2.9$  points (3-9 points) (12). A total of 22 cases had complications, including disseminated pulmonary tuberculosis (4 cases), secondary hypertension (8 cases), hypoproteinemia (7 cases), type II diabetes (5 cases), coronary heart disease (5 cases), previous myocardial infarction (2 cases), cardiac insufficiency (2 cases), tuberculous meningitis (2 cases), tuberculous encephalitis (2 cases), sinus tract caused by rupture of flow abscess (2 cases), abnormal liver function (2 cases) and drug eruption (2 cases).

**Grouping.** The 234 cases were divided into two groups according to the duration of standard anti-TB treatment. Group A (n=118) underwent anti-TB treatment  $\geq 4$  weeks, and surgery was performed until the symptoms of the TB infection alleviated. Group A were defined as having hemoglobin  $>100$  g/l, a decreased ESR, and a body temperature  $<37.2^\circ\text{C}$ . The control group (group B, n=120) underwent anti-TB treatment  $<4$  weeks following admission (the majority underwent 2-4 weeks of treatment), as long as the patient's general condition (temperature  $<38^\circ\text{C}$ ) improved, and the

chemotherapy was effective in lowering their ESR, CRP and other biochemical indexes. In this group, surgery was able to be performed if there was no surgical contraindication for preoperative examination.

The average mean cumulative anti-TB treatment time was  $43 \pm 14$  days (range, 28-56 days) in group A (treatment  $\geq 4$  weeks) and  $14 \pm 6$  days (range, 4-28 days) in group B (treatment  $<4$  weeks). There were six cases with standard anti-TB treatment  $<1$  week because of progressive aggravation of neurological symptoms, and their preoperative chemotherapy was  $<1$  week.

**Preoperative treatment.** The primary treatment included a standardized treatment of anti-TB drugs (isoniazid 5 mg/kg, maximum 300 mg; rifampicin 10 mg/kg, maximum 600 mg; ethambutol 15-25 mg/kg; pyrazinamide 15-30 mg/kg, maximum 2 g/day; and levofloxacin mesylate 0.4-0.6 g/day). Chemotherapy schemes were adjusted on the basis of standardized therapy, according to symptom relief, and laboratory and imaging examination. If the clinical symptoms or laboratory indicators were not improved, and the patients were considered to be resistant to or allergic to first-line anti-TB drugs, then second-line drugs were added. The specific second-line drugs used were adjusted according to the results of local puncture and *M. tuberculosis* strain identification and drug susceptibility tests. For the no-puncture or culture-negative patients, second-line drugs were adjusted according to clinical manifestations and other laboratory tests until the symptoms were relieved and inflammation was under control. The second-line drugs used mainly include levofloxacin, moxifloxacin and amikacin. For retreatment cases or suspected drug resistance cases, puncture and drainage under the guidance of B-ultrasound were performed to relieve symptoms. The specimens were retained. Obtained purulent fluid at the early stage was used for drug sensitivity testing and for guiding chemotherapy. Other preoperative supporting treatment, including using albumin and plasma to correct anemia or hypoproteinemia, and immune regulation for certain patients, were performed. For patients with tuberculosis meningitis, tuberculous encephalitis or other complications that may impact early surgery or anaesthesia, elective surgery was performed subsequent to these complications being treated or controlled.

**Surgical indications.** The surgical indications for relieving spinal cord compression in these patients were as follows: i) Thoracic intervertebral space stenosis with paravertebral abscess; ii) accompanied by a prolonged sinus tract; iii) the obvious formation of dead bone; iv) spinal destruction  $>50\%$ , secondary spinal stability damage and vertebral spondylolysis; v) accompanied by kyphosis and gradually aggravated; vi) secondary compression of the spinal cord, nerve root and accompanied by neurological deficits; vii) relapse of TB subsequent to multiple operations; viii) multiple segments of spinal TB, and had no obvious improvement or progressive aggravation following conservative treatment of neurological dysfunction; ix) imaging data revealed the extramedullary pressure to be dry compression or circular compression around the spinal cord or ring compression of fibrous tissue (13).

