OPERATIVE TECHNIQUE

Full-Endoscopic Transforaminal Debridement and Decompression for Brucellar Thoracic Spinal Epidural Abscess: A Minimally Invasive Alternative to Open Surgery

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Objective: Thoracic spinal epidural abscess (SEA) is a rare but dangerous condition, and traditional surgical methods are accompanied by extensive trauma and approach-related complications. Here we introduce the technique of full-endoscopic transforaminal debridement and decompression and evaluate its feasibility for treating brucellar thoracic SEA.

Methods: We performed thoracic full-endoscopic transforaminal decompression and debridement on two patients with neurological deficits caused by brucellar SEA, which is mainly composed of granulation tissue rather than pus. Postoperative MRI was conducted to confirm the presence of any residual abscess compressing the nerves. Frankel grading was employed to assess the recovery of neurological function, and complications were documented.

Results: There were no occurrences of dural tear, postoperative hematoma, or pulmonary complications. Their neurological function had significantly improved after surgery, and postoperative MRI confirmed no residual abscess compressing the spinal cord. During the 2-year follow-up, one patient achieved complete recovery (from Frankel-C to Frankel-E), while another patient improved from Frankel-A to Frankel-D. Neither patient experienced infection recurrence, instability, nor kyphotic deformity.

Conclusion: We described the novel application of transforaminal endoscopic surgery in brucellar thoracic granulomatous SEA and preliminarily indicated the feasibility of this technique as a minimally invasive alternative to open surgery.

Key words: Endoscopic Spine Surgery; Minimally Invasive Surgery; Spinal Brucellosis; Spinal Epidural Abscess

Introduction

Brucellosis, a zoonotic disease caused by brucella bacteria, is a public health problem in many developing countries.[1,2] The primary therapeutic modality for spinal brucellosis involves the concurrent administration of antibiotics, although the optimal combination of antimicrobials and the duration of treatment remain indeterminate.[1,3–5] Brucella-induced thoracic epidural abscesses are rare but dangerous conditions, necessitating prompt surgical intervention.[6] Due to the narrow thoracic spinal canal, the compression primarily affects the fragile spinal cord rather than the cauda equina and blood supply to the thoracic region, thoracic spine surgery faces greater challenges and is associated with poorer prognoses.[7] Additionally, brucellar epidural masses frequently consist predominantly of infectious granulation tissue rather than pus. The robust granulation tissue poses challenges for thorough debridement and is acknowledged as a significant predictor of residual or recurrent spinal epidural abscess (SEA).[7,8]

Traditional surgical options for thoracic SEA, especially procedures targeting the ventral aspect of the spinal

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cord, such as the transpedicular approach and extrapleural approach, may require extensive musculoskeletal trauma, accompanied by longer recovery time and higher complication rates.[9,10] The complication rate of anterior thoracic surgery has been reported to be between 10% and 50%, including major vascular and nerve injuries, pulmonary collapse, and empyema.[11,12] On the contrary, endoscopic spinal surgery (ESS), although most commonly used for lumbar degenerative pathology, provides a minimally invasive option to access the disc space and anterior epidural space, making this approach appealing for treating thoracic spondylodiscitis.[13–16] However, there are few reports on ESS for thoracic SEA. Here we introduce the technique of full-endoscopic transforaminal debridement and decompression for brucellar thoracic SEA (mainly composed of granulation tissue) and present two typical cases. The purpose of this study is to explore the feasibility of this minimally invasive endoscopic technique as an alternative to traditional debridement and decompression surgery for the treatment of SEA.

Surgical Technique

Anesthesia and Position

The surgery can be performed under general anesthesia or local anesthesia with conscious sedation. The following describes the surgical technique under local anesthesia. The patient was placed on the operating table in a prone position. Dexmedetomidine hydrochloride was pumped intravenously to keep the patient lightly to moderately sedated.

Working Portal Establishment

Before disinfection, we located and marked the target level and puncture trajectory through fluoroscopy. The puncture trajectory was planned on the axial MRI preoperatively (Figure 1A). We injected local anesthetic (mixture of 0.5% lidocaine and 0.25% ropivacaine) into the deep fascia and peri-foraminal area, and inserted an 18G spinal needle targeting the lateral aspect of the articular process under fluoroscopic guidance. After making an 8 mm skin incision, a dilator with a blunt tip was advanced to the extraforaminal area. The working cannula and endoscopic system (SPINENDOS GmbH, Munich, Germany) were then introduced (Figure 1B,C).

