Wiltse transforaminal thoracic interbody fusion approach for the treatment of single-segment thoracic spinal tuberculosis in elderly patients with osteoporosis: A retrospective study of 20 cases

HAO ZENG[1,2], SIMI LIAO[1], YINGFANG LIANG[3], ABU MORO[1], GUANGHUI CHEN[4] and HONGYU QIN[1]

[1]Department of Spine and Osteopathy Surgery, First Affiliated Hospital of Guangxi Medical University; [2]Guangxi Key Laboratory of Regenerative Medicine, Guangxi Medical University; [3]Department of Comprehensive Internal Medicine, Affiliated Tumor Hospital of Guangxi Medical University; [4]Department of Traumatology and Orthopedics of Traditional Chinese Medicine, First Affiliated Hospital of Guangxi University of Chinese Medicine, Nanning, Guangxi 530000, P.R. China

Received October 19, 2022; Accepted January 31, 2023

DOI: 10.3892/etm.2023.11834

Abstract. The aim of the present study was to investigate the clinical feasibility and efficacy of the Wiltse approach and TTIF in elderly patients with single-segment thoracic tuberculosis (SSTTB) complicated with osteoporosis and neurological dysfunction. Between January 2017 and January 2019, 20 elderly patients underwent the Wiltse TTIF approach at a single hospital. The follow-up time of these patients was 37.15±7.37 months (range, 24-48 months). The preoperative kyphosis angle was 35.41±6.71˚. The degree of neurological deficit in each patient was assessed using the Frankel spinal cord injury classification. In addition, TB activity was monitored using erythrocyte sedimentation rate and C-reactive protein levels, and the degree of osteoporosis was evaluated using femoral neck bone mineral density T-scores. The 20 patients with SSTTB were completely cured without recurrence. The postoperative kyphotic angle was 8.80±0.79˚, without significant loss of correction at the final follow-up. Bone graft fusion was observed within 6-9 months, with all patients reporting relief of their back pain. The neurological condition of all the patients improved postoperatively. The present study indicates that Wiltse TTIF surgery combined with anti-TB chemotherapy has satisfactory efficacy in elderly patients with SSTTB complicated by osteoporosis and neurological impairment.

Correspondence to: Dr Guanghui Chen, Department of Traumatology and Orthopedics of Traditional Chinese Medicine, First Affiliated Hospital of Guangxi University of Chinese Medicine, 89-9 Dongge Road, Nanning, Guangxi 530000, P.R. China
E-mail: 252093111@qq.com

Dr Hongyu Qin, Department of Spine and Osteopathy Surgery, First Affiliated Hospital of Guangxi Medical University, 6 Shuangyong Road, Nanning, Guangxi 530000, P.R. China
E-mail: 414135872@qq.com

Abbreviations: TTIF, transforaminal thoracic interbody fusion; TB, tuberculosis; STB, spinal TB; SSTTB, single-segment thoracic TB; BMD, bone mineral density

Key words: Wiltse approach, neurological deficits, spinal tuberculosis, single-segment

Introduction

In impoverished nations, tuberculosis (TB) has historically been a devastating infectious disease (1). Spinal TB (STB) is the most frequently occurring form of extrapulmonary TB, accounting for 50% of all skeletal TB cases (2). The primary treatment for STB is anti-TB chemotherapy; however, surgical treatment is useful for the alleviation of kyphosis-associated clinical symptoms, easing spinal cord compression and eliminating abscesses (3,4).

In 1968, Wiltse proposed a new method for spinal surgery that utilizes the gap between the multifidus and longissimus muscles. This approach significantly reduces the dissection time and traction of the multifidus muscle during surgery. It also takes full advantage of the integrity of the posterior bone and ligamentous structural complexes (5). The Wiltse transforaminal thoracic interbody fusion (TTIF) surgical approach has demonstrated excellent results in the treatment of intervertebral disc herniation and STB (6). However, reports on its application in the surgical treatment of single-segment thoracic TB (SSTTB) in elderly patients with osteoporosis are limited in the available literature, with the exception of a few case reports published in mainstream academic journals. In the present study, the preoperative and postoperative information of 20 patients with SSTTB who underwent Wiltse TTIF at a single institution were evaluated to assess the effects of this surgical approach on older patients with osteoporosis.