**Surgical procedures.** Surgery was performed according to the individual situation of the patients, including 98 cases of anterior approach (anterior tuberculosis scavenging, decompression, intervertebral bone graft and anterior nail rod system fixation); 78 cases of lateral anterior rib resection via an external thoracotomy or pleural approach; 20 cases of lateral thoracolumbar and abdominal incision through the pleural and retroperitoneum to the anterolateral vertebrae; two cases of posterior operation; and 40 cases of posterior fixation combined with one-stage or two-stage titanium cage fusion with anterior intervertebral discs. Sclerotic bone was removed thoroughly during surgery. Removed pathological tissue includes purulent fluid, tuberculous granulation tissue, caseous material, dead bone and necrotic intervertebral discs.

**Postoperative care and treatment.** Vital signs were monitored within 48 h after general anesthesia. The thoracic drainage and pulmonary extension were closely observed following transthoracic approach surgery. Thoracic drainage was stopped 48-72 h after surgery if the daily drainage volume <50 ml. Surveillance of complications including heart, lung and cerebrovascular complications were performed. Patients were required to maintain spinal stability and prevent spinal rotation. Following 2-3 weeks of bed rest, braces were used to protect the spine for 6-9 months. Regular imaging examination was performed in order to observe the recurrence of residual effusion or abscess, bone lesions and bone graft fusion. The bone graft fusion was evaluated by an X-ray, computed tomography and magnetic resonance imaging at 1, 3, 6, 9, 12 and 18 months postoperatively. The Bridwell criteria were used to evaluate the fusion of bone grafts (14) and were as follows: Grade I is the remodelling of the complete trabecular bone; grade II is that the bone is intact, the bone remodelling is incomplete, and there is no translucent area; grade III is that the bone is completely above or below the translucent zone; grade IV is that the bone collapses and absorbs. In the present study, grade I and II were considered as bone graft fusions. Neurological function was classified into A, B, C, D and E grade according to the ASIA nerve function scoring system (15), with points of 1 to 5, respectively. Standard rehabilitation exercises were performed based on the restoration of muscle strength with the protection of braces. Patients that continued to receive postoperative chemotherapy, pyrazinamide and levofloxacin mesylate treatments were stopped after 1 year. There were four patients with abnormal liver function during postoperative chemotherapy, and rifampin was replaced by rifapentine intermittently (2 times/week). The mean range time of postoperative chemotherapy was 18-24 months.

**Index assessment.** The bleeding amount (ml) during surgery, operative time (min) and ESR in the two groups were evaluated to compare perioperative safety. Surgical outcomes were evaluated by local pain relief (VAS), neurological function improvement [2002 American spinal injury association (ASIA) scale (12) score improving] and intervertebral fusion rate.

**Statistical analysis.** All measured data were presented as the mean  $\pm$  SD and analyzed using SPSS software (version 25.0;

IBM Corp., Armonk, NY, USA). Paired data including the VAS score and ESR change were compared using a Student's t-test, between groups prior to and following surgery. The count data, including the paired ASIA classification, were compared using a Student's t-test.  $P < 0.05$  was considered to indicate a statistically significant difference.

## Results

**Pre and post-operation data.** A total of 234 patients were selected for the current study. All operations were completed successfully. No spread of mycobacterium TB occurred following surgery. ESR and CRP were significantly lower in group A compared with group B, however, the other demographic data in the two groups were not indicated to be significantly different (Table I). The operation time in group A was 100-280 min and the bleeding volume was 550-1,500 ml. There were two cases that presented with TB recurrence and one case exhibited the recurrence of primary vertebral TB 2 months subsequent to surgery. These two cases recovered following the second operation and intensive anti-TB treatment. The operation time in group B was 120-270 min and the bleeding volume was 620-1,450 ml. There were five cases of sinus formation observed due to the delayed healing of the incisions, and the sinuses were excised. Patients recovered ~1 month after testing for drug sensitivity. There was one case of postoperative paraspinal abscess. The time of recurrence was 6 months after surgery, and the case recovered subsequent to draining the abscess and adjusting the anti-TB treatment. The bone graft fusion rate was 84.7% in group A and 85.8% in group B, 6 months after surgery, and the detailed bone graft fusion time is presented in Table II. The operation time, bleeding volume and bone graft fusion rate exhibited no significant difference between the two groups (Table II).