Visualized Foraminoplasty and Partial Laminectomy

Bipolar electrocoagulation was used to expose bone anatomical structures (Figure 2A). Under the endoscopic vision, foraminoplasty and partial laminectomy were performed using visualized trephine and high-speed burr (Figure 2B). Part of the facet joint, the upper edge of the pedicle and transverse process, and part of the lamina were excised as needed. For the upper and middle thoracic spine, rib head resection may be required due to the partial coverage of disc space. The bony structures should be adequately removed to achieve sufficient exposure of the extradural space and flexibility of instruments. The combined use of an endoscopic visual ring saw and a high-speed burr allows efficient and safe decompression of bony structures.

Debridement and Decompression

After removing the ligamentum flavum, the working cannula was placed into the spinal canal gently, and a large amount of inflammatory granulation tissue was flooding the endoscopic view. Careful exploration revealed that the dural sac was severely compressed by proliferating granulomatous tissue (Figure 3A). Brucellar epidural masses are mainly composed of granulation tissue. The interior of the granuloma may be compartmentalized, with not a substantial amount of pus, and some lesions may lack pus. Then we gently dissected and removed the granulation tissue with a nerve hook and grasping forceps (Figure 3B). Care should be taken to prevent tearing the dura, as epidural adhesion may be present. When removing granulation tissue near the dura mater, gentle manipulation is crucial. Begin by using a nerve hook to separate the granulation tissue from the dura mater. Before using tools like nucleus forceps to grasp the granulation tissue, ensure that the connection between the granulation tissue and the dural sac has completely loosened

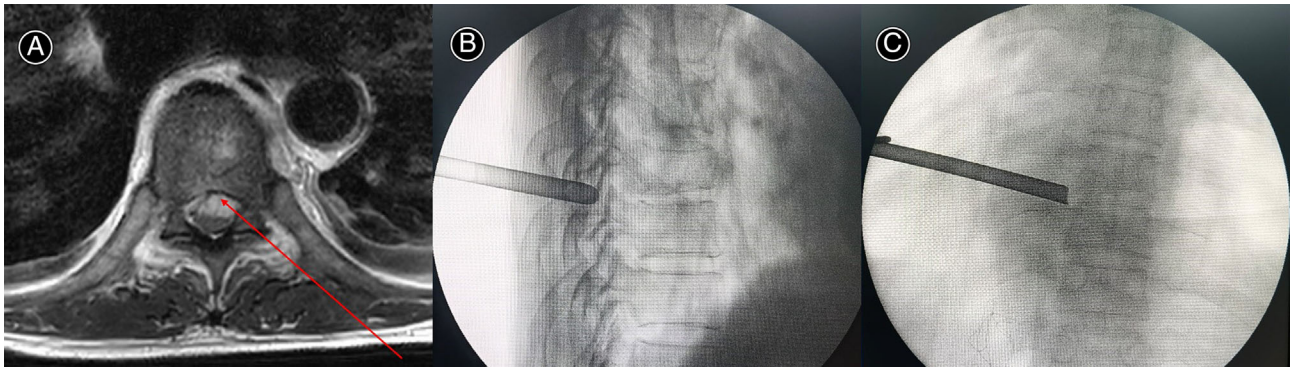

FIGURE 1 (A) The puncture trajectory (arrow) is measured on preoperative MRI axial view. (B, C) Intraoperative fluoroscopy confirms that the tip of the working cannula is touching the lateral border of the facet joint.

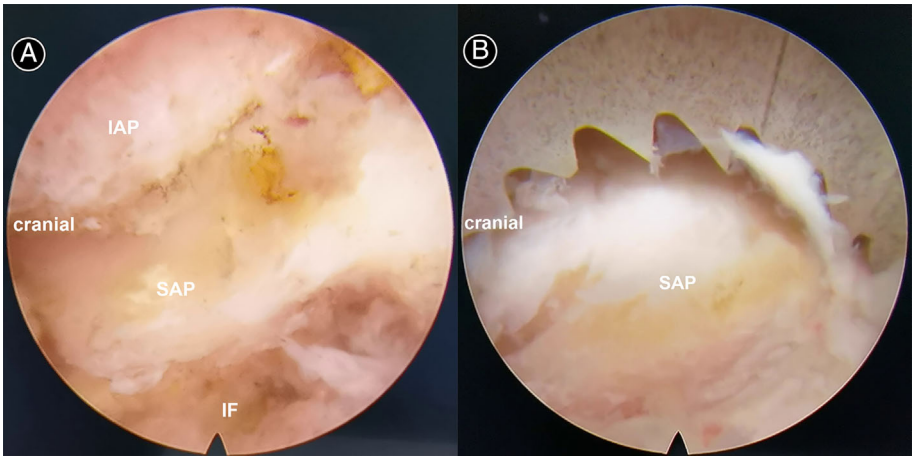

FIGURE 2 (A) The bony anatomy is exposed after soft tissue dissection. (B) Part of the superior articular process is resected under direct vision using a visualized trephine. IAP, inferior articular process; IF, intervertebral foramen; SAP, superior articular process.

