

Treatment of Severe Bone Destruction in L5-S1 Spinal Tuberculosis With Anterior Combined Posterior Approach

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Abstract

Background: There are many studies on the surgical treatment of lumbosacral tuberculosis, but both the anterior and posterior approaches present some shortcomings. This study aimed to evaluate the therapeutic efficacy of anterior debridement and bone graft, posterior fixation and fusion with navigation for L5-S1 tuberculosis with severe bone destruction.

Methods: This was a retrospective study of 24 patients with severe tuberculosis in L5-S1 who underwent anterior interbody arthrodesis and posterior pedicle screw internal fixation by open approach under computer navigation between February 2011 and November 2016. The erythrocyte sedimentation rate(ESR), C-reactive protein level(CRP),visual analogue scale(VAS), and lumbosacral angle were compared between before surgery, after surgery, and at the final follow-up. The fusion status of bone graft was evaluated with computed tomography(CT).

Results: The mean operation time was 244.58 minutes. The mean intraoperative blood loss was 413.75ml. The accuracy of screw placement was 96.43%. The mean follow-up period was 26.17 months. The average ESR, CRP, VAS, and lumbosacral angles were 65.96 mm/h, 52.93 mg/L, 4.96 points, and 107.94°, respectively, at preoperative, 34.17 mm/h, 16.47 mg/L, 1.58 points, and 116.12°, respectively, after surgery, and 14.08 mm/h, 6.20 mg/L, 0.58 points, and 115.97°, respectively, at the final follow-up period. The differences of ESR, CRP, VAS are statistically significant ($p < 0.05$). The difference of lumbosacral angles before and after surgery is statistically significant ($p < 0.05$) but there is no statistically significant difference between after surgery and the final follow-up period ($p > 0.05$). Nine patients with ASIA Grade D before surgery returned to Grade E by the final follow-up period. All patients achieved bone fusion. There was no recurrence of the disease.

Conclusions: Anterior debridement and bone graft fusion combined with navigated posterior pedicle screw fixation is a safe and effective treatment option for patients with severe bone destruction in L5-S1 spinal tuberculosis.

1. Introduction

Spinal tuberculosis is the most common form of extrapulmonary tuberculosis, accounting for 50–60% of all bone and joint tuberculosis.¹ Lumbosacral tuberculosis is extremely rare, accounting for only 2–3% of all cases of spinal tuberculosis reported in the literature.[1, 2] Similar to treatment of other forms of spinal tuberculosis, the treatment of L5-S1 spinal tuberculosis entails anti-tuberculosis drug therapy or combination surgery. However, for L5-S1 vertebral tuberculosis, the region has a complex anatomical structure and special biomechanical characteristics. Treatment is particularly difficult when severe bone destruction affects the stability of the lumbosacral segment, and both the anterior and posterior approaches present some shortcomings. Surgery via the anterior approach alone for the correction of kyphosis has little effect, barely maintains spine stability, and often leads to bone graft detachment. Surgery via the posterior approach alone for the complete debridement of lesions, such as anterior abscesses and damaged intervertebral discs, is difficult, and performing structural bone grafting to reestablish the stability of the anterior vertebral column is also difficult.[3, 4] This study aimed to investigate the efficacy of debridement and bone graft fusion through a one-stage paramedian retroperitoneal approach combined with navigated posterior-approach pedicle screw fixation for L5-S1 tuberculosis with severe bone destruction.

2. Materials And Methods

2.1 Study design and patients

At the time of admission, all participants provided written informed consent for their data stored in our hospital database and used for study purposes. This study was approved by our Ethical Committee.

A retrospective review of 24 patients with severe bone destruction associated with L5-S1 spinal tuberculosis who underwent lumbosacral spine surgery was performed at a single university-based spine clinic from February 2011 to November 2016. There were 13 male and 11 female patients, with ages ranging from 25 to 70 years (average 43.75 ± 11.78 years). The patients had varying degrees of low back pain. Nine patients had American Spinal Injury Association (ASIA) Grade D nerve compression, and six had a history of tuberculosis at other sites, including four patients with pulmonary tuberculosis, one patient with renal tuberculosis, and one patient with a tuberculocoele. All patients underwent X-ray, computed tomography (CT), and magnetic resonance imaging (MRI). They presented with paravertebral abscesses, sequestra and kyphosis of various sizes, as well as significant vertebral destruction and intervertebral space collapse. The surgery procedure was performed by the same team. All patients were pathologically diagnosed with lumbosacral tuberculosis.