**Long-term follow up.** No loosening or breakage of internal fixation were observed in the two groups during the follow-up period. The ASIA scores were not significantly different between the two groups prior to surgery, while the score improved in each of the groups 1 month after surgery compared with prior to surgery, but the improvement in group B was better compared group A, and the difference was statistically significant (data not shown). At the time of the 24-months follow up, neurological symptoms were completely relieved in 100 cases (ASIA E grade) in group A, partially relieved in 14 cases (ASIA C and D) and four cases exhibited no remission (ASIA A and B). There were 102 cases relieved in group B at the 24-month follow up mark. Overall, 13 cases partially improved and five cases had non-remission, and the nerve remission rate exhibited no significant difference between the two groups (Table II).

**ESR change.** The variance analysis of repeated measurement data was used to compare the change in ESR between the two groups. It was revealed that the change in ESR prior to and 1 week following surgery was significantly different between the two groups (all  $P < 0.01$ ). In addition, the change in ESR 1 month after surgery was also significant between group A and B ( $P < 0.01$ ). However, there was no significant difference

Table I. Baseline characters of 234 patients with spinal TB (the measurement value is expressed as the mean  $\pm$  standard deviation).

Parameters	Group A ( $\geq 4$ weeks)	Group B (<4 weeks)	P-value
Cases (N)	116	118	
Age (years)	49.3 $\pm$ 8.8	47.6 $\pm$ 7.8	0.098
Male/female (N)	74/42	77/41	0.514
Preoperative anti-TB time (day)	43 $\pm$ 14 (28-56)	20 $\pm$ 6 (14-28)	<0.0001
Preoperative VAS	6.6 $\pm$ 1.8	6.4 $\pm$ 1.7	0.379
Preoperative Cobb angle ( $^{\circ}$ )	32.9 $\pm$ 5.2	34.1 $\pm$ 4.8	0.0655
ESR (mm/h)	42.9 $\pm$ 1.2	54.1 $\pm$ 1.5	0.001
CRP (mg/l)	20.24 $\pm$ 3.68	26.78 $\pm$ 3.56	0.001
TB involved vertebra segment			
T <sub>1</sub>	1	3	
T <sub>2-3</sub>	12	10	
T <sub>4-6</sub>	4	6	
T <sub>5-8</sub>	16	14	
T <sub>9</sub>	20	22	
T <sub>10-12</sub>	59	67	
Combined disease			
Disseminated pulmonary tuberculosis	3	1	
Secondary hypertension	3	5	
Hypoproteinemia	4	3	
Type II diabetes	2	3	
Coronary heart disease	4	1	
Old myocardial infarction	1	1	
Cardiac insufficiency	0	2	
Sinus tract	1	1	
Abnormal liver function	0	2	
Drug eruption	2	0	

ESR, erythrocyte sedimentation rate; CRP, C-reactive protein; TB, tuberculosis; VAS, visual analogue scale.

Table II. Surgery condition and postoperative follow-up condition in 2 groups.