Materials and methods

Criteria for patient inclusion and exclusion. Wiltse TTIF is standard clinical surgical procedure and the Ethics Committee of the First Affiliated Hospital of Guangxi

Medical University (Nanning, China) approved the present study (ref. no. KY-E-152). All patients provided written informed consent for inclusion in this retrospective study. Between January 2017 and January 2019, the same surgeon operated on 20 elderly patients with SSTTB and osteoporosis at the First Affiliated Hospital of Guangxi Medical University. There were 12 males and 8 females, ranging in age from 65 to 80 years (mean, 70.25±4.19 years). The following criteria were used to make a diagnosis: i) Clinical symptoms and signs; ii) computed tomography (CT) and magnetic resonance imaging (MRI) findings; iii) laboratory test results, including hemoglobin, erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) concentration, as well as TB antibody (IgG and IgM) and tuberculin skin tests; iv) anti-TB chemotherapy was effective, as indicated by obvious radiographic changes; and v) histological microscopy and acid-fast bacillus test as the gold standard. The exclusion criteria were as follows: i) age <65 years; ii) normal femoral neck bone mineral density (BMD) T-score >-2.5 (7); iii) no neurological deficits; iv) multi-segment disease or lesions that require anterior bone fusion; and v) inaccessible para-vertebral or deep muscle abscesses and severe kyphotic deformities (>50˚). Only patients with neurological deficits were selected to reflect the characteristics and efficacy of Wiltse TTIF more clearly. The Frankel classification was used to assess nerve damage as follows: Grade A, complete loss of movement and sensation below the lesion level; Grade B, partial loss of sensation below the lesion level; Grade C, motor and sensory preservation below the lesion level, but with loss of function; Grade D, movement and sensation below the lesion plane are preserved, but with limited mobility; and Grade E, normal function.

Preoperative procedure. The majority of the patients were diagnosed with and treated for STB in the First Affiliated Hospital of Guangxi Medical University, and received anti-TB chemotherapy with the isoniazid, rifampicin, ethambutol and pyrazinamide (HREZ) regimen for 2-4 weeks prior to surgery. The remaining few patients came to the hospital for treatment after they had started anti-TB treatment with the HREZ regimen elsewhere. As their symptoms gradually worsened they were referred to the First Affiliated Hospital of Guangxi Medical University for surgical treatment. In a small number of cases, the patients had complex and changeable symptoms, and the diagnosis of TB was challenging. Therefore, anti-TB treatment was administered and if it was found that the symptoms of these patients improved significantly after anti-TB treatment, a diagnosis of TB was made. Patients who were paralyzed had received anti-TB treatment prior to admission to the hospital, and when they were admitted to the hospital, they had surgery immediately. One notable patient had been treated with the HREZ scheme for 3 weeks in the infectious diseases department of the First Affiliated Hospital of Guangxi Medical University, but his symptoms gradually worsened and paralysis occurred, so he immediately received surgery. The HREZ chemotherapy regimen constituted part of the anti-TB regimen and comprised the following drugs: Isoniazid (5-10 mg/kg/day), rifampicin (5-10 mg/kg/day), ethambutol (15 mg/kg/day) and pyrazinamide (25 mg/kg/day). The anti-TB drug HREZ when used preoperatively has two functions, one of which is the effective control of TB while the other is to improve the tolerance of patients to surgery and promote postoperative recovery. Patient's temperature was measured four times a day. Blood tests were performed every 3 days. Surgery was performed when anemia and hypoalbuminemia were completely under control and the ESR, CRP and body temperature of the patient had returned to normal or were markedly decreased. Calcitriol (0.25 μg/day) and calcium carbonate D3 (1 g/day) were administered orally prior to surgery in patients who had osteoporosis. Furthermore, zoledronic (4 mg) acid was infused intravenously once per year for 3-5 years after the surgery until the femoral neck BMD returned to normal levels.