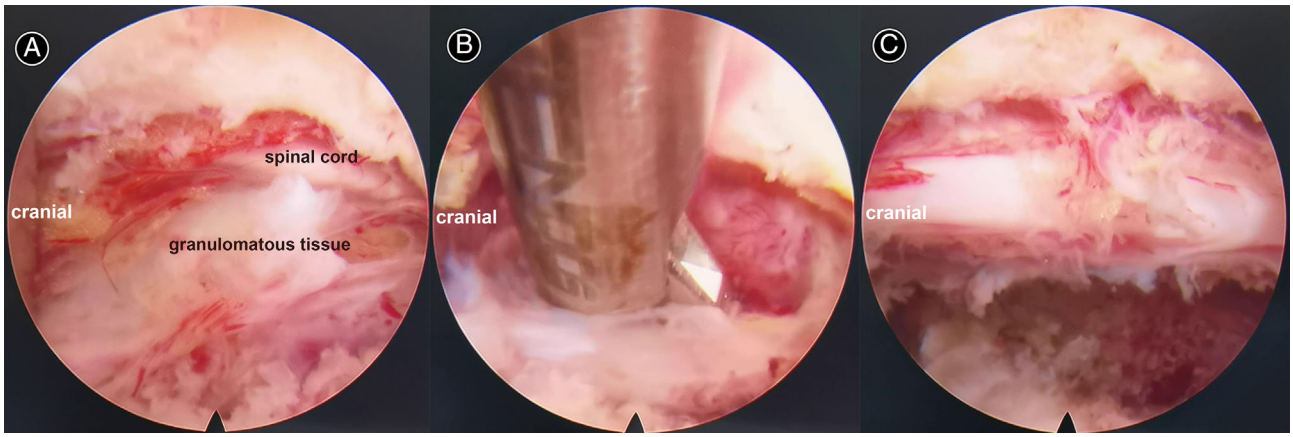

FIGURE 3 (A) The spinal cord is compressed by granulomatous tissue in the epidural space. (B) Excision of granulation tissue using endoscopic grasping forceps. (C) The pulsating dura mater floats freely in the irrigation solution after decompression.

to prevent dural tearing. Patient's feedback can help identify and protect nerves and dura mater. The standard for sufficient decompression is that the dural sac is not compressed, especially with no deformation or indentation at the proximal and distal ends, and the dural sac restores autonomous pulsation and fluctuates with water pressure (Figure 3C). Finally, a drainage tube with negative pressure was placed through the working portal. The excised tissues were subjected to microbial culture and pathological examination.

Illustrative Cases

The review and reporting of the two cases were approved by the institutional ethics committee (KYCS2023440) and with the consent of the patients themselves.

Case 1

A 50-year-old shepherd presented at a local hospital with symptoms of back pain, fever, and night sweats. A Rose Bengal test and a serum agglutination test (SAT) with a titer of 1/160 yielded a diagnosis of brucellosis. The patient commenced a three-week antibiotic regimen, comprising 200 mg/day of oral doxycycline and 600 mg/day of rifampicin, which alleviated the fever. Subsequently, however, the patient developed difficulties with walking and urination. Magnetic resonance imaging (MRI) revealed a T6-7 spinal cord compression caused by a hyperintense epidural mass (Figure 4A,B). He was subsequently transferred to our hospital for advanced management.

