Research Article

Spinal Tuberculosis With Neurological Deficit in Toddlers: Clinical Characteristics, Surgical Management, and Outcomes of Four Cases With Literature Review

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ABSTRACT

Background:
Spinal tuberculosis (TB) in very young children is uncommon but may cause extensive vertebral destruction, abscess formation, spinal deformity, and neurological impairment. Diagnosis may be challenging because clinical symptoms can be nonspecific and neurological assessment is often limited by age and cooperation. Literature describing spinal TB in children younger than 5 years remains limited. This study aimed to describe the clinical presentation, radiological findings, surgical management, and early neurological and functional outcomes of children with spinal TB and neurological impairment.
Methods:
A prospective case series was conducted involving children younger than 5 years diagnosed with spinal TB and presenting with lower-extremity paresis or paraplegia. Clinical, neurological, radiological, surgical, and functional outcomes were prospectively documented. All patients received antituberculous therapy and underwent surgical treatment for neurological impairment associated with extensive vertebral destruction and neural compression.
Results:
Four patients, comprising three girls and one boy, aged 2 years 4 months to 2 years 6 months, were included. All presented with progressively enlarging lumbar or paravertebral swelling and destructive spinal lesions with large intracanal abscesses. The involved levels ranged from T12–L1 to L2–L3. Neurological presentation ranged from refusal to walk with preserved spontaneous lower-extremity movement to complete loss of voluntary lower-extremity movement with spasticity. Surgical management was individualized according to disease extent and location. Three patients underwent anterior approaches with debridement and structural reconstruction, while one underwent posterior decompression and fusion with anterior bone graft reconstruction and extensive abscess evacuation. All patients demonstrated neurological improvement. Independent walking was achieved within six weeks to 2.5 months after surgery.
Conclusion:
Spinal TB in children younger than 5 years may present with extensive vertebral destruction, large intracanal and paravertebral abscesses, and severe neurological impairment. Despite severe preoperative deficits, neurological and functional recovery was observed following surgical decompression, debridement, reconstruction, and antituberculous therapy. Early recognition of changes in walking ability and lower-extremity function is important in toddlers. Surgical treatment should be individualized according to neurological status, neural compression, vertebral destruction, and spinal stability, with long-term follow-up because of the risk of growth-related spinal deformity.

Keywords: spinal tuberculosis; pediatric tuberculosis; tuberculous spondylitis; toddler; paraparesis; paraplegia; paravertebral abscess; spinal cord compression; spinal reconstruction.

INTRODUCTION

Tuberculosis (TB) is an ancient infectious disease with diverse clinical manifestations and remains a major global health problem. Although pulmonary disease represents the most common manifestation, TB may involve multiple organ systems, including the central nervous system, lymphatic system, and musculoskeletal system. Diagnosis in children is particularly challenging because of their variable and often nonspecific clinical presentation, which may mimic other common pediatric illnesses. According to the World Health Organization (WHO) Global Tuberculosis Report 2023, an estimated 1.3 million children younger than 15 years developed TB globally in 2022, with 214,000 deaths. However, the most recent data from the WHO Global Tuberculosis Report 2025 show a decline, with an estimated 1.2 million children and young adolescents (aged <15 years) developing TB in 2024, accounting for 11% of all incident cases. Deaths also decreased to approximately 174,000, representing 14.2% of all TB deaths. Despite this encouraging downward trend, the 2025 report highlighted that

43% of children with TB were missed for diagnosis and could not access treatment, underscoring the persistent challenges in pediatric TB care [1,2,3].

Children have historically contributed relatively little to TB transmission because they are less likely than adults to develop infectious pulmonary disease. Nevertheless, childhood TB represents an important component of the global TB burden, and substantial gaps remain in the identification, diagnosis, and treatment of children with TB infection and disease. Children younger than 5 years are particularly vulnerable to progression from TB infection to active disease and are more likely to develop severe forms of TB than older children [2,4]. Difficulties in obtaining adequate specimens, the paucibacillary nature of childhood TB, and nonspecific clinical manifestations further contribute to delayed diagnosis [2,4].

Spinal tuberculosis, or tuberculous spondylitis, is one of the most serious forms of musculoskeletal TB. Although spinal involvement accounts for a relatively small proportion of all TB cases, it may result in substantial vertebral destruction, spinal deformity, instability, and neurological impairment [5,6]. Pediatric spinal tuberculosis presents additional challenges because the vertebral column is still developing and the disease may produce rapid bone destruction and progressive deformity. Furthermore, kyphotic deformity may continue to progress during spinal growth even after the infection has become clinically inactive, necessitating prolonged clinical and radiological follow-up through skeletal maturity [7,8].