The inclusion criteria were:

- (1) lumbar tuberculosis lesion located in L5/S1 gap.
- (2) presence of necrotic bone and paravertebral abscess or segmental instability.
- (3) Significant destruction, such as the destruction of L5/S1 $\geq 2/3$ [5]

The exclusion criteria were:

- (1) active pulmonary tuberculosis.
- (2) multiple segments spinal tuberculosis requiring surgery.
- (3) incomplete follow-up data.
- (4) other destructive diseases, such as cancer.

2.2. Preoperative preparation

Anti-TB oral drugs with the HREZ standard chemotherapy regimen that consists of isoniazid 0.3 g/d, rifampicin 0.45 g/d, ethambutol 0.75 g/d, and pyrazinamide 0.75 g BID were administered for over 3 weeks preoperatively, combined with nutritional supplementation in the form of a high-protein diet. After admission, 750,000 IU streptomycin IM QD was given. The course of treatment is two months. Active tuberculosis was excluded by preoperative routine chest X-ray examination and multiple acid-fast staining sputum examinations. After the general condition of the patient improved and tuberculosis symptoms resolved, surgery was scheduled

2.3. Surgical management

The patient was placed in the supine position. The left hip was slightly lifted. An incision was made through a left paramedian approach to reach operative region. After incision, paraspinous pus, granulation tissue, sequestra, and

residual intervertebral discs were removed under direct vision and were sent for pathological examination and tuberculosis culture. The height of the residual intervertebral space was measured. The surgical instruments and gloves were replaced, and a tricortical iliac bone graft of appropriate size was harvested from the left anterior superior iliac spine and implanted into the L5-S1 intervertebral space without additional fixation(Fig. 1A-B). The length of the selected iliac bone graft would be slightly longer than the measured height of the L5-S1 intervertebral space to reduce the possibility of detachment after bone grafting. Intraoperative C-arm fluoroscopy confirmed proper bone graft placement. The patient was switched to the prone position. After incision, the pedicle screw was placed under computer navigation to improve the accuracy of the screw placement. Pedicle screws were inserted in 1 segment above and below the involved body if the pedicle screw channel of the involved body was destructed and the screw hold in the body was not strong enough. Pre-bent connecting rods were installed and appropriately extended longitudinally to correct kyphosis. The posterolateral bone grafting were performed with autologous iliac cancellous bone after full decortication of the transverse process and the lamina at the fixation segments.

2.4. Postoperative management

The drainage tube was removed when the drainage volume was less than 50mL/24h. The patients were encouraged to walk with a lumbosacral brace to reduce the occurrence of complications related to immobilization. The brace was worn for 12 weeks after surgery. The patients continued the oral HREZ after surgery. Six months later, the oral pyrazinamide was stopped. The patients continued 1 year regimens of HRE chemotherapy. For patients with complicated neurological dysfunction, mecobalamin 0.5 mg po TID was given. ESR and CRP levels, liver and kidney functions, and biochemical examinations were re-examined monthly for 3 months after surgery and every 3 months thereafter. X-ray and CT examinations of the lumbosacral segment were performed 3 months, 6 months, and 12 months after surgery and annually thereafter.

2.5. Observational indices and assessment criteria

Operation time, intraoperative blood loss, and surgery-related complications were recorded. The incidence of poor postoperative screw position detected by CT after surgery was calculated. Changes in ESR,CRP,VAS and lumbosacral angle measured by the Dubousset method[6](Because the inferior end plate has been destroyed in these patients, the lumbosacral angle measures the degree of kyphosis between the superior end plate of L5 and the posterior wall of the sacrum)were determined before surgery, after surgery, and at the final follow-up. The difference in ASIA grades before surgery and at the final follow-up period as well as tuberculosis recovery and bone graft fusion status at the final follow-up period were recorded.

