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# Mid- and Long-Term Efficacy of Surgical Treatment of L1-2 Vertebral Tuberculosis with Subdiaphragmatic Extraperitoneal Approach

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Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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**Background:** The L1-2 vertebral segment is the most common site of spinal tuberculosis. Traditional thoracoabdominal surgery in this segment risks trauma and complications. This study analyzed the surgical efficacy of the subdiaphragmatic extraperitoneal approach in the treatment of L1-2 spinal tuberculosis.

**Material/Methods:** Retrospective analysis of 67 patients with L1-2 vertebral tuberculosis who underwent posterior internal fixation was performed: 35 patients underwent the subdiaphragmatic extraperitoneal approach (group A) and 32 underwent the thoracoabdominal approach (group B). Operation time, intraoperative blood loss, postoperative hospital stay, postoperative nerve function recovery, deformity correction, bone graft fusion, lesion healing, erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), and complications were observed.

**Results:** In group A and group B, intraoperative blood loss was 712.00±64.66 mL and 1104.38±131.34 mL; average operation time was 3.16±0.67 h and 5.16±1.07 h; and postoperative hospital stay was 9.60±2.64 days and 13.69±3.87 days, respectively. At 6 months and 5 years after surgery, neurological function, visual analog scale score, and Cobb angle of all patients were significantly improved compared with those before surgery; ESR and CRP decreased to normal levels; lesions completely cured; and all patients had good bone graft fusion. Pulmonary complications occurred in 2 patients in group A and in 14 patients in group B.

**Conclusions:** The efficacy of subdiaphragmatic extraperitoneal approach was similar to that of the thoracoabdominal approach for L1-2 spinal tuberculosis, but the former has the advantages of less surgical trauma, shorter operation time, less intraoperative bleeding, and fewer postoperative pulmonary complications.

**Keywords:** **Orthopedic Procedures • Treatment Outcome • Tuberculosis, Osteoarticular**

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## Background

The first and second lumbar (L1-2) vertebral body belongs to the thoracolumbar anatomical area and is a predilection site of spinal tuberculosis [1]. The surgical methods used for spinal tuberculosis include the simple anterior approach, simple posterior approach, and combined posterior-anterior approach [2,3]. For the posterior-anterior and simple anterior approach lesion removal, decompression and bone graft fusion must be performed from the anterior approach. At present, it is generally accepted that for thoracolumbar tuberculosis including L1-2 tuberculosis, the thoracoabdominal approach is the standard approach for anterior surgery [2,4-6].

The surgical approach not only provides extensive and clear exposure for thoracolumbar tuberculosis, but also provides exposure for other thoracolumbar diseases, while playing a large role in ensuring good surgical efficacy [7,8]. However, the thoracoabdominal incision cuts the diaphragm from the chest wall and penetrates the thoracic (extrapleural) and extraperitoneal cavity. Although the exposure is extensive and clear, the biggest disadvantages are surgical trauma, bleeding, slow recovery, and frequent complications [4-6,9]. If the operation extends into the thoracic cavity, it will easily lead to complications of thoracotomy, such as pleural effusion and encapsulating effusion, which will increase the difficulty of subsequent treatment. König et al [10] found that the 12$^{th}$ thoracic (T12) and L1 vertebrae can be exposed through the upper abdominal midline incision and that it is feasible to remove the adjacent disc. However, this method is performed in the abdominal cavity, which causes significant damage to the abdominal organs and increases the incidence of complications, such as abdominal infection and adhesion. To the best of our knowledge, there is no research reported on the improvement of anterior surgical methods for L1-2 spinal tuberculosis.

This study retrospectively analyzed the 5-year clinical data of 67 patients with L1-2 vertebral tuberculosis treated with the subdiaphragmatic extraperitoneal approach and the thoracoabdominal approach. The surgical efficacy of the subdiaphragmatic extraperitoneal approach in the treatment of L1-2 spinal tuberculosis was discussed.

## Material and Methods

This study was reviewed and approved by the Ethics Committee of the General Hospital of Ningxia Medical University. All patients provided written informed consent. Patients with L1-2 vertebral tuberculosis who were treated in our hospital from January 2004 to October 2014 were included in the study. These patients were treated with posterior orthopedic internal fixation during hospitalization and the anterior approach for complete lesion removal, decompression, and bone graft fusion surgery during the same period or in a subsequent phase. All patients were followed up for 5 years. Patients with a T12-L1 intervertebral disc, L1 upper endplate tuberculosis, other vertebral tuberculosis, and active tuberculosis were not included in the study. Patient characteristics are shown in **Table 1**.

