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Single-stage posterior transforaminal lumbar interbody fusion, debridement, limited decompression, 3-column reconstruction, and posterior instrumentation in surgical treatment for single-segment lumbar spinal tuberculosis

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Objective: The aim of this study is to determine the feasibility and efficacy of surgical management of single-segment lumbar spinal tuberculosis (TB) by using single-stage posterior transforaminal lumbar interbody fusion, debridement, limited decompression, 3-column reconstruction, and posterior instrumentation.

Methods: Seventeen cases of single-segment lumbar TB were treated with single-stage posterior transforaminal lumbar interbody fusion, debridement, limited decompression, 3-column reconstruction, and posterior instrumentation. The mean follow-up was 36.9 months (range: 24–62 months). The kyphotic angle ranged from 15.2–35.1° preoperatively, with an average measurement of 27.8°. The American Spinal Injury Association (ASIA) score system was used to evaluate the neurological deficits and erythrocyte sedimentation rate (ESR) used to judge the activity of TB.

Results: Spinal TB was completely cured in all 17 patients. There was no recurrent TB infection. The postoperative kyphotic angle was 6.6–10.2°, 8.1° in average, and there was no significant loss of the correction at final follow-up. Solid fusion was achieved in all cases. Neurological condition in all patients was improved after surgery.

Conclusion: Single-stage posterior transforaminal lumbar interbody fusion, debridement, limited decompression, 3-column reconstruction, and posterior instrumentation can be a feasible and effective method the in treatment of single-segment lumbar spinal TB.

Keywords: 3-column reconstruction; debridement; limited decompression; lumbar spinal TB; posterior transforaminal lumbar interbody fusion; single-segment.

Level of Evidence: Level IV Therapeutic Study

The incidence of tuberculosis (TB) has increased throughout the world. Spinal TB, which is a common extrapulmonary form of TB, is the most frequent and serious form of skeletal TB.[1,2] Anti-TB chemotherapy still plays an irreplaceable role in treatment of spinal spondylitis. Moon et al.[1] reported that 54 patients of 56 cases (96.4%) presenting with spinal TB administrated by triple chemotherapy had favorable results. However,

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spinal TB is characterized by involved vertebrae, kyphosis deformity, and spinal cord compression. Besides debridement and decompression, surgeons strive for kyphosis deformity correction and prevention of postoperative deformity aggravation in the treatment of spinal TB. As with lumbar spinal TB, a variety of surgical treatments of this disease have been reported, including anterior only,[3,4] combined anterior and posterior,[5,6] posterior only,[7–11] and minimally invasive surgery.[12–14] Although the above surgical methods have their respective advantages and disadvantages, there is clinical consensus for selecting the posterior-only approach of combined laminectomy, debridement, bone grafting, and internal fixation for patients with focal spinal TB.[15] However, routine semi-laminectomy or laminectomy decompression during posterior-only surgery can lead to spinal posterior column defect, soft tissue adhesions, as well as complications such as intractable lower back pain, which seriously affect the quality of life of patients.[9,16] Therefore, the purpose of this study is to explore a new surgery procedure with less destruction of the spinal posterior column structure, and reduction of intraoperative trauma; additionally, this study aims to present postoperative complications of patients and evaluate the feasibility and efficacy of single-stage posterior transforaminal lumbar interbody fusion, debridement, limited decompression, 3-column reconstruction, and posterior instrumentation in the treatment of single-segment lumbar spinal TB.