Neurological examination revealed hypoesthesia below the costal margin, 2/5 muscle strength in both lower extremities, and weak contractility of the anal sphincter. His neurological status was assessed as C-grade using the Frankel grading system.[10] Computed tomography (CT) showed no osteolysis or deformity. On laboratory tests, his peripheral white cell count was normal, C-reactive protein (CRP) was 25 mg/L, and erythrocyte sedimentation rate (ESR) was 48 mm/h. We urgently performed endoscopic debridement and decompression via a transforaminal approach for him. Endoscopic exploration revealed severe compression of the spinal cord by a mass

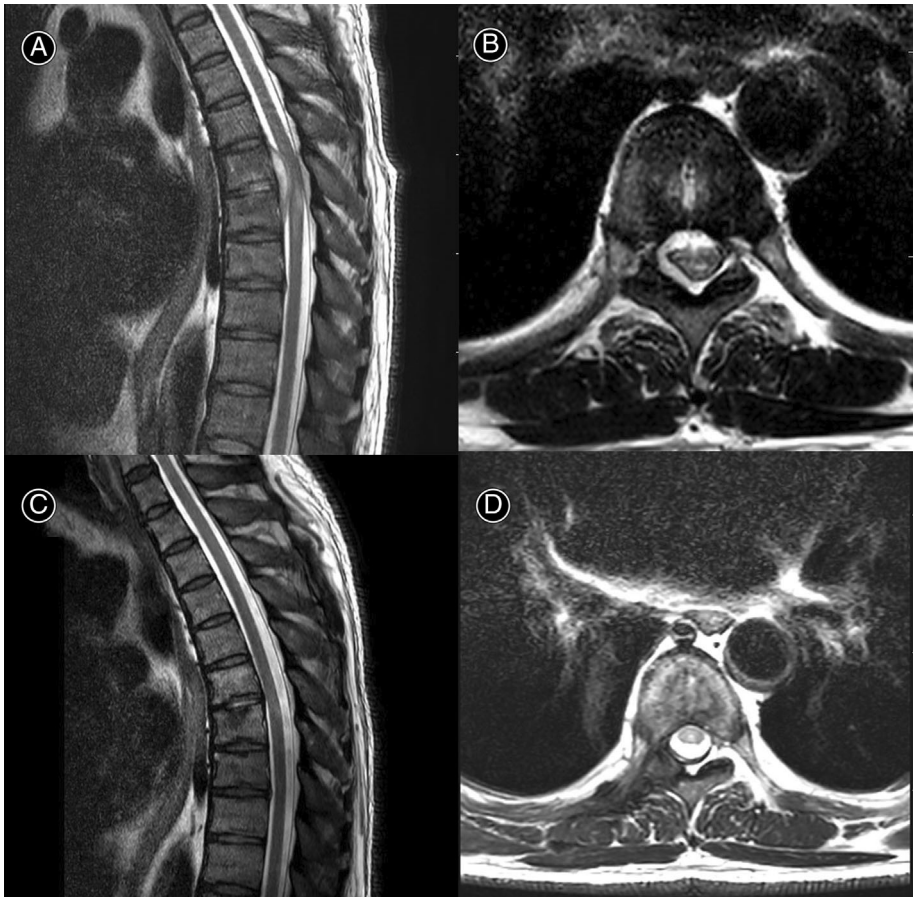

FIGURE 4 Case 1: (A, B) Preoperative T2-weighted MRI showing a hyper-signal epidural mass with spinal cord compression at the T6-7 level. (C, D) Postoperative 1-month MRI confirming the disappearance of the epidural abscess.

encompassing resilient infective granulation tissue and a minimal quantity of purulent fluid. He continued with 3 months of drug therapy after surgery. No pathogenic microorganisms were isolated from the specimen culture. Pathological examination showed proliferative noncaseous granulation tissue infiltrated by lymphocytes.

The muscle strength of lower limbs increased to grade 4 immediately after the surgery. Postoperative 1-month MRI confirmed the disappearance of the epidural abscess (Figure 4C,D). Outpatient examination at postoperative 3 months showed complete neurological recovery (Frankel-E). Until the last follow-up (26 months), no infection recurrence, residual back pain, spinal instability, and kyphosis were observed.

Case 2

A 57-year-old female farmer presented at a local hospital one month ago with fever and back pain. Her recent consumption of fresh dairy products was noted. Serological testing returned a positive result, with a serum agglutination test (SAT) titer of 1:320, confirming a diagnosis of brucellosis. She was prescribed a course of antibiotics, consisting of oral doxycycline (200 mg/day) and rifampicin (600 mg/day). Approximately one week ago, she began to experience progressively worsening motor weakness and urinary incontinence. Magnetic resonance imaging (MRI) revealed an anterior epidural abscess causing spinal cord compression at the T8/9 level (Figure 5A,B). Consequently, she was urgently transferred to our hospital for further treatment.

Neurological examination revealed paraplegia below the inguinal level (Frankel-A). Laboratory tests showed hypoproteinemia (29 g/L), elevated ESR (60 mm/h), and CRP (120 mg/dL). She underwent urgent full-endoscopic debridement and decompression. Following the operation, she continued to receive antibiotic treatment for 3 months. No pathogenic bacteria were found in sample culture. Pathological examination showed proliferative granulation tissue infiltrated by inflammatory cells.