**Table 1.** General information of the 2 groups before surgery.

| | Group A | Group B | *P* value |
|---|---|---|---|
| Number of cases (cases) | 35 | 32 | – |
| Age | 45.66±16.69 | 46.06±16.84 | 0.922 |
| Male/Female (cases) | 21/14 | 19/13 | 0.958 |
| Clinical symptoms | | | |
| Low back pain | 30 | 28 | 1.000 |
| Nerve damage | 16 | 15 | 0.924 |
| Low fever, night sweats | 17 | 14 | 0.693 |
| Fatigue | 21 | 17 | 0.570 |
| Cold abscess | 21 | 20 | 0.834 |
| Cobb angle (°) | 21.60±4.22 | 21.41±4.09 | 0.850 |
| ESR (mm/h) | 63.03±14.66 | 64.47±15.89 | 0.701 |
| CRP (mg/L) | 41.19±25.48 | 40.56±21.67 | 0.914 |
| VAS score | 5.49±1.93 | 5.63±1.86 | 0.765 |

Group A: subdiaphragmatic extraperitoneal approach; Group B: thoracoabdominal approach. Values are presented as number or mean±standard deviation. ESR – erythrocyte sedimentation rate; CRP – C-reactive protein; VAS – visual analog scale.





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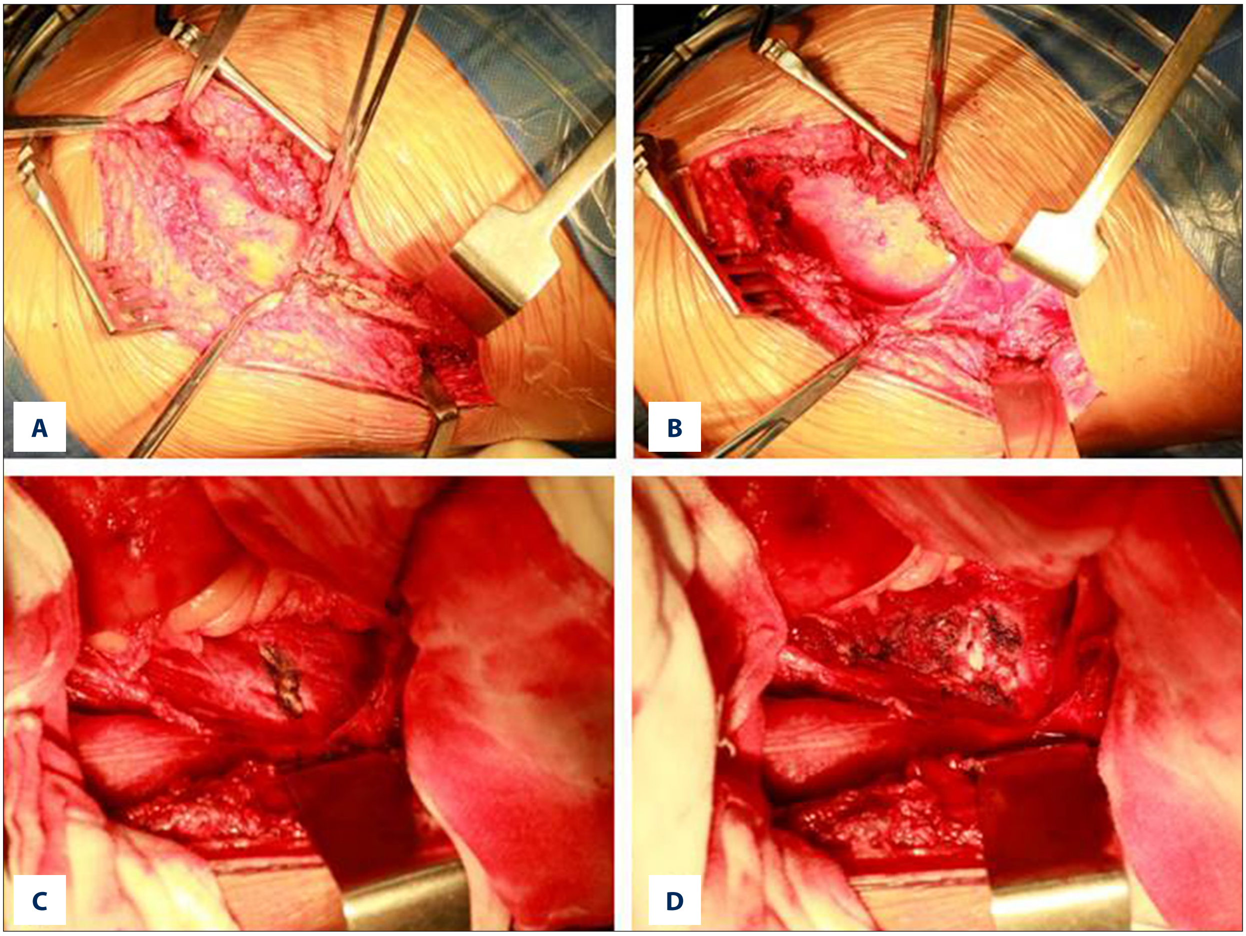