Patients and methods

Written informed consent was obtained from all patients, and the study protocol was approved by our hospital Ethics Committee. From January 2007–January 2013, 17 patients with lumbar spinal TB accompanied by neurological disorders or lower back pain who were unresponsive to chemotherapy were enrolled in our study: 8 patients were male, 9 were female, and the average age was 41.8 years (range: 15–75 years). Involved segments were observed at L1–L2 in 2 cases, L2–L3 in 5 cases, L3–L4 in 6 cases, and L4–L5 in 8 cases (Figure 1). There were 3 cases with multilevel vertebrae involved. Diagnosis was based on clinical and hematological criteria. All patients had symptoms of TB such as weight loss, low fever, fatigue, and suffered from lower back pain and/or kyphosis deformity. The kyphosis angle ranged from 15.2–35.1°, with an average of 27.8°. The classification of the American Spinal Injury Association (ASIA) was used to assess neurological deficit, finding 2 patients with Grade B, 5 patients with Grade C, 9 patients with Grade D, and 1 patient with Grade E (Figure 2). The average erythrocyte sedimentation rate (ESR) of patients upon admission was 47.6 mm/h (range: 26–75 mm/h) (Table 1). Indications for surgery in the study included progressive neurological deficit (13 cases), persistent lower back pain attributed to instability and mild local deformity or deformity likely to progress (14 cases), and difficulty in ruling out Mycobacterium TB unresponsive to chemotherapy regimens, which was later confirmed histologically during surgery (4 cases). However, for patients who presented with iliac fossa abscess or anterior abscess formation and multisegment lesions, anterior debridement was necessary.

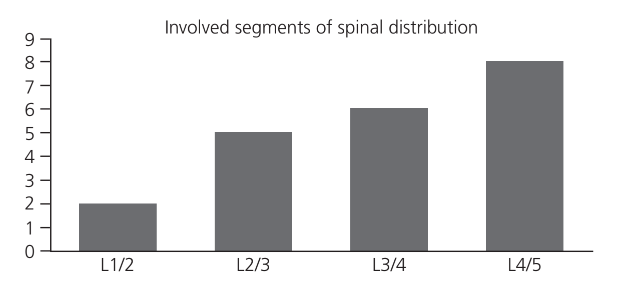

Fig. 1. Involved segments of spinal distribution of 17 cases (Y-axis signifies patients).

Patients participating in this study had a clinical diagnosis of spinal TB and were administrated anti-Tb drugs according to the HREZ chemotherapy regimen, consisting of isoniazid (5–10 mg/kg/day, with no more than 300 mg/day), rifampicin (5–10 mg/kg/day, with no more than 300 mg/day), ethambutol (15 mg/kg/day, with no more than 500 mg/day) and pyrazinamide (25 mg/kg/day, with no more than 750 mg/day) 2–4weeks before surgery. When ESR and temperature returned to normal or had significantly decreased and anemia and hypoproteinemia were rectified completely, surgical management was performed.

Patients were in the prone position after administration of general endotracheal anesthesia. Through a mid-

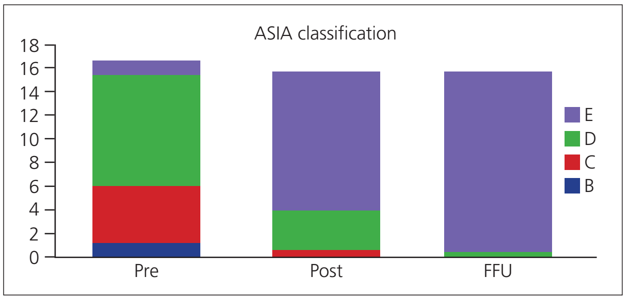

Fig. 2. Neurological status of 17 patients preoperatively, postoperatively, and at final follow-up. (Y-axis signifies patients). [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

Table 1. Clinical data on all patients.