Paravertebral and epidural abscess formation is a characteristic feature of spinal TB and may extend into the spinal canal, paravertebral tissues, or psoas muscles. Neurological impairment may result from direct neural compression by abscess, inflammatory granulation tissue, vertebral collapse, sequestrated bone, or progressive kyphotic deformity [5,6]. Although paravertebral abscess formation is relatively common in spinal TB, extensive abscess formation associated with significant neurological deficits in very young children is uncommon and represents a particular diagnostic and therapeutic challenge.

Management of pediatric spinal TB requires simultaneous consideration of infection control, neurological preservation, spinal stability, and the long-term consequences of vertebral destruction. Antituberculous chemotherapy remains the cornerstone of treatment, whereas surgical intervention is generally considered in the presence of progressive or severe neurological deficit, significant neural compression, spinal instability, extensive vertebral destruction, progressive deformity, or selected symptomatic abscesses [5,8]. Several surgical approaches and reconstruction techniques have been described, including anterior, posterior, and combined approaches, with the choice influenced by the location and extent of disease, neurological status, spinal stability, and surgeon expertise [7,9,10].

Despite the clinical importance of pediatric spinal TB, literature specifically addressing children younger than 5 years with severe spinal disease remains limited. In particular, there is a paucity of reports describing very young children presenting with destructive spinal TB, extensive intracanal or paravertebral abscess formation, and neurological impairment [11]. The present prospective case series describes four children younger than 5 years with spinal tuberculosis associated with neurological deficits and extensive abscess formation. We aimed to describe their clinical and radiological presentations, surgical management strategies, and early neurological and functional outcomes following treatment.

MATERIALS AND METHODS

This prospective case series was conducted to evaluate the clinical presentation, radiological characteristics, management, and outcomes of spinal tuberculosis in children younger than 5 years of age who presented with neurological deficits. Patients of either sex were eligible for inclusion if they had a clinical and radiological diagnosis of tuberculous spondylitis and presented with lower-extremity paresis or paraplegia. Patients with isolated spinal tuberculosis without neurological involvement, those older than 5 years, and those with an alternative diagnosis were excluded.

The current literature on pediatric spinal tuberculosis was reviewed, with particular attention to its clinical presentation, neurological complications, radiological characteristics, surgical management, and outcomes. The literature review was performed to provide a clinical context for the findings of the present case series and to compare the observed characteristics, treatment strategies, and neurological outcomes with those reported in previous pediatric cases.

All patients underwent a comprehensive clinical and neurological assessment at presentation. Neurological status was documented according to the degree of motor impairment, sensory involvement, and sphincter dysfunction, when present. Plain radiographs and magnetic resonance imaging (MRI) of the involved spinal segments were obtained to evaluate vertebral destruction, spinal alignment, paravertebral and epidural abscess formation, spinal canal compromise, and spinal cord involvement.

The diagnosis of spinal tuberculosis was established based on a combination of clinical and radiological findings, supported by microbiological and/or histopathological examination when available. All patients received standard antituberculous therapy according to the institutional pediatric tuberculosis protocol. Surgical treatment was considered based on the presence and severity of neurological deficits, spinal cord compression, extensive vertebral destruction, spinal instability, progressive deformity, and/or significant abscess formation. The surgical procedure was individualized according to the anatomical level, extent of disease, neurological status, and degree of spinal instability.

Patients were prospectively followed clinically and radiologically after treatment. Clinical outcomes included neurological recovery, ambulatory status, and persistence or resolution of neurological deficits. Radiological outcomes included resolution of abscess formation, progression or correction of spinal deformity, evidence of spinal fusion or healing, and implant-related complications when instrumentation was performed. Follow-up was continued until the most recent clinical and radiological assessment.

CASE PRESENTATIONS

Case 1

A 2.5-year-old girl was referred with a four-month history of a progressively enlarging lump over the lower back, which was first noticed by her mother. One month prior to admission, she developed progressive lower-extremity weakness and became unable to bear weight or walk independently. No reliable history of sensory disturbance or sphincter dysfunction could be obtained.