**Figure 1.** The subdiaphragmatic extraperitoneal approach: (**A**) expose and remove the 12$^{th}$ rib; (**B**) cut the abdominal wall muscles at the end of the ribbed bed and enter the extraperitoneum; (**C**) expose the psoas and square muscles; (**D**) cut the diaphragm and psoas attachment points lateral-anterior of the affected vertebra, push the crura of diaphragm upward, push the psoas away from the vertebra, and expose the L1-2 vertebral body and disc.

A total of 67 patients (average age 45.85±16.63 years, range 17-74 years; 27 women) were included in the study. The patients were divided into 2 groups according to the surgical approach performed. In group A, a subdiaphragmatic extraperitoneal approach (n=35) was performed, and in group B, a thoracoabdominal approach (n=32) was performed. Both surgical approaches were applicable to L1-2 spinal tuberculosis, and the surgical indications were the same. Since the theory and technology of the subdiaphragmatic extraperitoneal approach for the treatment of L1-2 spinal tuberculosis was developed in 2008, patients before that time were treated with the thoracoabdominal approach. The operations in both groups were performed by the same surgical team.

Patient diagnosis was based on clinical manifestations, imaging changes, laboratory tests, etiology, and histopathological changes. The laboratory tests included T-spot, erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP). Etiological examination included blood culture and puncture tissue or intraoperative pathological specimen culture. Imaging examinations included X-ray, computed tomography (CT), and magnetic resonance imaging (MRI). Surgical indications included larger bone defects, spinal instability, severe or progressive kyphosis, neurological symptoms of spinal cord or horsetail compression, larger abscesses, and sinus formation.

### Preoperative Management

All patients were administered streptomycin (20 mg/kg), isoniazid (5 mg/kg), rifampicin (10 mg/kg), and pyrazinamide (20 mg/kg) anti-tuberculosis drugs for 2 to 4 weeks before surgery. During this period, the patients were instructed to support the back with a brace, lie on a hard board, and strengthen nutritional support. Surgical treatment was performed when patients' systemic symptoms were relieved, their general conditions improved, and they could tolerate surgery.