Patient no	Age	Sex	Blood loss (ml)	Operation time (min)	Hospitalization time (day)	Involved segments	Follow-up (mon)	Lumbar kyphosis angle			ASIA			ESR	
								Pre	•Post	◆FFU	Pre	#Post	▲FFU	Pre	*Post 3 mon
1	24	Female	200	120	13	L3–L4	25	29.2	8.3	9.1	D	E	E	61	9
2	26	Male	300	125	16	L1–L3	27	32.1	7.3	9.1	C	D	E	26	5
3	57	Female	350	200	13	L1–L2	33	29.8	6.9	7.5	C	D	E	55	9
4	15	Female	340	105	13	L4–L5	36	15.2	7.3	8.2	D	E	E	50	8
5	29	Male	200	180	15	L3–L5	45	27.1	7	9	D	E	E	55	10
6	41	Male	250	140	14	L4–L5	28	28.1	9.3	10.1	C	D	E	66	7
7	47	Male	270	170	14	L2–L3	50	29.2	7.3	8.1	D	E	E	34	6
8	22	Male	290	170	14	L2–L3	62	23.3	7.8	8.2	B	C	D	59	11
9	65	Female	320	150	15	L4–L5	36	30.6	10.2	11.1	D	E	E	45	8
10	45	Male	340	105	16	L3–L4	36	29.4	7.4	9.2	E	E	E	29	9
11	75	Female	300	180	13	L3–L4	24	28.1	6.6	7.5	D	E	E	46	7
12	50	Male	270	190	14	L2–L3	40	35.1	10.1	11.2	B	D	E	35	4
13	48	Female	300	155	13	L4–L5	39	25.1	7.3	8.1	D	E	E	44	7
14	21	Female	380	255	12	L2–L5	29	33.4	9.4	11.2	C	D	E	75	13
15	35	Female	300	130	13	L4–L5	35	19.3	7	7.4	D	E	E	44	6
16	48	Female	210	100	14	L3–L4	35	28.3	9.1	10	D	E	E	49	7
17	63	Male	300	125	15	L4–L5	48	30.1	10.1	10.8	C	D	E	37	7
Mean values	41.8	289.4	152.9	13.9		36.9	27.8	8.1	9.2				47.6	7.8	

ASIA: American Spinal Injury Association score system; ESR: Erythrocyte sedimentation rate; Pre: Preoperation; Post: 4 weeks postoperation; FFU: Final follow-up; Post 3 mon: 3 months postoperation.
#Wilcoxon signed-rank test, comparing 4 weeks postoperative with preoperative in ASIA; $p<0.05$.
▲Wilcoxon signed-rank test, comparing final follow-up with 4 weeks postoperative in ASIA; $p<0.05$.
• Analyzed by paired t-test, comparing 4 weeks postoperative with preoperative in kyphosis angle; $t=18.321$, $p=0.000$.
◆ Analyzed by paired t-test, comparing final follow-up with 4 weeks postoperative in kyphosis angle; $t=-8.346$, $p=0.000$.
*Analyzed by paired t-test, comparing 4 weeks postoperative with preoperative in ESR; $t=13.907$, $p=0.000$.

line incision the posterior spinal elements including lamina, facet joints, and transverse processes were exposed (extraperiosteal dissection), extending 1 vertebra above and below the involved segments. Transpedicular screws were used in the side of vertebral lamina based on preoperative symptoms and imaging. Transpedicular screws were placed in the affected vertebrae if the upper part of the vertebrae was not destroyed by infection. Following transpedicular screws being implanted and C-arm X-ray confirming their accuracy, a temporary pre-bent approximately 20–30° rod was installed on the mild side of the lesion to avoid spinal cord injury induced by instability of the spine during decompression and focal debridement, and the severe side of the lesion was selected, which caused clinical symptoms or presented with paraspinal abscess at the decompression side. The 1/3 of the superior vertebra of the involved vertebrae and its ligamentum flavum were bitten down to expose the spinal canal; gradually, the scope of operation decompression was expanded according to the scope of the lesion and whether it was conducive to surgical invasion that did not involve facet joints, supraspinous ligament, and interspinous ligament. The decompression range was determined according to the extent of spinal canal stenosis and the scope of paraspinal abscess (limited laminectomy decompression, Figure 3a). A suitable flush tube was inserted to rinse the paravertebral abscess or psoas abscess with appropriate pressure to remove pus following removal of the necrotic disc and the collapsed vertebrae by curettes, through to healthy bleeding bone. Having finished debridement of the decompression side, the operating table was tilted 30° to the opposite side to expand the operative field for debridement of the abscess, sequestrum, caseous necrosis, and granulation tissue in the mild side. If the space created after focal debridement was too large, autogenous or allograft bone was selected for posterior fusion at the segment that underwent decompression and focal debridement (anterior and central columns reconstruction, Figure 3b). The above processes did not involve the facet joints, interspinal, and supraspinal ligaments. One g streptomycin and 0.2 g isoniazid were administered locally, and the allogeneic bone plate was trimmed to repair the bone defects (posterior column reconstruction, Figure 3c). The connecting rod was stabilized, the bone plate was placed rigidly under the fixed rod, and the segmental kyphosis was corrected; if necessary, the cross-connected instrument was connected across the spinous process. Drainage and incision sutures were performed postoperatively, and resected specimens were collected for bacterial culture and pathological diagnosis (Figure 3).