2.6. Statistical methods

Data were processed using SPSS 18.0 statistical software. All data were expressed as mean \pm standard deviation ($\bar{x} \pm s$).One-way MANOVA was used to compare the differences among the data collected before surgery, after surgery, and at the final follow-up period. The SNK test was used for pairwise comparisons between groups. The significance level was set at $\alpha=0.05$.

3. Results

3.1. Perioperative status

There were 13 male patients and 11 female patients, with ages ranging from 25 to 70 years (average 43.75 ± 11.78 years). At the time of admission, ESR were 4–120 mm/h (average 65.96 ± 33.79 mm/h), CRP levels were 2.9–217 mg/L (average 52.93 ± 46.66 mg/L), and VAS were 3–7 points (average 4.96 ± 1.12 points). The lumbosacral angles measured by the Dubousset method were 89.37° – 125.14° (average $107.94^\circ \pm 11.53^\circ$).

The operation times were 170–420 min (average 244.58 ± 59.53 min). Intraoperative blood losses were 100–1000 ml (average 413.75 ± 236.40 ml). Among the 112 screws, only four slightly broke through the medial wall of the pedicle, and the accuracy of screw placement was 96.43%. There were no vascular injuries, ureteral injuries, or new nerve injury complications. There was no retrograde ejaculation in male patients. All patients underwent real-time fluorescence quantitative PCR pathological examination, all of which supported the diagnosis of tuberculosis. The results are summarized in Tables 1 and 2.

Table 1
Patient Characteristics and Instrumented Fusion Levels(n=24)

Case No	Sex	Age(Yr)	Level	Tuberculosis History	ASIA	Instrumented Fusion Level	Operation Time(min)	Blood loss (ml)	Follow-up (month)
1	M	51	L5/S1	/	E	L4-S1	240	1000	23
2	M	70	L5/S1	Lung	E	L5-S1	175	400	35
3	F	44	L5/S1	/	E	L4-S1	200	400	22
4	F	42	L5/S1	/	E	L4-S1	210	400	20
5	M	42	L5/S1	/	D	L5-S2	340	400	27
6	F	33	L5/S1	Lung	E	L4-S1	275	400	24
7	F	33	L5/S1	/	E	L5-S1	255	100	48
8	F	48	L5/S1	/	D	L5-S1	170	100	21
9	M	51	L5/S1	/	E	L5-S1	210	300	30
10	M	40	L5/S1	/	E	L5-S1	270	600	28
11	M	50	L5/S1	Testicle	D	L5-S1	270	800	26
12	M	61	L5/S1	/	D	L5-S1	175	200	29
13	M	69	L5/S1	/	E	L5-S1	235	800	25
14	F	49	L5/S1	/	D	L5-S1	175	300	28
15	F	50	L5/S1	/	E	L5-S1	200	150	20
16	F	43	L5/S1	Lung	E	L5-S1	300	700	27
17	M	26	L5/S1	Kidney	D	L4-S1	280	500	24
18	M	30	L5/S1	/	D	L5-S1	295	300	22
19	F	41	L5/S1, T5-7	/	E	L4-S2/T5-7	220	500	23
20	M	30	L5/S1	Lung	E	L4-S1	225	600	21
21	M	41	L5/S1	/	D	L5/S1	210	200	28
22	F	41	L5/S1	/	D	L5-S1	220	200	26
23	F	40	L5/S1	/	E	L5-S1	300	330	29
24	M	25	L5/S1	/	E	L5-S1	420	250	22

F:Female; M:Male; L:Lumbar vertebra; S: Sacral vertebra; T:Thoracic vertebra

Table 2
Comparison of indexes between pre- and post-operation ($\bar{x} \pm s$)

Time	ESR (mm/h)	CRP (mg/l)	VAS score	Dubousset's SA(°)
Preop	65.96±33.79	52.93±46.66	4.96±1.12	107.94±11.53
Postop	34.17±24.36	16.47±17.25	1.58±0.78	116.12±7.23
Fin	14.08±7.81	6.20±4.96	0.58±0.65	115.97±6.79
Statistic	<i>F</i> =27.42 <i>P</i> =0.00	<i>F</i> =17.37 <i>P</i> =0.00	<i>F</i> =165.37 <i>P</i> =0.00	<i>F</i> =6.816 <i>P</i> =0.002
VAS: visual analog scale; ESR :erythrocyte sedimentation rate; CRP: C-reactive protein ;Preop: preoperative; Postop: postoperative; Fin: Final follow-up; SA=Sacrolumbar Angle				