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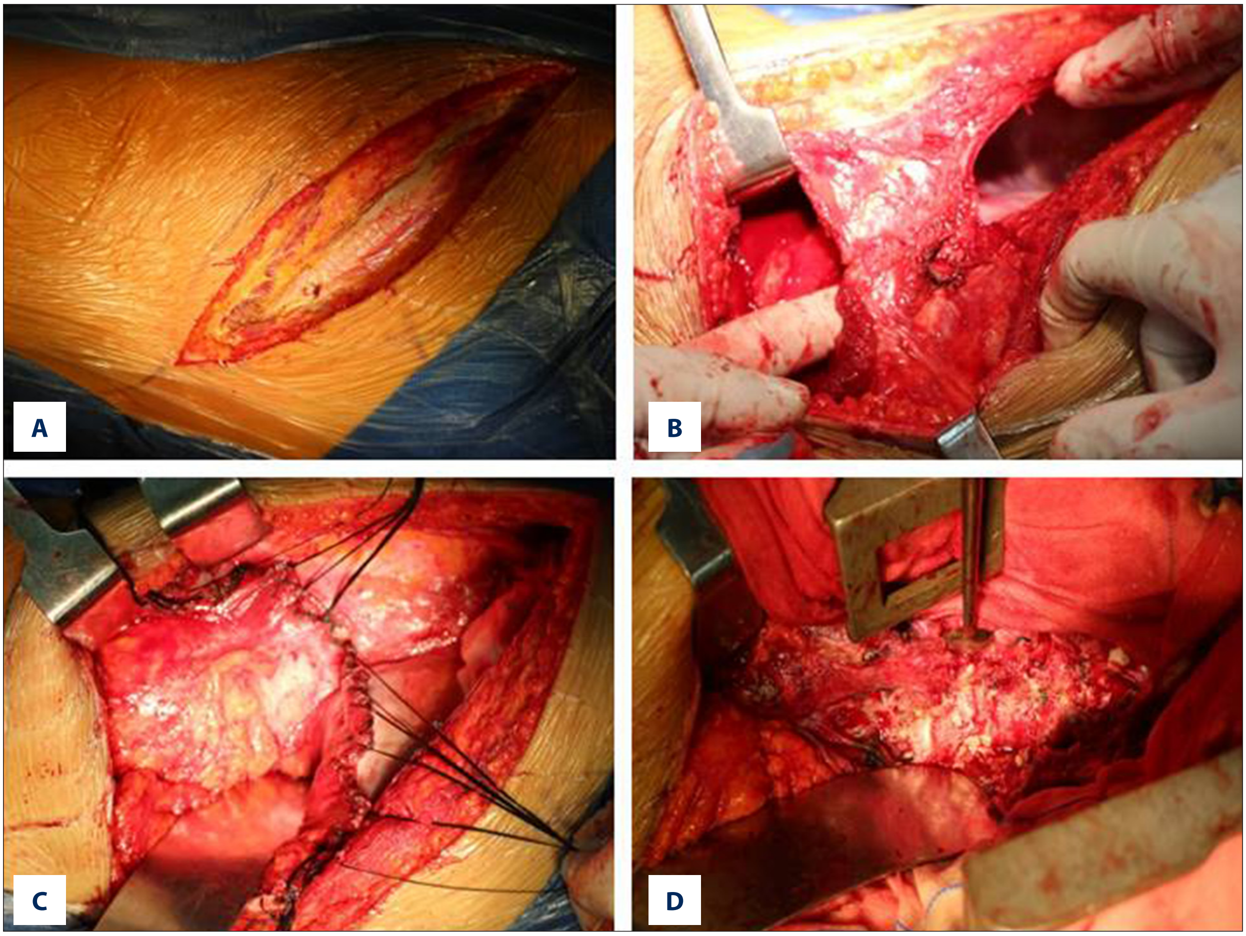


**Figure 2.** The thoracoabdominal approach: (**A**) expose and cut the 11$^{th}$ rib; (**B**) cut the rib bed and abdominal wall muscles, enter the extraperitoneal cavity and the thoracic cavity, expose the diaphragm; (**C**) cut the diaphragm muscle 2 cm away from the 11$^{th}$ rib attachment point; (**D**) expose L1-2 vertebral body and disc.

### Surgical Methods

Under general anesthesia, all patients underwent a posterior affected-vertebrae fixation and deformity correction using a horizontal link to increase stability [11,12]. After the completion of the posterior approach surgery, according to the patient's condition, complete anterior approach lesion removal, decompression, patella support, and bone graft fusion were performed either in the same procedure or in 2 stages [13,14]. The anterior surgery of the 2 groups adopted different surgical approaches.

In group A, the subdiaphragmatic extraperitoneal approach was performed (**Figure 1**). The patient was placed in the lateral position and the incision was made on the larger abscess side. The incision was made from the outer edge of the sacrospinalis muscle and extended obliquely forward and downward along the 12$^{th}$ rib to the front axillary line. The shallow and deep fascia along the direction of the incision was cut and the latissimus dorsi was exposed. The serratus posterior inferior muscle was cut at the upper end of the incision to expose the 12$^{th}$ rib. Then, a 12$^{th}$-rib subperiosteal dissection was performed and the rib was partially removed. An incision below the rib bed was made along the direction of the rib bed, avoiding the incision of the pleural cavity. After the lungs were properly bulged if necessary, the incision was made under the lower edge of the pleural cavity. The abdominal wall was sequentially cut at the end of the rib bed to enter the extraperitoneal space. The peritoneal, ureter, testis, or ovarian blood vessels were gently pushed to the midline using saline gauze. During the exposure process, if the peritoneum was torn, a continuous suture or purse suture was immediately made with a filament. The psoas muscle and the lateral arcuate ligament were exposed below the diaphragm and the crura of the diaphragm was cut off from the attachment point on the lateral-anterior of the L1 vertebral body and pushed upward using a periosteal stripper or homemade gauze "peanut". The psoas attachment point in the lateral-anterior of the affected vertebra was cut, the psoas was pushed away from the vertebra, and the L1-2 vertebra was exposed under the diaphragm.