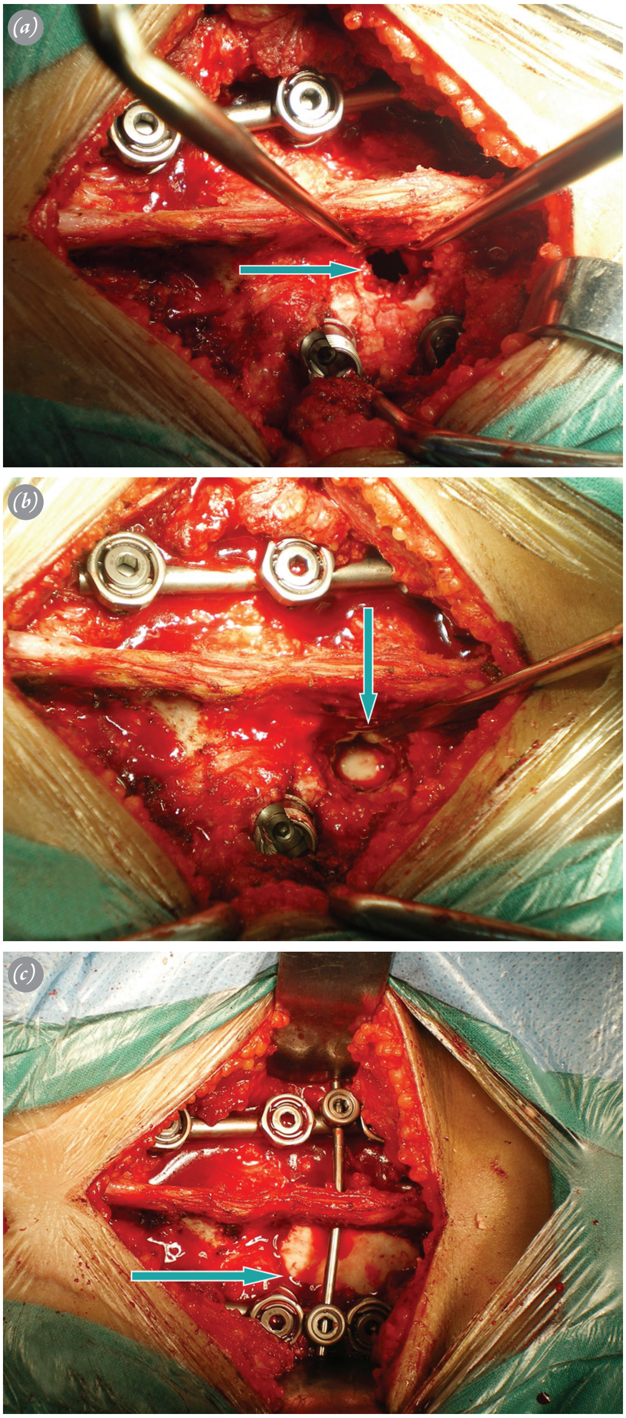

Fig. 3. Surgical process: **(a)** posterior debridement and limited decompression, **(b)** interbody allografting, **(c)** vertebral plate reconstruction. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

The drainage tube was removed when the volume of drainage was <30 ml. Oral HREZ chemotherapy was continued postoperatively. Pyrazinamide was discontinued 6 months postoperatively. Patients then received 9–12-month regimens of HRE chemotherapy

(6HREZ/9–12HRE).[17] Patients were examined clinically and radiologically at 3, 6, and 12 months postoperatively and thereafter once annually.