Neurological examination was challenging because of the patient's young age and limited cooperation. Nevertheless, a marked reduction in lower-extremity motor function was observed, particularly involving knee extension and ankle plantar flexion. The findings were consistent with significant lower-extremity motor impairment.

Radiographic evaluation demonstrated destructive changes involving the L1 and L2 vertebral bodies. Magnetic resonance imaging revealed extensive destruction of the L1–L2 vertebral segments associated with a large paravertebral and intracanal abscess extending from the T12 to L2 levels, resulting in significant spinal canal compromise.

Given the extensive vertebral destruction, large abscess formation, and progressive neurological deficit, surgical intervention was performed. A thoracophrenicolumbotomy approach was used to access the affected vertebral segments, followed by debridement of the infected and necrotic tissue. Reconstruction was performed using an inlay structural graft harvested from a rib. Postoperatively, the patient was managed with a thoracolumbosacral orthosis (TLSO) to provide additional spinal support during the healing period.

Following surgery and continuation of antituberculous therapy, the patient's lower-extremity motor function gradually improved. Progressive recovery of lower-extremity strength was observed during follow-up, and six weeks after surgery, she was able to stand and walk independently without assistance. The postoperative course was otherwise uneventful, with progressive clinical and functional recovery.

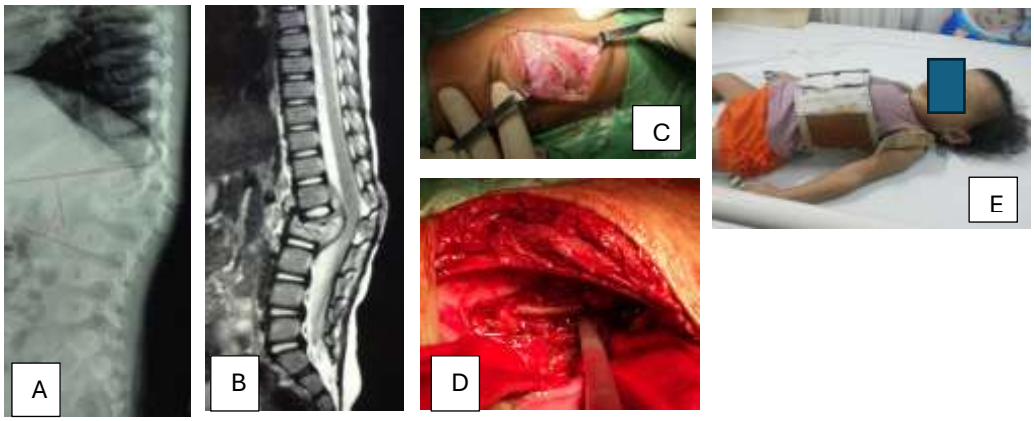


Figure 1. Clinical, radiological, and intraoperative findings of the patient.

A) Preoperative radiograph demonstrating marked L1–L2 vertebral body destruction. **(B)** Preoperative sagittal magnetic resonance imaging demonstrating extensive vertebral destruction with a large intracanal abscess extending from T12 to L2. **(C–D)** Intraoperative photographs demonstrating surgical exposure and debridement

of the involved spinal segments through a thoracophrenicolumbotomy approach, followed by inlay costal graft reconstruction. **(E)** Postoperative clinical photograph demonstrating the patient ambulating while wearing a thoracolumbosacral orthosis.

Case 2

A 2-year-4-month-old boy was referred with a six-month history of a progressively enlarging lump over the lower back, first noticed by his mother. Two months before admission, bilateral flank swellings developed, accompanied by progressive deterioration in his ability to walk independently. The family initially sought traditional medical treatment, and medical evaluation was delayed. One week before admission, the patient developed complete inability to move both lower extremities, prompting presentation to our hospital.

On neurological examination, there was marked impairment of motor function in both lower extremities, with no observable voluntary movement. Deep tendon reflexes at the knees and ankles were preserved, and the lower-extremity muscles demonstrated increased spastic tone, consistent with an upper motor neuron pattern of neurological impairment.

Preoperative imaging demonstrated severe destructive changes involving the thoracolumbar vertebral segment, particularly the T12–L1 levels. Magnetic resonance imaging revealed extensive vertebral destruction associated with a large paravertebral abscess with significant extension into the spinal canal. The inflammatory collection also extended bilaterally into the psoas muscles and surrounding paravertebral soft tissues, resulting in extensive spinal canal compromise and compression of the neural elements.