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**Table 2.** Perioperative indicators of the 2 groups of patients.

| Indicators | Group A | Group B | *P* value |
|---|---|---|---|
| Intraoperative blood loss (mL) | 712.00±64.66 | 1104.38±131.34 | 0.000 |
| Operation time (h) | 3.16±0.67 | 5.16±1.07 | 0.000 |
| Postoperative hospital stay (days) | 9.60±2.64 | 13.69±3.87 | 0.000 |

Group A: subdiaphragmatic extraperitoneal approach; Group B: thoracoabdominal approach. Data are presented as mean±standard deviation.

In group B, the traditional thoracoabdominal approach was performed (**Figure 2**). The incision started from the outer edge of the sacrospinalis muscle and extended along the 11$^{th}$ rib to the costal cartilage. The 11$^{th}$ rib was exposed, the periosteum was peeled off, and the 11$^{th}$ rib was partially removed. During the operation, the intercostal neurovascular bundle was protected. The rib bed and pleura were cut, part of the affected vertebrae in the chest cavity was exposed, and the collapsed lungs were protected with wet saline gauze. The layers of the abdominal wall were cut one by one, and saline gauze was used to push the peritoneum and its contents, the testis or ovarian blood vessels, and ureter to the midline. The psoas muscle and the anterolateral side of the affected vertebrae outside the peritoneum were exposed. Then, the diaphragm muscle was cut 2 cm away from the 11$^{th}$ rib attachment point, and the medial and lateral arcuate ligaments were cut and pulled with sutures at the same time to facilitate accurate suturing after surgery. At this time, the thoracic cavity and the abdominal cavity were completely communicated, and the affected vertebrae completely exposed.

After exposing the affected vertebrae in both groups, the periosteal strip of the affected vertebrae was performed. The arterial and venous blood vessels in the middle of the diseased vertebrae were carefully freed, ligated, and cut off. Then, thorough lesion removal, spinal canal decompression, deformity correction, and autologous iliac bone graft were performed [13,14]. According to the marks made during the operation, the diaphragm and psoas muscles were accurately sutured at the starting point. Negative-pressure drainage was placed in the wound under the diaphragm, and the chest wall and abdominal wall incisions were sutured layer by layer. In the thoracoabdominal approach group, it was necessary to place a closed thoracic drainage tube in the chest.

### Postoperative Treatment

Postoperative treatment was administered according to the following standards: symptomatic supportive treatment, such as anti-infection and fluid replacement, was routinely given after surgery. The drainage tube was removed when the drainage volume in the surgical area was less than 50 mL/day. After bed rest for 2 to 3 weeks, patients could usually walk with orthotics. Regular follow-up visits to the hospital were continued after discharge, and the follow-up of patients and management of chemotherapy regimens were performed by specialized doctors. The patients were instructed to avoid spinal flexion, lateral flexion, and rotation before bone graft healing. The SHRZ (streptomycin, isoniazid, rifampicin, pyrazinamide) chemotherapy regimen was continued after surgery, and the decision to discontinue treatment was made according to the patient's progress assessed in the follow-up.

### Statistical Analysis

IBM SPSS 25.0 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. The comparison of data between the 2 groups was performed by *t* test and chi-squared test as applicable, with a 2-tailed significance value of $\alpha$=0.05.

## Results

All 67 patients were followed up for at least 5 years. There were no significant differences in age, sex, and severity of disease before surgery between the 2 groups (**Table 1**). In group A and group B, intraoperative blood loss was 712.00±64.66 mL and 1104.38±131.34 mL, average operation time was 3.16±0.67 h and 5.16±1.07 h, and postoperative hospital stay was 9.60±2.64 days and 13.69±3.87 days, respectively; all differences were statistically significant (**Table 2**).

There were 16 patients (45.71%) in group A and 15 patients (46.88%) in group B with nerve injury before surgery, and the difference between the 2 groups was not significant ($P$>0.05). As assessed using the American Spinal Injury Association scale, 14 patients in group A and 13 patients in group B recovered to the E level at the last follow-up (**Table 3**), and there was no significant difference between the 2 groups ($P$>0.05). The Cobb angle in the 2 groups at 6 months after surgery was 3.77±2.17° in group A and 3.06±1.97° in group B, and the last follow-up was 4.94±2.35° in group A and 4.72±2.40° in group B; there was no significant difference in the Cobb angle between the 2 groups during the same period. During the





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**Table 3.** Changes in ASIA indicators before and after surgery in the 2 groups.

| ASIA Grade | Group A (n=35) | | | | | | Group B (n=32) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Preoperative | Postoperative | | | | | Preoperative | Postoperative | | | | |
| | | A | B | C | D | E | | A | B | C | D | E |
| A | | | | | | | | | | | | |
| B | 2 | | | | 1 | 1 | 1 | | | 1 | | |
| C | 4 | | | | 1 | 3 | 4 | | | | 1 | 3 |
| D | 10 | | | | | 10 | 10 | | | | | 10 |
| E | 19 | | | | | 19 | 17 | | | | | 17 |

Group A: subdiaphragmatic extraperitoneal approach; Group B: thoracoabdominal approach. ASIA – American Spinal Injury Association.