Parameters	Group A ( $\geq 4$ weeks)	Group B (<4 weeks)	P-value
Cases (N)	116	118	
Amount of bleeding (ml)	725 $\pm$ 40 (549-1,500)	732 $\pm$ 50 (619-1,450)	0.09
Operation time (min)	170 $\pm$ 40	160 $\pm$ 50	0.209
Grafted bone fusion time (month)	7.2 $\pm$ 1.4	6.8 $\pm$ 2.1	0.263
Grafted bone fusion rate (6 month, %)	84.5%	85.8%	0.825
Actual follow-up time 24 month after operation	25.6 $\pm$ 2.0	26.1 $\pm$ 2.2	0.058
Improvement of neurologic symptoms at 24 months postoperative			
Complete remission (ASIA E)	99	101	0.948
Partial remission (ASIA C and D)	13	12	0.780
Non-remission (ASIA A and B)	4	5	0.973

ASIA, 2000 American spinal injury association scale.

in ESR between the two groups 6 or 24 months after surgery, which demonstrated that the infection of TB has been treated effectively (Table III).

*VAS comparison.* VAS scores all decreased significantly in the two groups 24 months following surgery ( $P=0.001$  compared with prior to surgery; Table IV). VAS scores, however,

Table III. Change in ESR in 2 groups prior to and following operation.

Parameters	Group A ( $\geq 4$ weeks)	Group B ( $< 4$ weeks)	P-value
Cases (N)	116	118	
Preoperative ESR (mm/h)	42.8 $\pm$ 1.2	54.1 $\pm$ 1.5	<0.001
ESR 1 week after operation	23.8 $\pm$ 1.2	29.8 $\pm$ 2.1	<0.001
ESR change 1 month after operation	22.4 $\pm$ 1.4	24.7 $\pm$ 1.8	<0.001
ESR 6 month after operation	16.76 $\pm$ 1.3	17.01 $\pm$ 1.3	0.374
ESR 24 month after operation	6.9 $\pm$ 0.7	7.0 $\pm$ 0.8	0.3061

ESR, erythrocyte sedimentation rate.

Table IV. Comparison of VAS scores between 2 groups of patients prior to and following operation.

Parameters	Group A ( $\geq 4$ weeks)	Group B ( $< 4$ weeks)	P-value
Cases (N)	116	118	
1 day prior to operation	6.8 $\pm$ 3.1	7.1 $\pm$ 3.0	0.439
6 weeks after operation	3.4 $\pm$ 1.9	3.6 $\pm$ 1.8	0.212
6 months after operation	2.7 $\pm$ 0.9	2.4 $\pm$ 0.8	0.0702
24 months after operation <sup>a</sup>	1.1 $\pm$ 0.7	1.2 $\pm$ 0.8	0.306

<sup>a</sup>P<0.001 vs. before operation. VAS, visual analogue scale.

exhibited no significant difference between the two groups (all P>0.05; Table IV).

*Improvement of neurological function.* The neurological function of the two groups were around ASIA score B prior to the surgery and improved to C 1 month following surgery, which indicates that, to a certain degree, the neurological functions recovered in each of the groups. As presented in Table V, the recovery of neurological function in group B 1 month following surgery was significantly better compared with group A (P=0.001), that is, the postoperative neurological function recovered at different anti-TB treatment rates following surgery. Early surgery may relieve decompression and improve postoperative neurological function for patients with thoracic spinal TB.

## Discussion

Spinal TB is the local manifestation of systemic mycobacterium TB infection. The principle of 'early, combined, appropriate, regular and full course' is important for spinal TB treatment (16). Drug therapy should be performed throughout the whole treatment process (17-19). If necessary, drug sensitivity tests should be performed in order to guide drug therapy. It is generally believed that >4-6 weeks standardized anti-TB treatment is necessary (7,20). This way, it is possible to control the activity of TB, stabilize the bone lesions, revive the constitution and is beneficial to the implementation of surgery and prognosis. Patients with spinal TB whose ESR >40 mm/h

Table V. Comparison of neurological function scores (2000 American spinal injury association scale) in 2 groups of patients.