Surgical procedure. After receiving general anesthesia, patients were placed in the prone position and an X-ray of the C-arm was used to locate the surgical segment. The preoperative MRI indicated the distance separating the muscle space from spinous processes. The subcutaneous tissues and fascia were then carefully separated by making a posterior midline longitudinal incision until the medial multifidus and lateral longissimus muscles were separated, and the intermuscular space was entered. The paravertebral muscles were then separated using a hemilaminectomy retractor to reveal the transverse processes, laminae and interlaminar spaces. Subsequently, in order to avoid complications such as loosening, fracture and delayed healing after screw implantation in elderly patients with osteoporosis, pedicle screws were implanted under the guidance of C-arm CT. If only one side of the vertebral body was involved, a screw was implanted on the uninvolved side, and then two screws were applied to the vertebral bodies above and below the affected vertebral body. If it was not possible to implant screws into the affected vertebral body, then two screws were respectively applied to the two vertebral bodies above the affected vertebral body and two screws were respectively applied to the two vertebral bodies below the affected vertebral body. During local debridement and decompression, a temporary pre-curved rod was placed on the side where the spinal cord and nerves were less compressed, to prevent spinal instability. Subsequently, unilateral facetectomy and laminectomy were performed along the medial pedicle on the side with symptoms or severe paravertebral abscess. A rib adjacent to the costovertebral joint was removed, if necessary. In cases where improved exposure was required, the thoracic nerve root was sacrificed. The extent of paravertebral abscesses and degree of spinal stenosis typically determined the decompression range. The paravertebral space was flushed using a suitable flushing tube until pus was no longer observed. Subsequently, the necrotic vertebrae and discs were removed with a curette until only healthy bones remained. Then, the titanium cage was placed in position, the rods were tightened, and kyphosis was slowly and carefully corrected via the compression and extension of the internal fixation instruments. Following local debridement and decompression, the involved segments were fused posteriorly with allografts or autografted bone. Relatively large pieces of bone were used for grafting when the defects were loose or extensive. Grafts obtained from debridement could also be used to fill this gap. A combination of 1.0 g streptomycin and 0.2 g isoniazid was then administered locally. Drainage was preferentially performed using negative pressure drainage.

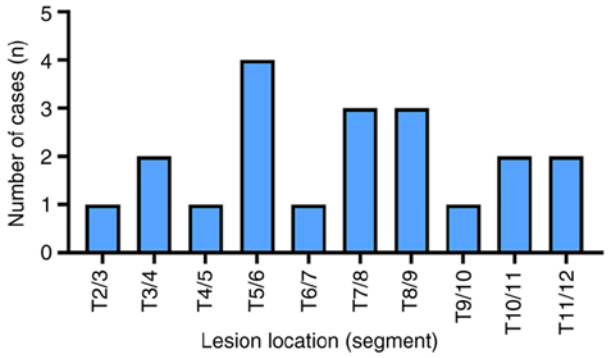

Figure 1. Levels of the involved vertebrae in patients with single-segment thoracic tuberculosis. T, thoracic.

Table I. Clinical details of the 20 patients with single-segment thoracic tuberculosis.

Parameter	Mean ± SD
Duration of surgery, min	155.00±52.92
Intraoperative blood loss, ml	153.75±41.64
Hospital stay, days	6.80±1.51
Follow-up period, months	37.15±7.37
BMD T-score	-4.27±1.51
Bony fusion, months	7.70±1.46

BMD, bone mineral density.

The resected specimens were sent for postoperative bacterial culture and pathological diagnosis.

Postoperative care. When <30 ml drainage was observed, which usually occurred on postoperative day 3, the negative-pressure drainage tube was removed. Continuous administration of oral HREZ anti-TB chemotherapy was performed until 6 months postoperatively. Pyrazinamide was then discontinued and an HRE regimen was administered over the next 9-12 months. Postoperative treatment for osteoporosis was continued for ≥3 months postoperatively. To promote bone graft fusion and prevent the internal fixation from loosening, bed rest for ≥3 months and the use of braces during limited activities were advised for patients with severe osteoporosis who had undergone extensive bone grafting. At 1 week and 3, 6 and 12 months after surgery, all patients underwent clinical and radiological examinations. Annual follow-up visits were recommended following these examinations. Postoperative follow-up CT was also recommended to assess the degree of graft fusion, complete bone union, pseudoarthrosis and other conditions.

Statistical analysis. The values are expressed as the mean ± standard deviation. The statistical significance of differences in kyphosis angle, ESR and CRP at preoperative, postoperative, 3-month postoperative and final follow-up time points were assessed using univariate repeated measure ANOVA with Bonferroni hoc test. Friedman and Nemenyi tests were used to assess the statistical significance of differences in Frankel grades at the aforementioned time points. The analysis was performed using SPSS software (version 24.0; IBM Corp.). P<0.05 was considered to indicate a statistically significant difference.