3.2. Follow-up results

Follow-up was conducted in 24 patients for 20–48 months (average 26.17 ± 5.93 months). Average ESR, CRP, VAS scores, and lumbosacral angles of all patients were 34.17 ± 24.36 mm/h, 16.47 ± 17.25 mg/L, 1.58 ± 0.78 , and $116.12^\circ \pm 7.23^\circ$, respectively, after surgery, and 14.08 ± 7.81 mm/h, 6.20 ± 4.96 mg/L, 0.58 ± 0.65 , and $115.97^\circ \pm 6.79^\circ$, respectively, at the final follow-up period. The changes in these data with respect to the preoperative values were statistically significant ($p < 0.05$). The exception was that there was no significant difference between lumbosacral angle after surgery and at the final follow-up period ($p > 0.05$), ESR, CRP, and VAS improved further at the final follow-up period with respect to values after surgery ($p < 0.05$) (Table 2). Nine patients with ASIA Grade D before surgery returned to Grade E by the final follow-up period. Delayed wound healing in posterior incision were identified in 1 case, and the wound healed in the fourth week after change dressing. Although local bone resorption of iliac bone graft were identified in 1 case, solid posterolateral fusion was achieved at the final follow-up, and no correction loss occurred. There were no other complications such as bone graft displacement, tuberculosis recurrence, internal fixation loosening or fracture occurred during the follow-up period, and fusion was achieved in all cases at the final follow-up with the healing time of 6-18 months (average 8.25 ± 2.83 months). Typical case and pictures are shown in Fig. 2A-N.

4. Discussion

Tuberculosis is an internal medicine disease, and its treatment is primarily based on anti-tuberculosis drugs that can achieve good therapeutic effects.[7, 8] A long-term follow-up study showed that although conservative treatment achieved good outcomes, residual low back pain and kyphosis were more common in late stages.[9] Currently, it is generally believed that patients should be treated with surgical intervention as long as there is progressive aggravation of neurological dysfunction, massive paraspinal abscess and sequestrum formation, severe pain not significantly relieved with medication, or significant bone destruction that affects spinal stability. [10, 11] The purpose of the operation is complete lesion removal, spinal canal decompression, correction of deformity, and re-establishment of spine stability through bone grafting and stable internal fixation. After the

operation, patients can quickly return to normal life as a consequence of rehabilitation exercise.[4, 12] However, the methods to achieve these goals are controversial.[3, 4]

Since Hodgson first reported the treatment of spinal tuberculosis using the “Hong Kong operation” in 1960,[13] tuberculosis debridement and internal fixation through an anterior approach has become the preferred surgical approach for spinal tuberculosis. The advantages of the anterior-approach surgery are as follows: (1) direct access to the lesion for complete debridement and direct spinal canal decompression.[4, 14] (2) anterior vertebral column stability can be reestablished immediately through intervertebral bone grafting, and the compressive stress is conducive to postoperative bone fusion.[15](3)it can appropriately improve kyphosis. Nevertheless, the disadvantages of anterior-approach surgery are that the bone graft bears high compressive stress after anterior-approach lesion debridement alone, and the bone graft is prone to collapse and absorption, causing insufficient support for the lumbosacral segment. Furthermore, the lumbosacral segment is an inflection point of biomechanical change where the local stresses are large. Without internal fixation, long-term bed rest after surgery is required, and the bone graft can be displaced or even become detached due to excessive stretching or torsion of the waist.[16] Selection of anterior-approach internal fixation therefore requires greater exposure, increasing the risks of surgery, and has greater requirements on the residual vertebral bone. It has been reported that the complication rate increased by 50% as the scope of surgical exposure was increased and internal fixation was placed on normal vertebral bodies.[17] Weinstein pointed out that the pedicle itself provides 60% of the total pedicle screw anti-pullout strength; cancellous bone accounts for approximately 15–20%, and the anterior cortical bone accounts for approximately 20–25%.[18] Sun et al. reported that the average improvement in lumbosacral angle after posterior-approach surgery was 44.3°.[19] whereas the average improvement in lumbosacral angle after anterior-approach surgery was only approximately 9.5°.[3] Therefore, the anti-pullout strength, the ability to correct kyphosis, and the ability to maintain corrective effect with posterior-approach fixation is better than with anterior-approach fixation. Nevertheless, posterior-approach tuberculous lesion debridement alone is often incomplete and is prone to recurrences after surgery, especially in patients with significant bone destruction of the anterior vertebral column and large abscesses in the psoas major muscle or iliac fossa.[20] Moreover, the stability of the anterior vertebral column is not easily reestablished by structural bone grafting via posterior-approach surgery alone; this leads to loss of lumbosacral height and the effect of kyphosis correction.[15, 21]Therefore, the first choice for L5-S1 spinal tuberculosis with severe bone destruction is a combined anterior-posterior approach. [4, 11, 21]