One week after surgery, she was able to control urination autonomously. The strength of some lower limb muscles recovered to grade 2, and she could move her legs horizontally on the bed. One month after surgery, the follow-up MRI showed no residual epidural mass compressing the spinal cord (Figure 5C,D). The patient could ambulate with a walker at postoperative 3 months. One year after surgery, her neurological status was rated as Frankel-D. There was no kyphosis, spinal instability, or residual back pain during the follow-up (24 months).

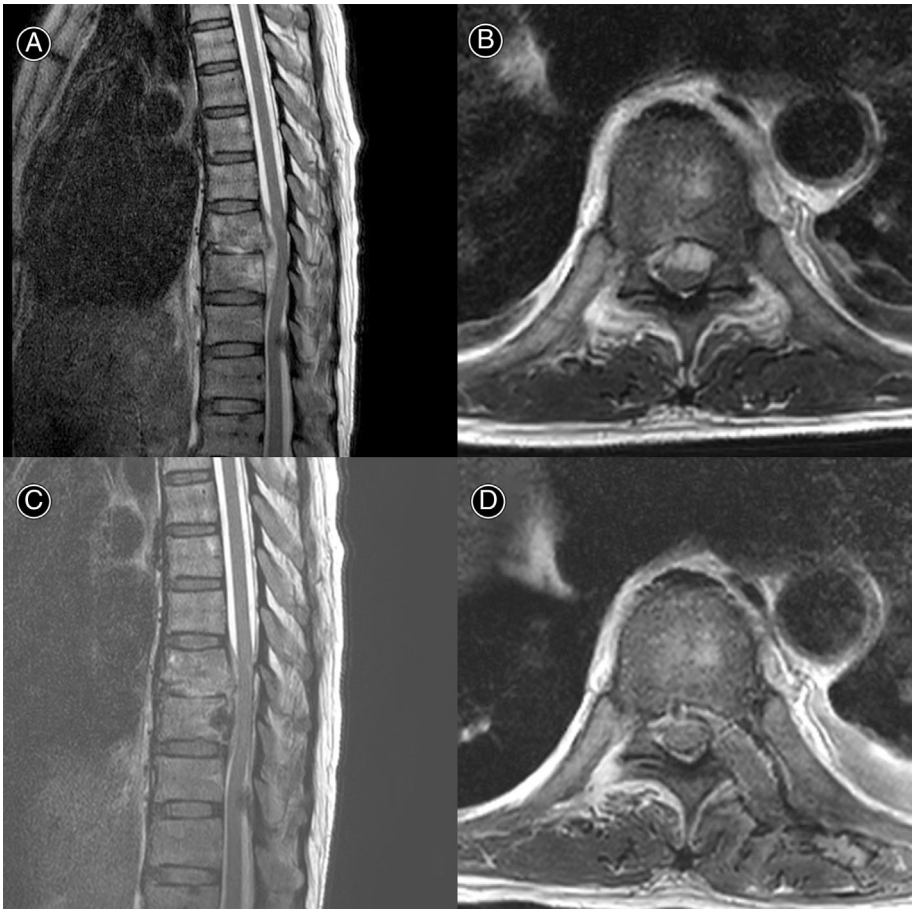

FIGURE 5 Case 2: (A, B) Preoperative T2-weighted MRI showing an anterior epidural abscess with spinal cord compression at the T8-9 level. (C, D) Postoperative 1-month MRI showed no residual epidural abscess compressing the spinal cord.

Discussion

Due to the favorable response of Brucella species to antibiotics, several cases of Brucella-related SEA successfully treated with pharmacotherapy have been documented in the literature.[17–19] The authors contend that patients with intact neurological functions should receive systemic antibiotic therapy under close monitoring. It is imperative to recognize that some patients might experience sudden neurological impairments during pharmacological treatment, as exemplified by the two cases reported herein. Once neurological deficits occur, surgical intervention should be performed at the earliest opportunity, because early decompression is associated with more favorable outcomes.[20–23] The treatment of spinal brucellosis has a relatively high failure rate.[24] It is essential to continue a 3-month course of medication post-surgery in order to prevent the recurrence of infection or transition to a chronic state.