Kyphosis angle was recorded pre- and postoperatively and during follow-up. To record kyphosis angel, lateral X-ray was observed, and 2 lines were drawn, 1 through the superior surface of the first normal vertebra cephalic to the lesion and 1 through the inferior surface of the first normal vertebra caudal to the lesion. Perpendiculars were drawn from these lines, and the angle was measured at their intersection. Additionally, neurological status and ESR were recorded. Using SPSS 19.0 software (SPSS Inc., Chicago, IL, USA), kyphosis angle and ESR were statistically analyzed by paired t-test pre- and postoperatively and during follow-up, and neurological function was statistically analyzed by Wilcoxon signed-rank test pre- and postoperatively and during follow-up. Discrepancy of the normal distribution was analyzed by Wilcoxon rank-sum test, with a significance level of 0.05 (Table 1).

Results

Mean blood loss was 289.4 ml (range: 200–380 ml); mean operation time was 152.9 min (range: 100–255 min); mean hospitalization time was 13.9 days (range: 12–16 days). Wounds healed without chronic infection or sinus formation. No complication related to instrumentation or bone grafted occurred. One patient showed symptoms of mild pneumonia postoperatively; the symptoms disappeared after the patient received anti-inflammatory and symptomatic supportive treatment for 2 weeks.

Neurologic deficits in all patients were improved at final follow-up examination. Results were evaluated by ASIA classification: 1 case improved by 3 grades, 6 cases improved by 2 grades, and 9 cases improved by 1 grade (Table 1, Figure 2). Statistical analysis demonstrated that there was significant difference between pre- and postoperative measurements ($p<0.05$). One patient presented with no neurological deficit preoperatively, and 1 patient showed incomplete neurological function postoperatively, which was attributed to delayed diagnosis because of financial issues. All patients experienced pain relief.

Mean kyphosis angle was 27.8° preoperatively (range: 15.2–35.1°); mean kyphosis angle decreased significantly to 8.1° postoperatively (range: 6.6–10.2°) ($p<0.05$) (Table). Mean kyphosis angle was 9.2° at final follow-up (range: 7.4–11.2°), whose loss of correction was 1.1°. It still significantly improved in comparison to the preoperative measurements ($p<0.05$) (Table 1).

Intervertebral bone graft and bone graft between vertebral plates were performed in all patients. Lateral X-ray and computed tomography (CT) were used to assess the fusion and the formation of a bone bridge. All patients achieved bone fusion within 8–11 months postoperatively, which was confirmed by 2 different surgeons based on the modified criteria of Lee et al.[18] for radiological fusion, including definitive bone trabecular bridging across the graft-host interface, no movement (<3°) on a flexion-extension radiograph, and no gap at the interface.

Average pretreatment ESR was 47.6 mm/h (range: 26–76 mm/h), which normalized within 3 months in all patients. There was a statistical difference between preoperative ESR and 3-month postoperative follow-up ESR ($p<0.05$) (Table 1).