With respect to the order, Zeng et al. believe that because performing posterior-approach fixation leads to stiffness of the fixed segment, it will be difficult for anterior bone graft to support the anterior vertebral column after anterior-approach surgery.[2] Therefore, performing anterior-approach surgery first is recommended for patients with severe bone destruction in L5-S1 spinal tuberculosis. For anterior-approach bone grafting, the size of the iliac bone graft should be appropriately larger than the measured height in order to be conducive to reducing dislocation of the bone grafting interface under compressive stress and to promoting bone graft fusion.[15] For posterior-approach bone grafting with autologous iliac cancellous bone, the cartilage surface of the facet joints in the lumbosacral region should be removed, including the L5-S1 spinal facet joint articular surface, and full decortication of the transverse process and the residual lamina can be performed to improve postoperative bone graft fusion and maintain the effect of kyphosis correction.

In order to improve postoperative bone graft fusion rate and reduce surgical complications, it is necessary to preserve as many of the residual vertebrae as possible and to place screws on the residual vertebrae to reduce the

fixed segments. Since Steinmann et al. first reported successful placement of pedicle screws by image-based technique in 1993,[22] this technology has been developed into computer navigation technology and has been widely used in spinal surgery. Studies have shown that the success rates of screw placement with traditional positioning based on anatomical landmarks combined with surgeon's experience and intraoperative imaging or nerve monitoring were 90.3–94.1%.[23, 24] Wood et al implanted 627 pedicle screws in 150 patients at the same institution under computer navigation, and the overall complication rate (including poor pedicle screw placement and pedicle screws requiring adjustment) was 3.83%.[25] Siasios et al. suggested that the accuracy of screw placement under computer navigation was 95.3–100%.[26] It can be seen that screw placement under computer navigation is more accurate than the traditional method. Especially for residual vertebrae, the screws successfully placed at one time can increase the anti-pullout strength. In the present study of 24 patients, only 4 of 112 screws slightly broke through the medial wall of the pedicle, and the accuracy of screw placement was 96.43%. The possible causes are that the navigational device placement was not tight, resulting in intraoperative deviation, or that there were operational errors by the surgeon during screw placement.

We achieved good surgical outcomes in 24 patients with severe bone destruction in L5-S1 spinal tuberculosis. There were no vascular injuries, ureteral injuries or new nerve injury complications, and intraoperative screw placement under computer navigation was accurate. In all patients, ESR, CRP, VAS, and lumbosacral angles significantly improved one month postoperatively and at the last follow-up compared with the values before surgery. Although local bone resorption of iliac bone graft were identified in 1 case, solid posterolateral fusion was achieved at the final follow-up, and no correction loss occurred. There were no other complications such as bone graft displacement, tuberculosis recurrence, internal fixation loosening or fracture occurred during the follow-up period, and fusion was achieved in all cases at the final follow-up.

Several limitations should be considered while interpreting the results of this study. This was a retrospective analysis of patients from a single-center, which limits generalizability of study findings. The small sample size of our study (n=24) decreases the power of the results. Some prospective randomized control trial studies with larger sample sizes are needed to validate our results.