**Table 4.** Changes of Cobb angle, VAS score, ESR, CRP index before and after surgery in the 2 groups.

| | Group A | Group B | P value |
|---|---|---|---|
| Case | 35 | 32 | – |
| Cobb angle (°) | | | |
| Preoperative | 21.60±4.22 | 21.41±4.09 | 0.850 |
| 6 months after surgery | 3.77±2.17 | 3.06±1.97 | 0.167 |
| Last follow-up | 4.94±2.35 | 4.72±2.40 | 0.701 |
| VAS score | | | |
| Preoperative | 5.49±1.93 | 5.63+1.86 | 0.765 |
| 6 months after surgery | 0.74±0.74 | 0.91±0.96 | 0.437 |
| Last follow-up | 0.20±0.47 | 0.34±0.70 | 0.325 |
| ESR (mm/h) | | | |
| Preoperative | 63.03±14.66 | 64.47±15.89 | 0.701 |
| 6 months after surgery | 11.51±4.45 | 10.47±4.02 | 0.318 |
| Last follow-up | 8.69±3.60 | 8.81±3.59 | 0.886 |
| CRP (mg/L) | | | |
| Preoperative | 41.19±25.48 | 40.56±21.67 | 0.914 |
| 6 months after operation | 1.23±0.44 | 1.32±0.46 | 0.382 |
| Last follow-up | 1.10±0.34 | 1.15±0.39 | 0.547 |

Group A: subdiaphragmatic extraperitoneal approach; Group B: thoracoabdominal approach. Values are presented as number or mean±standard deviation. VAS – visual analog scale; ESR – erythrocyte sedimentation rate; CRP – C-reactive protein.

6-month follow-up after surgery, the visual analog scale (VAS) scores of the 2 groups of patients were significantly lower than before surgery, and at the last follow-up, only a small number of patients in the 2 groups had mild back pain. Six months after surgery and the last follow-up, the ESR and CRP levels decreased to normal levels (**Table 4**).

No spinal cord, nerve, large blood vessel, or important organ damage occurred in the 2 groups during surgery. At the last follow-up, there was no recurrence of the lesions in the 2 groups, and the bone grafts healed well, with continuous callus formation (**Figure 3**). No abdominal-related complications, recurrence of tuberculosis, incision infection, internal fixation fracture, or prolapse occurred in the 2 groups after surgery. A reexamination of liver function 1 month after surgery revealed that 4 patients in group A and 3 patients in group B had elevated transaminase levels, which returned to normal 1 month after the addition of hepatoprotective drugs. Encapsulated