Discussion

The lumbar spine is characterized as a capacious spinal canal with floating nerve roots, which can be relatively tolerant to compression because of abscess and granulation tissue; this makes TB in this region develop slowly and be amenable to conservative treatment.[8] However, when patients are predisposed to neurological defect, kyphosis deformity, sequestered bone, or large paraspinal abscess, conservative regimes are inferior to surgical approaches, though chemotherapy is generally very effective way in controlling and treating the disease. While different surgical management approaches have been reported,[3–9] the one-stage posterior-only approach is increasing in popularity with patients with single-segment lumbar spinal TB due to the advantages of relatively minimal invasion and satisfactory clinical outcomes.[19–22] Controversies regarding posterior-only surgery in treatment of lumbar spinal TB focus on whether it will affect the stability of the spine because of largely traumatic destruction of vertebral posterior column and facet joints and whether it will produce complications such as lower back pain.[7,9,23] To address these arguments, we improved the traditional posterior surgical methods by means of limited decompression and 3-column reconstruction, performed with extensive clinical experience and understanding of the literature.

Caspar et al.[24] defined limited decompression for lumbar spinal stenosis as when only the clinically relevant sides and levels are decompressed, while the spinous processes, the interspinous ligaments, the medial portion of ligamentum flavum, and the functionally important parts of the facet joints were preserved. Kramer et al.[25] observed that degenerative lumbar spinal stenosis takes place predominantly at the interlaminar region on the level of the disc, involving facets and bulging of the ligamentum flavum. Resection of the whole lamina may not be necessary, and they found a significant reduction of volume loss in extension following limited interlaminar decompression. In contrast, there was no significant additional reduction of volume loss in extension after complete laminectomy in comparison to limited interlaminar decompression in their biomechanical study designed to assess the effect of different decompression techniques using cadaver lumbar spine models. In the treatment of single-segment lumbar spinal TB, however, we utilized the principles and methods above in the surgical treatment of lumbar spinal stenosis and achieved successful clinical results. The limited decompression in treatment of lumbar spinal TB is based on the complete removal of the lesion and effective or clinically relevant decompression to maintain the integrity and stability of anatomical structures of the spine. However, extensively exposing and resecting mostly vertebral plates in conventional posterior surgery may cause serious damage to the posterior column of the spine, which can easily lead to iatrogenic spinal instability and long-term postoperative lower back pain,[26] although the operative field is relatively open. Thorough debridement is a relative concept; it is deemed sufficient if the lesion can be removed effectively to achieve the purpose of treatment and there is no linear relationship between range of decompression and thoroughness of debridement, which largely depends on the surgeon's expertise and familiarity. Extent of decompression is not determinant of operational success, the key of which is the effective removal of the focus of TB in the lesion. Therefore, the purpose of limited decompression