Results

Basic conditions. In total, 20 cases were examined, 12 of which were male and 8 female, with an average age of 70.25±4.19 years. The involved thoracic segments are shown in Fig. 1. The mean duration of surgery was 155.00±52.92 min, and the mean intraoperative blood loss was 153.75±41.64 ml. The mean length of hospital stay was 6.80±1.51 days, and the follow-up period was 37.15±7.37 months. The average BMD T-score was -4.27±1.51 (Table I). During the follow-up period, postoperative complications included cerebrospinal fluid leakage (1 case), imbalanced water and electrolytes (5 cases), infection of a superficial wound (1 case) and mild intestinal obstruction (2 cases). The internal fixation and bone grafting were not associated with any complications. Following the first week of anti-inflammatory or symptomatic supportive treatment, the symptoms of the patients markedly improved.

Nervous system status. The neurological symptoms of all patients gradually improved during the follow-up period. The results of the preoperative Frankel classification assessment were as follows: Grade A, 1 case; Grade B, 3 cases; Grade C, 7 cases; and Grade D, 9 cases. Only two patients had Grade D at the most recent follow-up, and the remaining 18 patients had full functional recovery and were classified as Grade E (Fig. 2). At the most recent follow-up, the statistical analysis revealed a significant difference (P=0.012; Table II) between the preoperative and postoperative Frankel classifications.

Kyphosis, bone fusion, ESR and CRP. The mean preoperative kyphotic angle was 35.41±6.71˚, which significantly reduced to 8.80±0.79˚ postoperatively (P<0.05). At the last follow-up, the mean kyphotic angle was 9.99±0.92˚ with a correction loss of 1.18±0.37˚, and the difference from the previous angles was statistically significant (P<0.05). A statistically significant difference was also detected between the preoperative and postoperative ESR and CRP levels (both P<0.05; Table II). Postoperative lateral X-ray/CT was used to measure the degree of fusion in all patients after bone grafting and impact drafting. Within 7.70±1.46 months after surgery, all patients had adequate bone fusion (Table I). Representative images for a single patient are presented in Fig. 3.

Discussion

Approximately one-half of all cases of bone and joint TB are STB, a common musculoskeletal disease (2). Despite ongoing efforts by the World Health Organization and local health authorities, TB continues to affect vulnerable individuals, including the elderly (8).

The most commonly used treatment options for STB include anti-TB medication, bed rest and supportive medication. However, in the absence of drug treatment, the risks of surgery, mortality, infection transmission and recurrence are often greatly increased (9). The risks associated with surgical

Table II. Statistical analysis of the clinical results.

Schedule	Preoperative	Postoperative	3 months after surgery	Final follow-up	X^2/F^a	P-value
Frankel, n					10.886	0.012
A	1	0	0	0		
B	3	1	0	0		
C	7	3	1	0		
D	9	6	5	2		
E	0	10	14	18		
Kyphosis angle, °	35.41±6.71	8.80±0.79[b]	9.23±0.53[b]	9.99±0.92[b-d]	344.532	<0.001
ESR, mm/h	68.70±16.76	19.85±3.50[b]	8.45±1.73[b,c]	6.45±1.03[b-d]	426.787	<0.001
CRP, mg/l	25.15±9.60	9.09±3.01[b]	4.8±1.95[b,c]	5.1±1.62[b,c]	94.901	<0.001

[a]All values in this column are F-values with the exception that for the Frankel data. [b]P<0.05 vs. preoperative; [c]P<0.05 vs. postoperative; [d]P<0.05 vs. 3 months after surgery. ESR, erythrocyte sedimentation rate; CRP, C-reactive protein.