Parameters	Group A ( $\geq 4$ weeks)	Group B ( $< 4$ weeks)	P-value
Prior to operation	2.1 $\pm$ 0.5	2.0 $\pm$ 0.6	0.164
1 months after operation	3.1 $\pm$ 0.7	3.5 $\pm$ 0.6	0.001
6 months after operation	3.6 $\pm$ 0.5	3.8 $\pm$ 0.6	0.0057
24 months after operation	4.4 $\pm$ 0.5	4.5 $\pm$ 0.4	0.0895

are not recommended for surgical treatment (21,22), while an ESR >80 mm/h is forbidden for surgery. However, this may delay the treatment of neurological deficits in a number of patients, and even cause more serious consequences, including paraplegia (23).

The present study retrospectively analyzed the prognosis of different preoperative anti-TB times in 234 patients with thoracic TB combined with neurological deficits. The results revealed that early surgery is better for postoperative neurological recovery. It is generally believed that for safe surgery, and in order to avoid the recurrence and diffusion of TB following surgery, all patients should receive standardized anti-TB treatment for at least 4 weeks prior to surgery (7). The standard treatment may alleviate the symptoms of TB poisoning, improve patients' appetite, correct anemia and hypoproteinemia (Hb>100 g/l; serum albumin >30 g/l), and control ESR <40 mm/h. However, the ESR is hard to decrease in partial patients and even increases following anti-TB treatment. This may be associated with the larger abscess around the lesion, and not caused by resistance to TB infection and the ineffectiveness of chemotherapy. For patients who were accompanied by incomplete paralysis or progressive neurological symptoms, the primary objective of treatment is to restore their neurological function. It is unnecessary to adhere to a certain timing of anti-TB treatment and should undergo early emergency surgery. At the same time, in spinal TB, primarily manifested by kyphosis following the rest period, it is suggested that anti-TB drugs should be prepared prior to surgery in order to prevent the activation of mycobacterium TB (24). Generally, all patients received anti-TB treatment for

at least 2 weeks prior to surgery in the present study. In view of safety, surgery is performed when the symptoms of TB poisoning are decreased, ESR <40 mmol/h and hemoglobin >100 mmol/l. For cases of the progressive exacerbation of neurological deficits (including lesions that tend to exhibit active, more purulent discharge from the wound), the surgery should be performed early, as if the focus of the infection is not removed by surgery, the ESR is hard to decrease, and the paralysis may become aggravated (25). These patients do have relatively lower ASIA scores; however, only a few of these patients were recruited in the present study, thus, the preoperative ASIA score was almost similar between the two groups.

In a previous systematic review, Yousefifard *et al* (26) indicated that for patients with traumatic spinal cord injuries, early spinal decompression surgery may improve neurological recovery and is associated with less post-surgical complications. A number of studies have indicated that although the nerve compression in patients with spinal TB is mostly slow, the longer the spinal cord is damaged, the more serious the paraplegia symptoms are (27). The compression may result in irreversible changes and a worse prognosis, and thus, the patient should receive surgery as soon as possible (27). Particularly for patients with progressive exacerbation or severe paraplegia, using anti-TB drugs prior to surgery is not an option. All in all, surgical treatment is a phased auxiliary means for spinal TB, while anti-TB treatment is the safety guarantee for surgery (28). The present study demonstrated that the ASIA score increased more in patients with a shorter standardized anti-TB treatment time. This result has important clinical significance, as minor improvements in neurological function may result in substantial changes in the quality of life for these patients. The improvement of quality of life further optimizes the efficiency of follow-up treatment (29).

Unstandardized drug treatment is one of the main factors contributing to the recurrence of spinal TB infection, resulting in the secondary damage of the spinal cord (30). Consequently, emergency surgery cannot be performed blindly for patients with spinal TB with neurological deficits. For patients who received >1 week's anti-TB treatment and nutritional support treatment, surgery may be performed early once the patients' general symptoms and TB poisoning has improved (20,25). In a domestic retrospective analysis in China, Qin *et al* (31) analyzed 32 cases of retreated patients with spinal TB with paraplegia and revealed that the main reason for surgery failure was not performing anti-TB treatment, or insufficient anti-TB treatment, prior to surgery. In the present study, the curative effect in the 118 cases that received early surgery was 89.8%, with 106 cases recovered to ASIA grade D or E, which was similar to the curative effect demonstrated by Xu *et al* (32) and Moon *et al* (33).