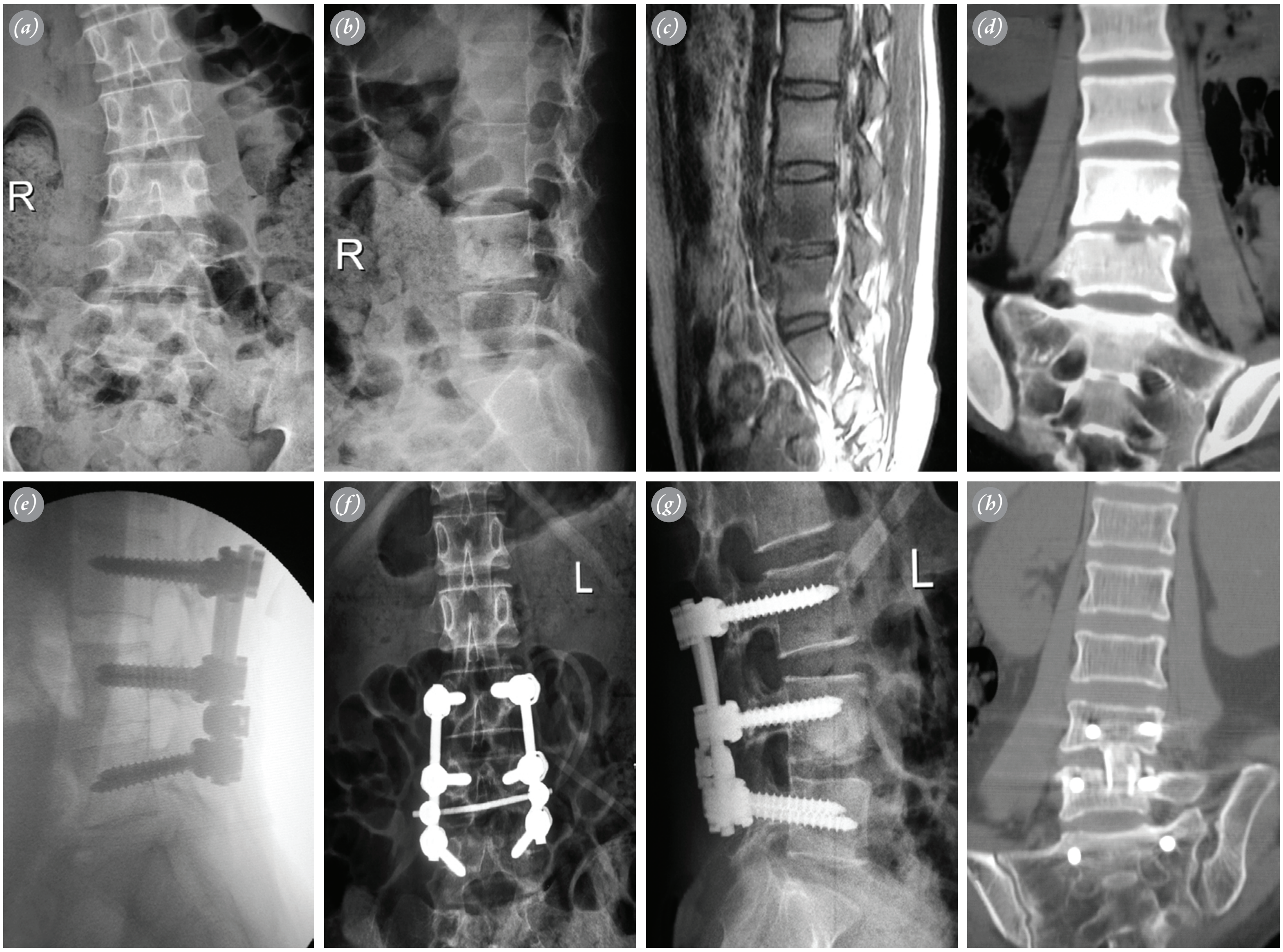

Fig. 4. A 15-year-old girl presented with continued back pain and did not respond to anti-TB drugs (anti-TB treatment for 6 months), which seriously affected her quality of life. Culture and susceptibility testing postoperatively confirmed multidrug-resistant Mycobacterium TB. **(a–d)** Preoperative lateral and anteroposterior X-ray, MRI and CT image; **(e)**: intraoperative C-arm photo; **(f, g)** X-ray showed that the posterior column of the spine was preserved well, and the reconstructed vertebra plate had reached good bone fusion postoperatively; **(h)** The coronal CT found that intervertebral bony union was achieved, and there was no occurrence of secondary or iatrogenic spinal stenosis and no complications related to internal fixation at final-follow up.

is to minimize the range of bone resection, maximize retention of the posterior column of the spine, effectively reduce iatrogenic injury, and avoid the occurrence of postoperative complications. This simplifies the surgical operation, shortens operation time, and reduces blood loss and spinal interference to a certain extent. In our study, mean blood loss was 289.4 ml (range: 200–380 ml), mean operation time was 152.9 min (range: 100–255 min) and mean hospitalization time was 13.9 days (range: 12–16 days), which were less than previously reported results.[6–9] In our study, 2 patients experienced cerebrospinal fluid leakage, and 1 had water-electrolyte imbalance. These complications were successfully treated. It has been suggested that removing the TB focus using the posterior approach could cause intraspinal infection and central nervous system complications such as TB meningitis.[5] However, no patients in our study developed TB meningitis, a finding consistent with other reports.[27]