5. Conclusion

Anterior debridement and bone graft fusion combined with navigated posterior pedicle screw fixation allows not only complete debridement of necrotic tissue in the anterior and intervertebral space of the lumbosacral segment under direct vision and reconstruct anterior column with autologous tricortical iliac bone, but also obtain postoperative stability and facilitate bone graft fusion, which is a safe and effective treatment option for the treatment of severe bone destruction in L5-S1 vertebral tuberculosis.

Abbreviations

ESR=erythrocyte sedimentation rate; CRP=C-reactive protein level; VAS=visual analogue scale; ASIA=American Spinal Injury Association; CT=computed tomography; MRI= magnetic resonance imaging.

Declarations

Ethics approval and consent to participate

This study was conducted with approval from the Ethics Committee of West China Hospital and was performed in accordance with the Declaration of Helsinki. At the time of admission, all participants provided written informed consent for their data stored in our hospital database and used for study purposes.

Consent for publication

Not applicable.

Competing interests

The author(s) declare that they have no conflict of interest.

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Authors' contributions

Jing xue and Tao li participate in the design of this study and they both carried out the study and collected important background information. Hao liu and Yueming song completed literature search, data acquisition. Quan gong and Limin liu completed data analysis and statistical analysis. Jing xue completed original writing of this manuscript.

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Availability of data and materials

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

References

1. Rajasekaran S, Shanmugasundaram TK, Prabhakar R, Dheenadhayalan J, Shetty AP, Shetty DK. Tuberculous lesions of the lumbosacral region. A 15-year follow-up of patients treated by ambulant chemotherapy. *Spine (Phila Pa 1976)*. 1998;23(10):1163-7.
2. Zeng H, Wang X, Pang X, Luo C, Zhang P, Peng W, et al. Posterior only versus combined posterior and anterior approaches in surgical management of lumbosacral tuberculosis with paraspinal abscess in adults. *Eur J Trauma Emerg Surg*. 2014;40(5):607-16.
3. Song JF, Jing ZZ, Chen B, Ai ZS, Hu W. One-stage anterolateral surgical treatment for lumbosacral segment tuberculosis. *Int Orthop*. 2012;36(2):339-44.
4. Xu Z, Wang X, Shen X, Luo C, Wu P, Zeng H. One-stage lumbopelvic fixation in the treatment of lumbosacral junction tuberculosis. *Eur Spine J*. 2015;24(8):1800-5.
5. He Q, Xu J. Comparison between the antero-posterior and anterior approaches for treating L5-S1 vertebral tuberculosis. *Int Orthop*. 2012;36(2):345-51.