Laminectomy is the most common procedure for managing thoracic SEA. However, it carries the risk of post-operative instability and kyphotic deformity, necessitating supplementary internal fixation. Biomechanical studies have indicated that even without evident anterior column damage, laminectomy significantly reduces stability. The inter-laminar fenestration offers a more limited approach, minimizing its impact on stability. More importantly, it proves challenging to expose and eradicate the ventrally located lesions via the posterior approach, due to the unfeasibility of mobilizing the thoracic dural sac. Intraoperative ultrasonography has been employed as an imaging modality in spine surgery.[7,25] The absence of the subarachnoid space near the epidural collection and the missing spinal cord pulsation under ultrasound indicates incomplete decompression. Nevertheless, the efficacy of ultrasonography in imaging ventral lesions remains constrained. Löhr observed that, despite the utilization of intraoperative ultrasonography, 22.2% of patients necessitated subsequent surgeries due to residual abscesses.[7]

Anterior approach enables direct access to the lesion, thorough debridement, decompression, and curvature reconstruction, representing the most effective method for spondylitis. However, considering the longer surgical time, increased blood loss, and higher incidence of complications, this method may be excessively aggressive for Brucella SEA, which often does not involve severe vertebral destruction or instability, unlike spinal tuberculosis.[26–28] In addition, the patients in poor condition may be forced to undergo delayed decompression or conservative treatment due to difficulty tolerating these major spinal surgeries.

Some minimally invasive attempts to treat epidural abscesses have been described in the literature. Ran[29] and Akbik[30] respectively reported CT-guided and endoscopic percutaneous drainage in the treatment of extensive suppurative SEA with satisfactory results. However, solid abscesses, which is consisted primarily of granulation tissue rather than pus, are generally considered contraindications to this procedure.

Much evidence suggests that endoscopic surgery is a reliable alternative for treating spondylodiscitis.[14–16] Nevertheless, to our knowledge, there are no reports on endoscopic management of Brucella thoracic epidural abscesses. Here, we introduce the surgical technique of transforaminal full-endoscopic treatment of Brucella SEA in the thoracic spine. We believe that for patients with symptoms of myelopathy or radiculopathy caused by thoracic SEA, regardless of the severity of neurological impairment, as long as there are no signs of instability, attempts can be made to perform debridement and decompression under endoscopy. The transforaminal approach is particularly suitable for cases where the lesion is located on the ventral and lateral sides of the spinal cord. The favorable outcomes of our two cases demonstrate the feasibility of this technique as an alternative to traditional open surgery. Compared to traditional surgical methods, this technique has the following advantages. Firstly, the lesion located ventrally can be directly accessed via a transforaminal approach, reducing the trauma and risk of anterior approach surgery. Secondly, debridement and decompression can be performed under high-definition magnification within the endoscopic field of view. Thirdly, it maximally reduces iatrogenic injuries and lowers the risk of route-related complications. Moreover, patients under local anesthesia can provide real-time feedback, which can reduce the risk of nerve injury and obviate the side effects of general anesthesia, such as postoperative nausea, vomiting, and delirium.

There are some tips about this technique. Firstly, determining the anesthesia method for surgery should take into consideration the corresponding advantages and disadvantages. Local anesthesia is more suitable for patients with multiple comorbidities and poor surgical candidacy. Patients under local anesthesia can offer real-time feedback, mitigating the risk of nerve injury and avoiding the side effects associated with general anesthesia, such as postoperative nausea, vomiting, and delirium. However, patients may report intense pain during proximal exploration due to irritation of the intercostal nerve. Similar situations may also occur during the removal of granulation tissue adhered to the surface of the dura mater. On the contrary, general anesthesia can provide intraoperative controlled hypotension to reduce bleeding during endoscopy, a smoother surgical process, and a better experience for both surgeons and patients. Secondly, thoracic ESS is prone to segmental errors, so precise localization is crucial. For beginners unfamiliar with the anatomical structures under thoracic endoscopy, there might be a situation of losing direction. In such cases, repositioning through fluoroscopy is necessary to clarify the precise instrument position. Additionally, it should be noted that granulation tissue may be covered by a pseudocapsule, which may be mistakenly thought to be the dura mater. In such cases, careful identification should be made with a nerve hook. Under endoscopic view, the granulation tissue appears deep red, but there is minimal bleeding when removing the granulation tissue. Once the dura mater is torn, infection may spread to the central nervous system, resulting in severe consequences. Therefore, the use of forceps to tear granulation tissue should be approached with caution until the separation between the dura mater and the lesion is confirmed with a nerve hook.