A higher than normal ESR value is not a surgical contraindication. The large abscess, drug insensitivity and anaemia may all affect the ESR (34). Thus, the 'dynamic decline of ESR' should be used as the one main operative indication. In the present study, the dynamic decline of ESR was used as one of main indications for patients receiving early surgery, and the results revealed that the prognosis of these patients was similar compared with those patients that received anti-TB

treatment >4 weeks. In addition, the improvement of neurological function in early surgery patients was better compared with patients received anti-TB treatment >4 weeks. The results from the present study demonstrated that standard anti-TB treatment and the dynamic decline of ESR are the two main indications for early surgery in patients with spinal TB with neurological deficits, except for patients with the progressive exacerbation of paraplegia. However, the combination of basic diseases is an indication against early surgery.

The current expert consensus indicates that anti-TB treatment may decrease the number of TB bacilli in the focus, inhibit the growth of TB bacilli and avoid the spread of TB bacilli to the whole body (7). The use of anti-TB drugs has drawn much attention, but the treatment time remains controversial. The focus of the controversy lies in whether early surgery for patients with spinal TB with neurological deficits is optimal, as early surgery may cause the spread of TB in the body (35). Preoperative use of anti TB drugs for 4 weeks is a more acceptable option (36,37). However, at present, there is no basic research that confirms its necessity. The present study used anti-TB medicine for 1-2 weeks; if patients' symptoms, ESR and CRP decreased, the surgery was able to be performed, and no TB bacilli spread occurred following surgery, which meant that surgery was able to be performed under the premise of effective anti-TB treatment.

The standardized anti-TB treatment, spinal canal decompression, bone graft fusion and internal fixation are notable for the recovery of neurological deficits (5). The results of the present study demonstrated that following this combination therapy, the quantity of intraoperative bleeding, operation time and bone graft fusion rate in the two groups was not different, which means that the standard anti-TB treatment, as opposed to the treatment time, is the key for spinal TB treatment. Through the present study, it can be confirmed that active and effective preoperative anti-TB treatment is essential. For active spinal TB, if it is not urgent, including in patients with progressive neurological deficits, adequate anti-TB treatment should still be administered prior to surgery, so as to improve the safety and prognosis of the operation.

There are a number of limitations in the present study. The follow-up time in the present study is 24 months, and the patient data for only one hospital was summarized. A longer follow-up period and multi-center clinical research should be factored in to future studies. Additionally, this study is a retrospective study, and a prospective study with a greater number of patients should be conducted to validate the conclusion from the current research.

In conclusion, the timing of surgery for spinal TB should be comprehensively judged according to the symptoms of patients, and the effect of anti-TB treatment. Early diagnosis and treatment may be beneficial for the prognosis of these patients. The restriction of ESR may be relaxed and surgery should be performed early. For patients with active TB combined with neurological deficits, surgery should be performed as soon as possible under standard anti-TB treatment. Early surgery is relatively safe and may substantially improve neurological function in patients with spinal TB with neurological deficits. While for patients with early surgical contraindications, the prognosis may improve subsequent to controlling the combined diseases and having postponed surgery.

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## Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

## Authors' contributions

CGJ and XWY conceived and designed the study; CGJ, ZLD, LMY and JGG acquired the data; FSL, LBW and ZL performed the statistical analysis.

## Ethics approval and consent to participate

All patients provided written informed consent for using their medical data. The present study was ethically approved by the Ethics Committee of Chest Hospital of Hebei Province.

## Patient consent for publication

Not applicable.

## Competing interests

All authors declare that they have no competing interests.

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