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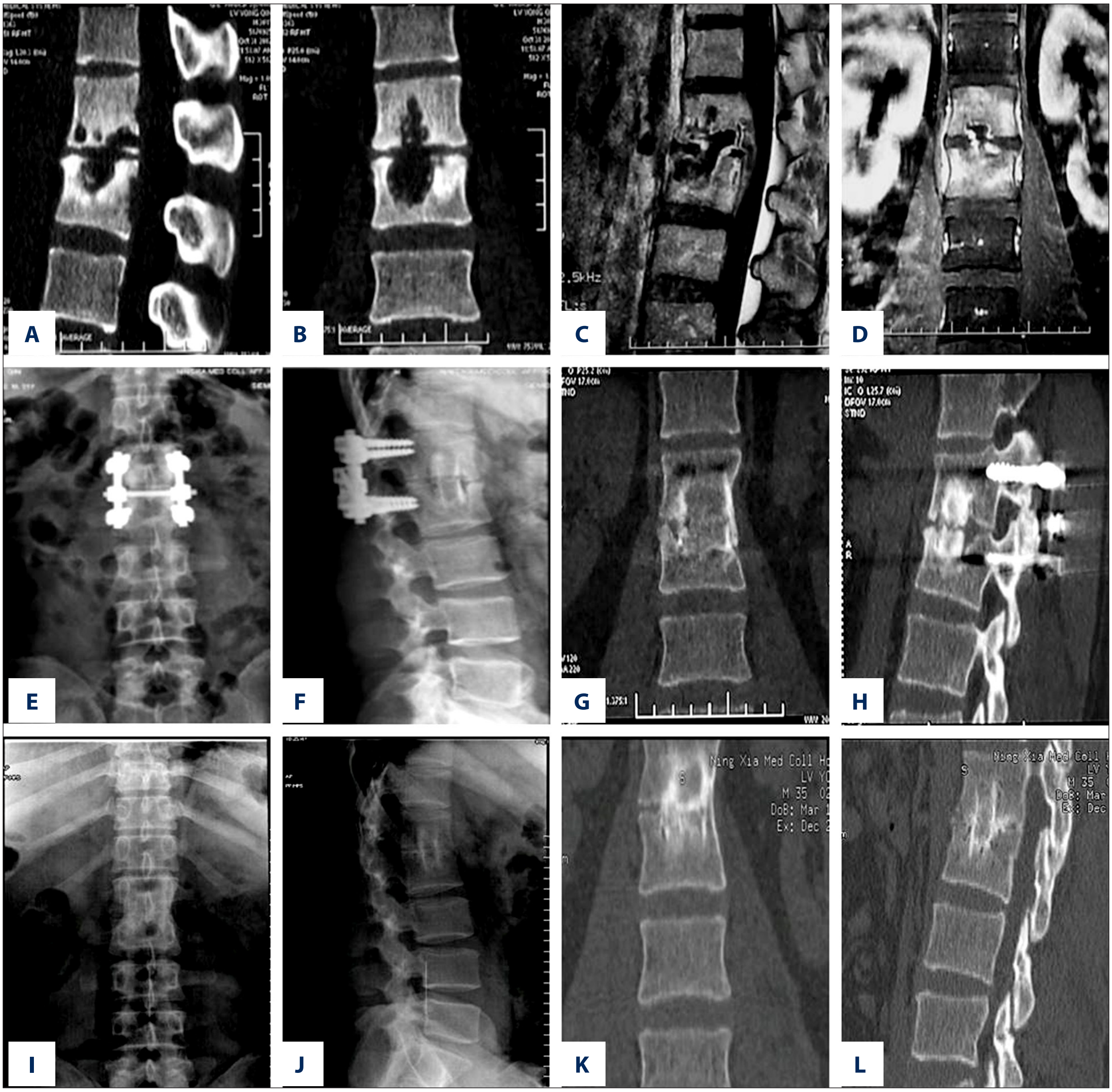


**Figure 3.** A 30-year-old male patient diagnosed with L1-2 vertebral tuberculosis was treated with posterior affected-vertebrae fixation, anterior subdiaphragmatic extraperitoneal approach for thorough lesion removal, and autologous iliac bone graft fusion. (**A, B**) Preoperative computed tomography (CT) showed obvious bone destruction. (**C, D**) Enhanced magnetic resonance imaging before surgery showed vertebral signal changes, vertebral bone destruction, and paravertebral abscess. (**E-H**) X-ray and CT at 6 months after surgery showed pedicle screw fixation and good bone graft fusion. (**I-L**) X-ray and CT 5 years after surgery showed that the pedicle screw had been completely removed, the lesion had completely cured, and the bone graft had completely fused.





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pleural effusion occurred in 2 patients in group A, and pulmonary-related complications occurred in 14 patients in group B, including 11 patients with atelectasis and 8 patients with encapsulated pleural effusion. The difference between the 2 groups was statistically significant.

## Discussion

The L1-2 vertebra is located at the junction of the chest and abdominal cavity. There are many important organs, blood vessels, and nerves in front of the vertebra, and the anatomy is complicated. To better reveal the visual field of the operation, the thoracoabdominal approach is often selected for anterior surgery [4,5,9,15]. This approach can fully expose the lesion, and the surgeon can operate under direct vision, so the operation is safe, and the treatment effect is good. However, this approach can lead to long surgical incisions, significant trauma, and long operation time. Incision of the diaphragm and pleura increases the risk of lung-related complications [16-20] and ultimately extends the length of hospital stay and increases the cost of hospitalization. Pettiford et al [5] reported 91 patients with thoracolumbar infection, tumors, and disc disease who were treated with the thoracoabdominal approach, of which 34 patients had pulmonary complications after surgery. Shi et al [9] reported 55 cases of thoracolumbar tuberculosis in patients treated with the thoracoabdominal approach, and pulmonary complications occurred in 20 patients after surgery, including 17 cases of atelectasis and 18 cases of encapsulated pleural effusion. In our study, the thoracoabdominal approach was used to treat 32 cases of L1-2 vertebral tuberculosis, and 14 patients had pulmonary complications, including 11 patients with atelectasis and 8 patients with encapsulated pleural effusion, which was similar to the data presented in the literature. However, in the subdiaphragmatic extraperitoneal approach group, only 2 of the 35 patients had encapsulated pleural effusion, which was significantly fewer patients than in the thoracoabdominal approach group.