We recommend routine postoperative MRI follow-up. If there is poor neurological improvement and MRI shows residual or recurrent nerve compression, additional minimally invasive or open surgery may be inevitable. Fortunately, we observed improvement of neurological symptoms in the early postoperative period in our cases. Nerve decompression on MRI and the recovery of patients' neurological function indicate the feasibility of endoscopic decompression treatment for SEA with severe neurological impairment. It should be recognized that this technique is not applicable to cases with signs of instability, such as severe bone destruction and kyphosis. Anterior column reconstruction and rigid fixation are required to reconstruct stability at this point.[9,27,31] However, spinal brucellosis is a relatively less destructive process with significantly lower instability and deformity incidence than pyogenic spondylodiscitis and spinal tuberculosis.[6,32] In spinal brucellosis, bone healing commences nearly concurrently with the inflammatory process and frequently leads to the formation of anterior bony protuberances and sclerosis. The vertebral bodies can maintain integrity throughout the entire course. Typically, in chronic Brucella spondylitis, the spine stabilizes through sclerosis and osseous ankylosis, with rare occurrences of vertebral collapse, angular deformities, or spinal convexity. In addition, if the abscess is located on the dorsal side of the spinal cord, an interlaminar approach may be a better choice. The efficacy and safety of ESS for SEA need to be further evaluated in prospective comparative studies with large sample sizes and long-term follow-up.

Conclusion

We described the novel application of transforaminal endoscopic surgery in brucellar thoracic granulomatous SEA and preliminarily indicated the feasibility of this technique as a minimally invasive alternative to open surgery.

Conflict of Interest Statement

The authors declare that there are no conflicts of interest.

Ethics Statement

All procedures performed in the study were in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The review

and reporting of the two cases were approved by the institutional ethics committee and with the consent of the patients themselves.

Author Contributions

Conceptualization: Da Liu, Tong Wu. Investigation: Tong Wu, Fan-he Meng, Jing-han Lu. Methodology: Da Liu, Zheng Fan. Writing – Original Draft: Tong Wu. Writing – Review & Editing: Da Liu, Tong Wu, Zheng Fan, Fan-he Meng, Jing-han Lu.

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Consent to Publish

The participants have consented to the submission of the case report to the journal.