6. Dubousset J. Treatment of spondylolysis and spondylolisthesis in children and adolescents. *Clin Orthop Relat Res.* 1997;(337):77-85.
7. Moon MS, Moon YW, Moon JL, Kim SS, Sun DH. Conservative treatment of tuberculosis of the lumbar and lumbosacral spine. *Clin Orthop Relat Res.* 2002;(398):40-9.
8. Bhojraj S, Nene A. Lumbar and lumbosacral tuberculous spondylodiscitis in adults. Redefining the indications for surgery. *J Bone Joint Surg Br.* 2002;84(4):530-4.
9. Pun WK, Chow SP, Luk KD, Cheng CL, Hsu LC, Leong JC. Tuberculosis of the lumbosacral junction. Long-term follow-up of 26 cases. *J Bone Joint Surg Br.* 1990;72(4):675-8.
10. Zhang T, Ma L, Lan X, Zhen P, Wang S, Li Z. One-Stage Anterolateral Debridement, Bone Grafting, and Internal Fixation for Treating Lumbosacral Tuberculosis. *Asian Spine J.* 2017;11(2):305-313.
11. Sundararaj GD, Behera S, Ravi V, Venkatesh K, Cherian VM, Lee V. Role of posterior stabilisation in the management of tuberculosis of the dorsal and lumbar spine. *J Bone Joint Surg Br.* 2003 ;85(1):100-6.
12. Assaghir YM, Refae HH, Alam-Eddin M. Anterior versus posterior debridement fusion for single-level dorsal tuberculosis: the role of graft-type and level of fixation on determining the outcome. *Eur Spine J.* 2016;25(12):3884-3893.
13. HODGSON AR, STOCK FE, FANG HS, ONG GB. Anterior spinal fusion. The operative approach and pathological findings in 412 patients with Pott's disease of the spine. *Br J Surg.* 1960 ;48:172-8.
14. Zhao J, Lian XF, Hou TS, Ma H, Chen ZM. Anterior debridement and bone grafting of spinal tuberculosis with one-stage instrumentation anteriorly or posteriorly. *Int Orthop.* 2007;31(6):859-63.
15. Safran O, Rand N, Kaplan L, Sagiv S, Floman Y. Sequential or simultaneous, same-day anterior decompression and posterior stabilization in the management of vertebral osteomyelitis of the lumbar spine. *Spine (Phila Pa 1976).* 1998;23(17):1885-90.
16. Mukherjee SK, Dau AS. Anterior lumbar fusion in Pott's disease. *Clin Orthop Relat Res.* 2007 ;460:93-9.
17. Yilmaz C, Selek HY, Gürkan I, Erdemli B, Korkusuz Z. Anterior instrumentation for the treatment of spinal tuberculosis. *J Bone Joint Surg Am.* 1999;81(9):1261-7.
18. Weinstein JN, Rydevik BL, Rauschnig W. Anatomic and technical considerations of pedicle screw fixation. *Clin Orthop Relat Res.* 1992;(284):34-46.
19. Sun L, Song Y, Liu L, Gong Q, Zhou C. One-stage posterior surgical treatment for lumbosacral tuberculosis with major vertebral body loss and kyphosis. *Orthopedics.* 2013;36(8):e1082-90.
20. Talu U, Gogus A, Ozturk C, Hamzaoglu A, Domanic U. The role of posterior instrumentation and fusion after anterior radical debridement and fusion in the surgical treatment of spinal tuberculosis: experience of 127 cases. *J Spinal Disord Tech.* 2006;19(8):554-9.
21. Bezer M, Kucukdurmaz F, Aydin N, Kocaoglu B, Guven O. Tuberculous spondylitis of the lumbosacral region: long-term follow-up of patients treated by chemotherapy, transpedicular drainage, posterior instrumentation, and fusion. *J Spinal Disord Tech.* 2005;18(5):425-9.
22. Steinmann JC, Herkowitz HN, el-Kommos H, Wesolowski DP. Spinal pedicle fixation. Confirmation of an image-based technique for screw placement. *Spine (Phila Pa 1976).* 1993;18(13):1856-61.
23. Silbermann J, Riese F, Allam Y, Reichert T, Koeppert H, Gutberlet M. Computer tomography assessment of pedicle screw placement in lumbar and sacral spine: comparison between free-hand and O-arm based navigation techniques. *Eur Spine J.* 2011 ;20(6):875-81.

24. Kosmopoulos V, Schizas C. Pedicle screw placement accuracy: a meta-analysis. *Spine (Phila Pa 1976)*. 2007;32(3):E1111-20.
25. Wood MJ, McMillen J. The surgical learning curve and accuracy of minimally invasive lumbar pedicle screw placement using CT based computer-assisted navigation plus continuous electromyography monitoring - a retrospective review of 627 screws in 150 patients. *Int J Spine Surg*. 2014;8:27.
26. Siasios ID, Pollina J, Khan A, Dimopoulos VG. Percutaneous screw placement in the lumbar spine with a modified guidance technique based on 3D CT navigation system. *J Spine Surg*. 2017;3(4):657-665.