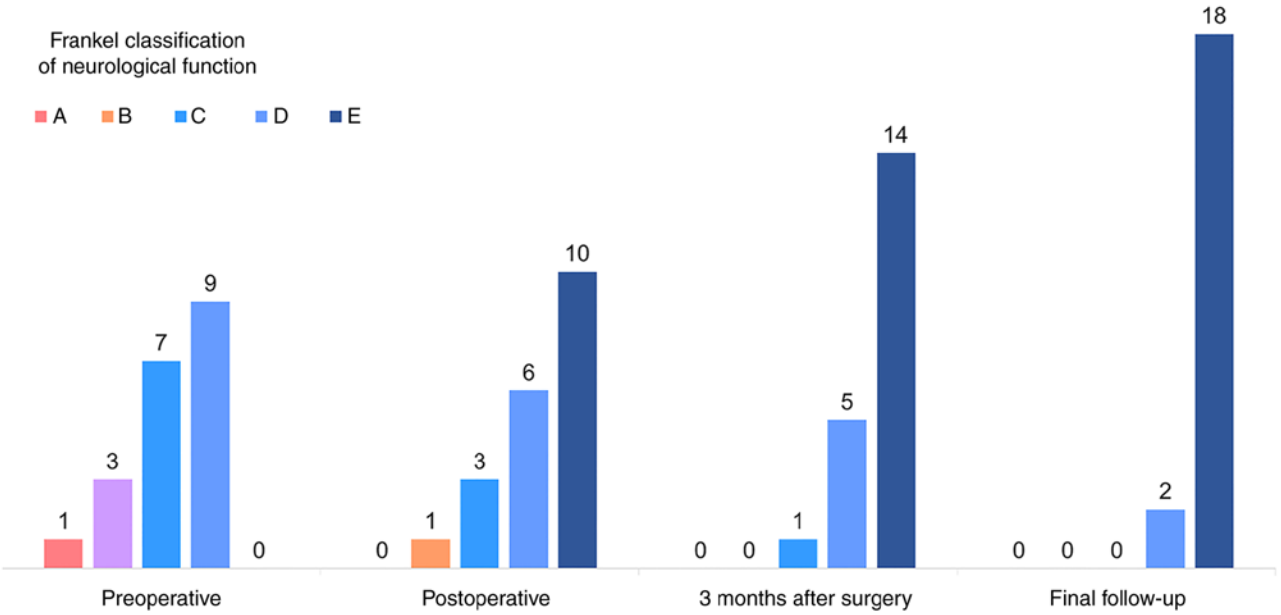

Figure 2. Neurological status of the 20 patients with single-segment thoracic tuberculosis at different time points. The numbers above the columns represent the number of cases.

treatment are also markedly increased due to elderly patients frequently having various accompanying chronic diseases or disorders. Therefore, anti-TB chemotherapy and conservative treatments are preferred over surgical treatment for elderly patients to avoid the risks and complications associated with surgery. However, this may result in the onset of neurological symptoms and the worsening of any existing spinal deformities (10). Similarly, prolonged bed rest as part of conservative treatment not only has an impact on quality of life but also has associated adverse effects. The inability of anti-TB drugs to penetrate tuberculous bone lesions results in inadequate or ineffective treatment. As a result, the removal of necrotic tissues and paravertebral abscesses, alleviation of neurological symptoms, and improvement or stabilization of spinal deformities all require surgical treatment in elderly patients.

However, there are conflicting opinions regarding the surgical options for elderly patients with SSTTB. Although anterior surgery is effective in correcting kyphosis and relieving nerve compression (11), it does not directly remove tuberculous lesions or facilitate bone grafting. Additionally, the mediastinal organs, sternum, clavicle and ribs interfere with surgical procedures, making anterior surgery more challenging and prone to intra- and postoperative complications. The combined anterior-posterior approach has a positive clinical effect, but requires at least two separate surgeries, takes several hours to complete, frequently results in extensive blood loss, has a prolonged recovery period after surgery and is unsuitable for elderly patients (12).

Posterior surgery has made significant progress in the treatment of STB over the past few decades. The posterior pedicle screw system has been widely used to improve spinal stability and correct spinal deformities. It has been demonstrated to be effective in treating disorders of the thoracic spine, resulting in neurological dysfunction and segmental instability (8).