References

1. Franco MP, Mulder M, Gilman RH, Smits HL. Human brucellosis. Lancet Infect Dis. 2007;7(12):775–86.
2. Tali ET, Koc AM, Oner AY. Spinal brucellosis. Neuroimaging Clin N Am. 2015; 25(2):233–45.
3. Chelli Bouaziz M, Ladeb MF, Chakroun M, Chaabane S. Spinal brucellosis: a review. Skeletal Radiol. 2008;37(9):785–90.
4. Tekkök IH, Berker M, Ozcan OE, Ozgen T, Akalin E. Brucellosis of the spine. Neurosurgery. 1993;33(5):838–44.
5. Ulu-Kilic A, Karakas A, Erdem H, Turker T, Inal AS, Ak O, et al. Update on treatment options for spinal brucellosis. Clin Microbiol Infect. 2014;20(2): 075–82.
6. Erdem H, Elaldi N, Batirel A, Aliyu S, Sengoz G, Pehlivanoglu F, et al. Comparison of brucellar and tuberculous spondylodiscitis patients: results of the multicenter "Backbone-1 study". Spine J. 2015;15(12):2509–17.
7. Löhr M, Reithmeier T, Ernestus RI, Ebel H, Klug N. Spinal epidural abscess: prognostic factors and comparison of different surgical treatment strategies. Acta Neurochir. 2005;147(2):159–66. discussion 66.
8. Rammeh S, Romdhane E, Riahi H, Chebbi Y, Bouaziz MC, Achour W, et al. Granulomatous spondylodiscitis: a case series with focus on histopathological features. J Spinal Cord Med. 2021;44(2):282–7.
9. Schwab JH, Shah AA. Spinal epidural abscess: diagnosis, management, and outcomes. J Am Acad Orthop Surg. 2020;28(21):e929–38.
10. Yao YC, Lin HH, Chou PH, Wang ST, Liu CL, Chang MC. Risk factors for residual neurologic deficits after surgical treatment for epidural abscess in the thoracic or lumbar spine. Spine J. 2020;20(10):1638–45.
11. Cheung KM, Al GS. Approach-related complications of open versus thoracoscopic anterior exposures of the thoracic spine. J Orthop Surg-Hong k. 2008;16(3):343–7.
12. Faciszewski T, Winter RB, Lonstein JE, Denis F, Johnson L. The surgical and medical perioperative complications of anterior spinal fusion surgery in the thoracic and lumbar spine in adults. A review of 1223 procedures. Spine. 1995; 20(14):1592–9.
13. Abreu PGP, Lourenço JA, Romero C, Almeida GND, Pappamikail L, Lopes MF, et al. Endoscopic treatment of spondylodiscitis: systematic review. Eur Spine J. 2022;31(7):1765–74.
14. Lin CY, Chang CC, Chen YJ, Tsai CH, Tsou HK, Lin CS, et al. New strategy for minimally invasive endoscopic surgery to treat infectious spondylodiscitis in the thoracolumbar spine. Pain Physician. 2019;22(3):281–93.
15. Pawar A, Manwani C, Thete R, Bapat M, Peshettiwar V, Gore S. Endoscopic decompression can be effective for diagnosing and treating tubercular spondylodiskitis with early epidural spinal compression: a retrospective study of 18 cases. Asian Spine J. 2018;12(5):803–9.
16. Yamada K, Takahata M, Nagahama K, Iwata A, Endo T, Fujita R, et al. Posterolateral full-endoscopic debridement and irrigation is effective in treating thoraco-lumbar pyogenic spondylodiscitis, except in cases with large abscess cavities. Eur Spine J. 2023;32(3):859–66.
17. Köse Ş, Senger SS, Çavdar G, Yavaş S. Case report on the development of a brucellosis-related epidural abscess. J Infect Dev Ctries. 2011;5(5):403–5.
18. Akpinar O, Guzel M. Spinal stenosis caused by epidural and paraspinal abscess due to brucella infection. J Pak Med Assoc. 2020;70(7):1275–8.
19. Güzey FK, Emel E, Sel B, Bas NS, Ozkan N, Karabulut C, et al. Cervical spinal brucellosis causing epidural and prevertebral abscesses and spinal cord compression: a case report. Spine J. 2007;7(2):240–4.
20. Alton TB, Patel AR, Bransford RJ, Bellabarba C, Lee MJ, Chapman JR. Is there a difference in neurologic outcome in medical versus early operative management of cervical epidural abscesses? Spine J. 2015;15(1):10–7.
21. Pitaro NL, Tang JE, Arvind V, Cho BH, Geng EA, Amakiri UO, et al. Readmission and associated factors in surgical versus non-surgical management of spinal epidural abscess: a Nationwide readmissions database analysis. Global Spine J. 2023;13(6):1533–40.
22. Stratton A, Gustafson K, Thomas K, James MT. Incidence and risk factors for failed medical management of spinal epidural abscess: a systematic review and meta-analysis. J Neurosurg. 2017;26(1):81–9.
23. Darouiche RO. Current concepts: spinal epidural abscess. N Engl J Med. 2006;355(19):2012–20.
24. Alp E, Doganay M. Current therapeutic strategy in spinal brucellosis. Int J Infect Dis. 2008;12(6):573–7.
25. Wang Y-q, Liu X-g, Jiang L, Jiang L, Wei F, Yu M, et al. Intraoperative ultrasonography in "cave-in" 360° circumferential decompression for thoracic spinal stenosis. Chin Med J (Engl). 2011;124(23):3879–85.
26. Nakase H, Matsuda R, Tamaki R, Tei R, Park YS, Sakaki T. Two-stage management for vertebral osteomyelitis and epidural abscess: technical note. Neurosurgery. 2006;58(6):E1219.
27. Duarte RM, Vaccaro AR. Spinal infection: state of the art and management algorithm. Eur Spine J. 2013;22(12):2787–99.
28. Lener S, Hartmann S, Barbagallo GMV, Certo F, Thomé C, Tschugg A. Management of spinal infection: a review of the literature. Acta Neurochir. 2018; 160(3):487–96.
29. Ran B, Chen X, Zhong Q, Fu M, Wei J. CT-guided minimally invasive treatment for an extensive spinal epidural abscess: a case report and literature review. Eur Spine J. 2018;27(Suppl 3):380–5.
30. Akbik OS, Shin PC. Endoscopic transforaminal drainage of a ventrally located thoracic epidural abscess. World Neurosurg. 2020;139:268–73.
31. Katonis P, Tzermiadianos M, Gikas A, Papagelopoulos P, Hadjipavlou A. Surgical treatment of spinal brucellosis. Clin Orthop Relat Res. 2006;444:66–72.
32. Liu X, Zheng M, Jiang Z, Wang G, Li T, Sun J, et al. Computed tomography imaging characteristics help to differentiate pyogenic spondylitis from brucellar spondylitis. Eur Spine J. 2020;29(7):1490–8.