The strict indications of the surgery used in lumbar spinal TB should be emphasized: significantly deformed dura and nerve roots, the presence of spinal stenosis, and no severe kyphotic deformity; focus or paraspinal abscess confined to a single segment or multi-segment with one center; spinal cord compression by paravertebral/epidural abscess with little or no psoas or iliac abscessation; patients who had undergone several anterior operations, in whom the anatomical structure was unclear; severe or progressive neurological dysfunction and persistent lower back pain unresponsive to conventional therapy; and elderly patients with complicated comorbidities intolerant of extreme surgical intervention. When lesions are confined to the anterior vertebral column, when there is severe multilevel vertebral TB, or when psoas or iliac abscesses are located far from the lumbar vertebrae, the routine posterior-only or posterior–anterior approach should be prioritized.

Fig. 5. A 41-year-old male with spinal TB at L4–L5. **(a–d)** Preoperative lateral and anteroposterior X-ray, sagittal MRI and CT image; **(e, f)** X-ray showed that 18.8° correction of kyphosis angle was obtained, the posterior column of spine was preserved well, and the reconstructed vertebral plate had reached good bone fusion postoperatively; **(g, h)** The CT scan found that intervertebral bony union was achieved, and there was no recurrence of TB at final follow-up.

Some studies[28] showed that the posterior column of the spine plays an irreplaceable role in maintaining its stability and resistance to shear force, rotational force, and compressive stress. Biomechanically, interbody fusion allows reconstruction of the spinal anterior and central column, which effectively bears the compression of the body, and reconstruction of lamina and associated structures maintains the integrity of the posterior column and shares the axial load of internal fixation, which largely minimize the incidence of postoperative complications related to instrumentation.[29] Nevertheless, vast laminectomy can cause bone defects, extensive soft tissue adhesions, and intractable lower back pain postoperatively, which affect the efficacy of surgery and may lead to failed back surgery syndrome (FBSS).[23] Chandler and Cappello[30] reported that a mass of laminectomy can fill the gap with scar tissue and form the so-called laminectomy membrane. Abnormally proliferative fibrous connective tissue often adheres to the dural sac and nerve roots, which affect the axoplasmic transport of nerve fiber, arterial supply, and venous drainage, resulting in a series of clinical symptoms. Hollingworth, et al.[31] reported that in 8–10% of patients, FBSS is due to epidural scar formation and nerve root compression. Thus, to inhibit the formation of the laminectomy membrane is to prevent the formation of FBSS, and establishment of the barrier between the dural sac and scar tissue is an effective means to prevent postoperative adhesions. Reconstructed vertebral plate as bone support is able to effectively rebuild the spinal anatomy structure and maintain the stability of the spine; additionally, it serves as the bone barrier between the dural sac and soft tissue and can effectively prevent rear dense fiber scar tissue from invading the subdural sac and nerve roots, preventing iatrogenic spinal stenosis.[32] At final follow-up, neurologic deficits in all patients in our study were improved, anterior fusion and reconstructed vertebra plate fusion were radiologically incorporated, and there was no occurrence of secondary or iatrogenic spinal stenosis or complications related to internal fixation (Figure 4, 5).

Limitations of the present study are that it is preliminary, retrospective in nature, and the surgery indications are relatively narrow.

Single-stage posterior transforaminal lumbar interbody fusion, debridement, limited decompression, 3-column reconstruction, and posterior instrumentation can be an effective treatment of single-segment lumbar spinal TB. It is characterized by minimum traumaticity, rapid postoperative recovery, earlier ambulation, and fewer complications. However, the indication of the surgery is relatively limited, which should be considered comprehensively for each individual. To date, the clinical and radiographic results of these patients have been good, though the results are preliminary and for a small group of patients with relatively short follow-up for in some cases. We recommend future studies with a large number of patients and longer follow-up.

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Conflics of Interest: No conflicts declared.

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