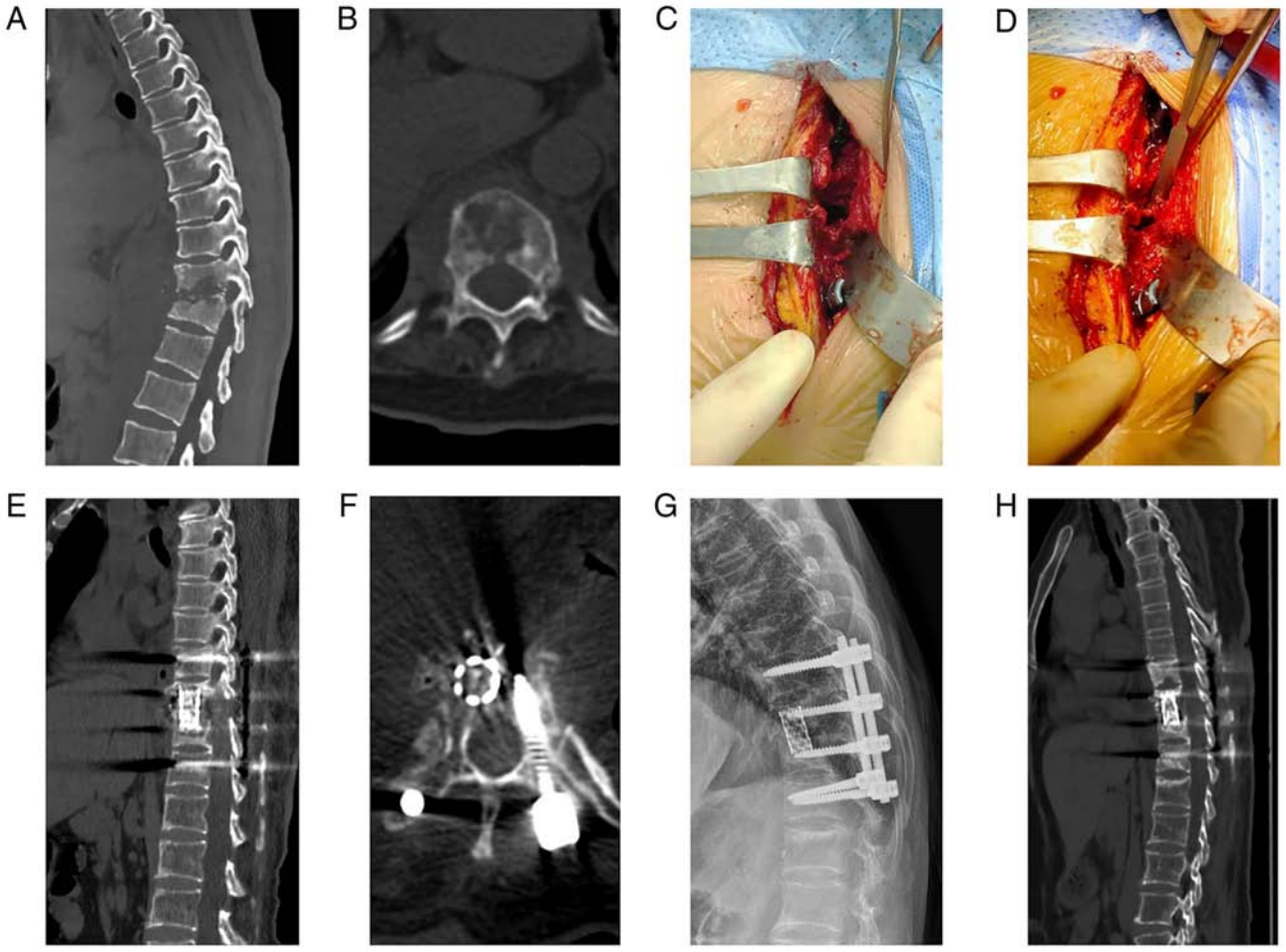

Figure 3. Images of a 75-year-old patient with T9/10 lesions who underwent surgery using the Wiltse TTIF approach. (A) Sagittal and (B) coronal pre-operative imaging reveals severe spinal cord compression and destruction of the T9/10 vertebrae. (C and D) Images captured during the Wiltse TTIF surgery. Kyphosis correction is evident on the postoperative (E) sagittal and (F) coronal CT scans. (G) X-ray at the third month following surgery reveals good bone fusion and no obvious loss of kyphosis correction. (H) Sagittal CT scan at 9 months after surgery demonstrates satisfactory graft fusion without spinal tuberculosis relapse. TTIF, transforaminal thoracic interbody fusion; CT, computed tomography.

Harms and Rolinger (13) first advocated for posterior TTIF, which is regarded as an improvement on posterior thoracic interbody fusion (PTIF) and was successful in resolving the issue of excessive nerve retraction and its associated complications. However, the multifidus muscle is extensively stripped during the traditional TTIF procedure, which damages its blood supply and innervation. As a result, the multifidus muscle degenerates, atrophies and undergoes fibrosis and the deposition of adipose tissue after surgery. Additionally, the procedure requires a long time to complete. When surgeries are prolonged, the extensive retraction of the paraspinal muscles, which are the innermost multifidus muscle groups, raises intramuscular pressure. This results in local hypoxia and sometimes irreversible ischemic degeneration and necrosis, which frequently has a significant impact on the physiological function of the multifidus muscle and increases the risk of persistent lower back pain after surgery (14). In 1968, Wiltse (5) proposed a novel strategy by utilizing the space between the longissimus and multifidus muscles. The integrity of the posterior bone and ligamentous structures is maximized by this strategy, which can significantly reduce damage to the multifidus muscle caused by dissection or traction.