Figures

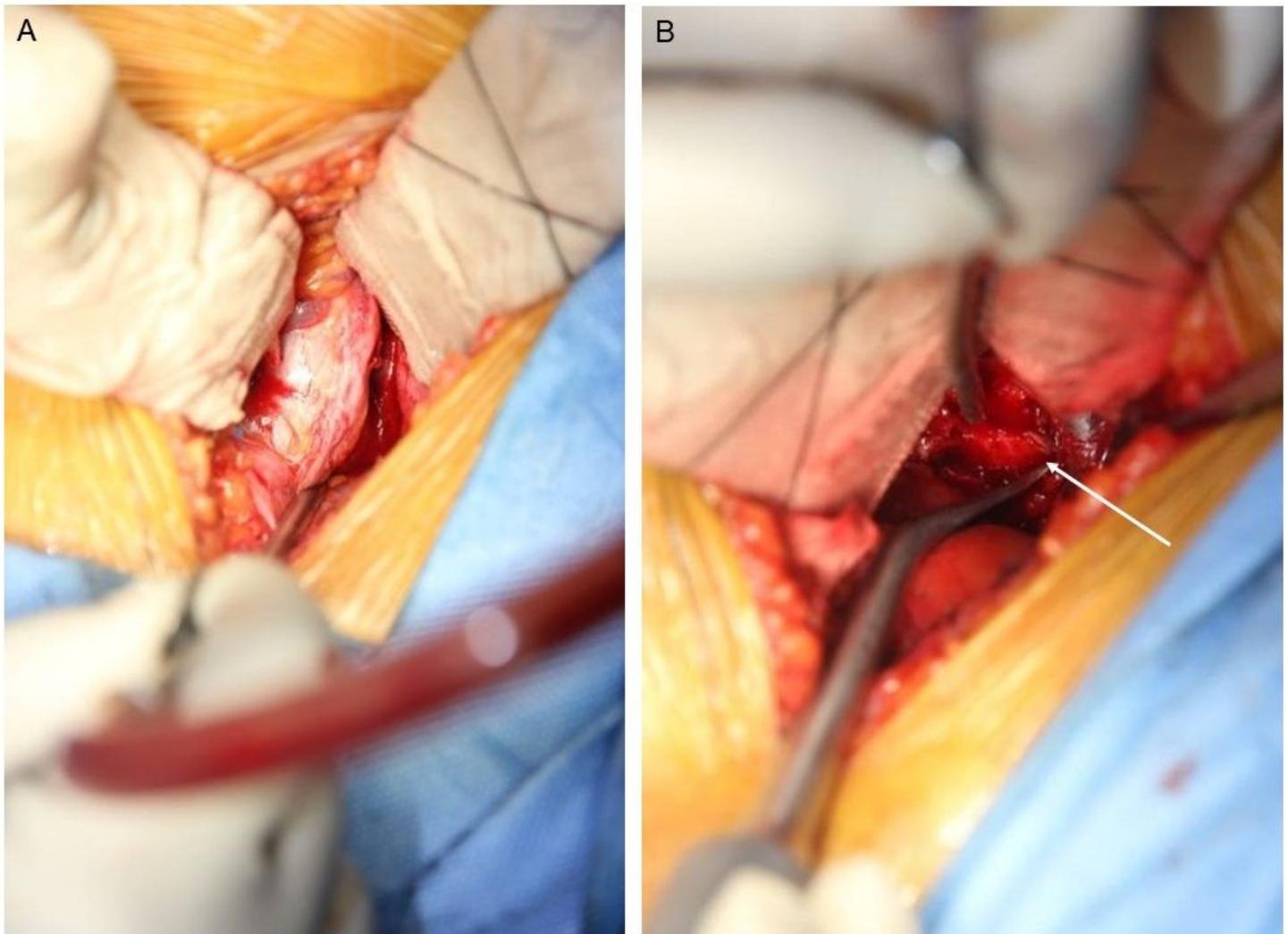


Figure 1

A: Exposed L5-S1 region through the space between left and right common iliac artery. B: Granulation tissue, sequestra, abscess and residual intervertebral discs were removed under direct vision. A tricortical iliac bone graft (arrow) was implanted into the L5-S1 intervertebral space without additional fixation.

Figure 2 is available in the Supplemental Files section

Figure 2

A 51-year-old man with L5-S1 vertebral tuberculosis complicated by paraspinal and intraspinal abscess formation. Preoperative radiographs (A,B),CT(C,D) and MRI(E,F,G) showed bony destruction from the L5 to S1 vertebrae. Radiographs (H,I)at the final follow-up showed no correction loss of lumbosacral angle. CT showed accurate screw placement(J,K) and bony union(L,M,N) was achieved at L5-S1.

Supplementary Files

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