With the subdiaphragmatic extraperitoneal approach, the 12$^{th}$ rib needs to be removed to avoid obstruction above the incision. After the extraperitoneal separation under the diaphragm, the lateral-anterior part of the L1-2 vertebrae can be clearly exposed by the incision. In a basic autopsy study, Straus et al [21] found that the attachment point of the diaphragm to the vertebra was mainly between the L1-2 intervertebral disc and the upper edge of the T12 vertebra. Sun et al [22], after dissecting 21 cadavers, found that on both sides of the vertebra, most of the diaphragm attachment points were located between the upper edge of the T12 vertebra and the L1-L2 disc (38 of 42), whereas in front of the vertebra, most of the diaphragm attachment points were located between the upper edge of T12 and the lower edge of L1 (20 of 21). The attachment point of the psoas muscle on the vertebral body is located in the groove between the vertebral body and the transverse process, starting from T12 and the sides of all lumbar vertebrae and discs. Therefore, during surgery, simply cutting the diaphragm attachment point and the psoas major attachment point lateral-anterior of the affected vertebrae and intervertebral disc, pushing the crura of the diaphragm upward with the periosteal stripper, and pushing the psoas muscle to one side can fully expose the affected vertebrae and disc [23].

In this study, we collected the clinical data of 67 patients with L1-2 vertebral tuberculosis treated with either the subdiaphragmatic extraperitoneal approach or the thoracoabdominal approach. There were no statistically significant differences between the groups in ESR, CRP, Cobb angle, VAS score, bone graft fusion, healing of the lesion, and recovery of neurological function before and after surgery. Compared with the thoracoabdominal approach, the subdiaphragmatic extraperitoneal approach was performed only under the diaphragm, without cutting the pleura and diaphragm attached to the ribs, which not only shortened the operation time, but also significantly reduced the amount of intraoperative blood loss and the postoperative hospital stay of patients. These results suggest that the subdiaphragmatic extraperitoneal approach can be used to treat L1-2 vertebral tuberculosis with the same treatment effect and less surgical trauma as the traditional thoracoabdominal approach. In addition, the subdiaphragmatic extraperitoneal approach does not enter the thoracic cavity, which reduces the loss of lung function and avoids bleeding caused by damage to the thoracic organs. Due to the shortened operation time, the time for anesthesia and intubation during operation is reduced, and the incidence of postoperative atelectasis and pleural effusion is reduced [6].

Few articles have reported the use of the subdiaphragmatic extraperitoneal approach to treat L1-2 spinal tuberculosis. In this study, we analyzed the advantages and disadvantages of 2 surgical approaches in the treatment of L1-2 vertebral tuberculosis through a retrospective comparative study. The results suggest that the subdiaphragmatic extraperitoneal approach can be preferred, especially for patients with older age, poor constitution, and poor lung function, who cannot tolerate thoracotomy. However, not all cases of L1-2 vertebral tuberculosis can be treated with this approach. If the lesion involves the upper end of the L1 vertebra, the subdiaphragmatic extraperitoneal approach may not completely expose the diseased area. Even if the spine is tilted or the ribs are lifted, the retractor can be tilted too much, and the operation could be discontinued [22]. Therefore, if the affected vertebrae are difficult to expose and the lesion cannot be completely removed applying the subdiaphragmatic extraperitoneal approach, the thoracoabdominal approach must be performed as soon as possible, since it is the complete removal of the lesion that is a prognostic of a successful spinal tuberculosis surgery [13,24].





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The present study has some limitations, including a small sample size and retrospective design. In the next study, we will design a prospective randomized controlled study and expand the sample size to allow for more convincing conclusions.

## Conclusions

The results of this study show that, compared with the traditional thoracoabdominal approach, the subdiaphragmatic extraperitoneal approach can be regarded as more suitable for the surgical treatment of L1-2 vertebral tuberculosis. The 2 approaches have the same surgical efficacy, but the subdiaphragmatic extraperitoneal approach has the advantages of less surgical trauma, shorter operation time, less intraoperative bleeding, and fewer postoperative pulmonary complications.

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**Statement**

The work was implemented and completed at the General Hospital of Ningxia Medical University.

**Conflicts of Interest**

None.

**Declaration of Figures Authenticity**

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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