In practice, the intermuscular TTIF approach is rarely used to treat osteoporosis in elderly patients with STB. However, the Wiltse TTIF method benefits from the following: It is anatomically straightforward, easing the learning curve for novice surgeons. Natural spaces between the multifidus and longissimus muscles are used for access, instead of crude dissection and extensive retraction of the paraspinal muscle complexes. This prevents denervation and devascularization of the multifidus muscle, which can lead to ischemic degeneration and necrosis. As a result, it maintains the physiological functions of the multifidus muscle while maintaining the stability of the spine. Therefore, postoperative chronic lower back pain is less common but postoperative recovery takes longer. According to the present research, patients who underwent Wiltse TTIF spent an average of 6.80±1.51 days in the hospital. For thoracic TB treated using a posterior-only approach, our previous study found that the mean hospital stay was 12.4±4.1 days (15). This suggests that the Wiltse TTIF approach effectively reduced hospital stay. Second, the Wiltse intramuscular TTIF strategy shortens the duration of surgery and anesthesia, which typically results in less blood loss during the procedure and lower overall risks associated with the procedure. Among the 20 patients in the present study, there were few cases where the

upper thoracic vertebrae were involved, and mainly the middle and lower thoracic vertebrae were affected. It was necessary to remove some rib bones to reach the intervertebral disc; however, the bone was loose and not particularly hard. In addition, the use of an ultrasonic osteotome simplified the surgical process. This may be advantageous because the majority of elderly patients have accompanying medical conditions and comorbidities, which could be deemed fatal or cause the patient to be unsuitable for prolonged surgical treatment. According to the findings of the present study, the Wiltse TTIF approach took an average of 155.00±52.92 min to perform on patients and resulted in a blood loss of 153.75±41.64 ml on average. The surgery time for patients who underwent a posterior-only approach was 152.1±24.4 min, and the amount of blood lost was 650.7±150.2 ml (15). Although the Wiltse TTIF approach is effective at reducing intraoperative blood loss, it does not discernibly reduce the duration of surgery. Third, it can achieve the same internal fixation as obtained using PLIF, assisting in the stabilization of the spinal column and preventing the worsening of kyphosis and the neurological manifestations that accompany it. Finally, the surgical area enables the removal of any paraspinal abscesses that may be present, which is advantageous for the successful surgical treatment of STB and its healing. The Wiltse TTIF method, by contrast, has two major drawbacks. First, there is the possibility of further injury to the spinal cord and nerve roots, similar to that observed with PTIF spinal decompression. Second, complete anterolateral debridement is challenging, but anti-TB drugs have made it possible for TB lesions to spontaneously merge and heal; therefore, thorough debridement is not essential (8).

The treatment plan for elderly patients with osteoporosis and STB may be based on the findings of the present study, with conservative treatment, such as bed rest, anti-TB chemotherapy and anti-osteoporosis treatment being considered in addition to regular MRI and blood sample reviews and evaluations every 4-8 weeks. Second, after the adjacent vertebral segments without tuberculous lesions have been cemented, cortical bone trajectory (bicortical bone screw) or root screws can be used in elderly patients with severe osteoporosis and aggravated neurological symptoms. The fixed segment can be appropriately extended if the fixation is loose or insecure. In elderly patients with severe osteoporosis, the Wiltse approach can also aid in maintaining adequate postoperative spinal stability by preserving the spinous processes and associated attachments, including the spinous process, interspinous ligament, lamina and other bony structures. Lastly, TB genetic analysis, drug susceptibility testing and drug resistance testing can be performed on intraoperative specimens to guide the selection of postoperative anti-TB medications.

In conclusion, the one-step Wiltse TTIF approach is feasible and efficient for the treatment of elderly patients with osteoporosis and SSTTB. The postoperative clinical and imaging results in the present study are very promising; however, the follow-up time was short. Further confirmation of the findings of the study requires a larger number of patients and extended follow-up period for this type of surgical procedure. New research projects may also be performed to study the effect of this surgical method on patients with other complications.

Acknowledgements

Not applicable.

Funding

This study was supported by the National Natural Science Foundation of China (grant no. 82160420) and the Clinical Climbing Program of the First Affiliated Hospital of Guangxi Medical University (grant no. YYZS2020022).

Availability of data and materials

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

Authors' contributions

HZ designed and supervised the study. YL and SL performed the data collection and analysis. AM and HQ assisted with pathology and image preparation. HQ and GC prepared and revised the manuscript. GC conducted data analysis and interpretation. All authors read and approved the final manuscript. HZ and HQ confirm the authenticity of all the raw data.

Ethics approval and consent to participate

The study was approved by the Medical Ethics Committee of the First Affiliated Hospital of Guangxi Medical University (ref. no. KY-E-152).

Patient consent for publication

Informed written consent was obtained from all 20 patients for the publication of this case report and the accompanying images.

Competing interests

The authors declare that they have no competing interests.

References

1. Zhao Y, Li M and Yuan S: Analysis of transmission and control of tuberculosis in Mainland China, 2005-2016, based on the age-structure mathematical model. Int J Environ Res Public Health 14: 1192, 2017.
2. Cormican L, Hammal R, Messenger J and Milburn HJ: Current difficulties in the diagnosis and management of spinal tuberculosis. Postgrad Med J 82: 46-51, 2006.
3. Zeng H, Shen X, Luo C, Xu Z, Zhang Y, Liu Z, Wang X and Cao Y: 360-degree cervical spinal arthrodesis for treatment of pediatric cervical spinal tuberculosis with kyphosis. BMC Musculoskelet Disord 17: 175, 2016.
4. Wang LJ, Zhang HQ, Tang MX, Gao QL, Zhou ZH and Yin XH: Comparison of three surgical approaches for thoracic spinal tuberculosis in adult: Minimum 5-year follow up. Spine (Phila Pa 1976) 42: 808-817, 2017.
5. Wiltse LL: The paraspinal sacrospinalis-splitting approach to the lumbar spine. Clin Orthop Relat Res (91): 48-57, 1973.
6. Jin YM, Chen Q, Chen CY, Lyu J, Shi B, Yang C and Xia C: Clinical research and technique note of TTIF by wiltse approach for the treatment of degenerative lumbar. Orthop Surg 13: 1628-1638, 2021.

7. Kan B, Zhao Q, Wang L, Xue S, Cai H and Yang S: Association between lipid biomarkers and osteoporosis: A cross-sectional study. BMC Musculoskelet Disord 22: 759, 2021.
8. Zhang HQ, Lin MZ, Shen KY, Ge L, Li JS, Tang MX, Wu JH and Liu JY: Surgical management for multilevel noncontiguous thoracic spinal tuberculosis by single-stage posterior transforaminal thoracic debridement, limited decompression, interbody fusion, and posterior instrumentation (modified TTIF). Arch Orthop Trauma Surg 132: 751-757, 2012.
9. Hayashi S, Takeuchi M, Hatsuda K, Ogata K, Kurata M, Nakayama T, Ohishi Y and Nakamura H: The impact of nutrition and glucose intolerance on the development of tuberculosis in Japan. Int J Tuberc Lung Dis 18: 84-88, 2014.
10. Moon MS: Tuberculosis of the spine. Controversies and a new challenge. Spine (Phila Pa 1976) 22: 1791-1797, 1997.
11. Lu G, Wang B, Li J, Liu W and Cheng I: Anterior debridement and reconstruction via thoracoscopy-assisted mini-open approach for the treatment of thoracic spinal tuberculosis: Minimum 5-year follow-up. Eur Spine J 21: 463-469, 2012.
12. Zhang HQ, Guo CF, Xiao XG, Long WR, Deng ZS and Chen J: One-stage surgical management for multilevel tuberculous spondylitis of the upper thoracic region by anterior decompression, strut autografting, posterior instrumentation, and fusion. J Spinal Disord Tech 20: 263-267, 2007.
13. Harms J and Rolinger H: A one-stager procedure in operative treatment of spondylolistheses: Dorsal traction-reposition and anterior fusion (author's transl). Z Orthop Ihre Grenzgeb 120: 343-347, 1982 (In German).
14. Kawaguchi Y, Yabuki S, Styf J, Olmarker K, Rydevik B, Matsui H and Tsuji H: Back muscle injury after posterior lumbar spine surgery. Topographic evaluation of intramuscular pressure and blood flow in the porcine back muscle during surgery. Spine (Phila Pa 1976) 21: 2683-2688, 1996.
15. Zeng H, Zhang P, Shen X, Luo C, Xu Z, Zhang Y, Liu Z and Wang X: One-stage posterior-only approach in surgical treatment of single-segment thoracic spinal tuberculosis with neurological deficits in adults: A retrospective study of 34 cases. BMC Musculoskelet Disord 16: 186, 2015.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0) License.