Because of the severe neurological deficit, extensive spinal destruction, and large epidural, paravertebral, and bilateral psoas abscesses, urgent surgical decompression and stabilization were performed. A posterior decompression and instrumented fusion were undertaken, followed by anterior debridement and packing of bone graft into the involved vertebral region. Approximately 400 mL of purulent material was evacuated from the infected vertebral region and the extensive bilateral psoas abscesses.

Postoperatively, the patient was managed with a thoracolumbosacral orthosis and continued antituberculous therapy. Remarkable early neurological improvement was observed following decompression. Voluntary movement of the toes and ankle was detected immediately after surgery, and knee extension became possible approximately one week postoperatively. The patient subsequently demonstrated progressive recovery of lower-extremity motor function during follow-up. Independent walking was achieved approximately 2.5 months after surgery.

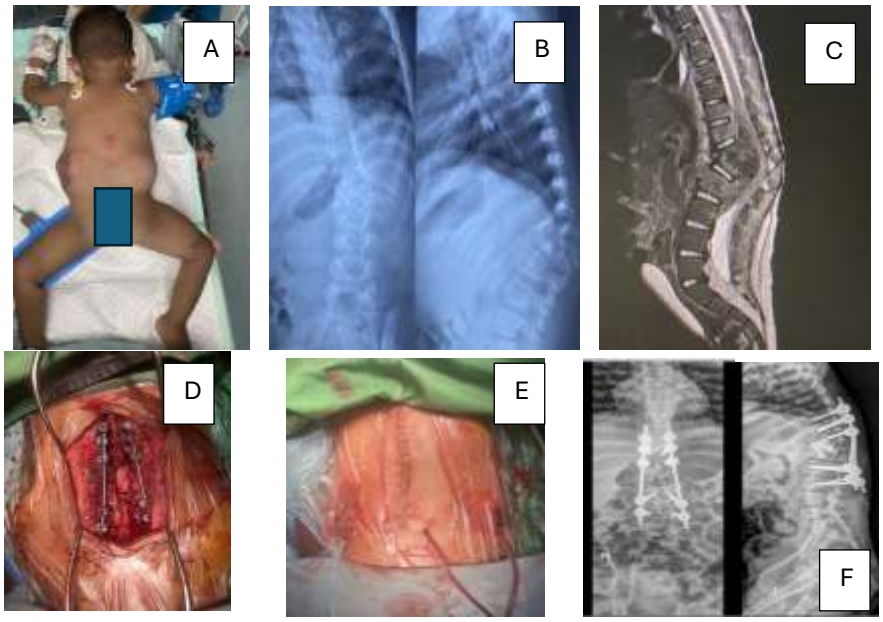


Figure 2. Clinical, radiological, and intraoperative findings of the second patient.
(A) Preoperative clinical photograph demonstrating prominent lower-back and bilateral flank swellings. **(B)** Preoperative radiograph demonstrating severe destructive changes involving the thoracolumbar vertebral segment. **(C)** Sagittal magnetic resonance imaging demonstrating extensive vertebral destruction with a large intracanal abscess and extensive paravertebral and bilateral psoas abscess formation. **(D–E)** Intraoperative photographs demonstrating evacuation of extensive purulent material from the infected vertebral region and

bilateral psoas abscesses, with multiple vacuum drains placed for postoperative drainage. **(F)** Postoperative radiograph demonstrating posterior decompression and instrumented spinal fusion.

Case 3

A 2.5-year-old girl was brought to our hospital because of progressive refusal to walk that had developed over the preceding two weeks. Her parents reported a three-month history of a gradually enlarging lump over the lower back. During the same period, the child appeared progressively thinner and had a deteriorating nutritional status.

On physical examination, the patient appeared undernourished. She was still able to move both lower extremities spontaneously; however, neurological assessment was limited by agitation and discomfort. She appeared to experience pain when encouraged to stand or walk and subsequently refused to bear weight. Ankle clonus was elicited on neurological examination, suggesting the presence of an upper motor neuron sign.

Plain lumbosacral radiographs demonstrated marked destructive changes involving the Th10–12 vertebral bodies. Magnetic resonance imaging revealed extensive destruction of the involved segments associated with an intracanal abscess causing significant spinal canal compromise.

In view of the progressive neurological symptoms, extensive vertebral destruction, and significant intracanal abscess, surgical intervention was performed. A thoracophrenicolumbotomy approach was used for debridement of the involved vertebral segments and evacuation of the abscess. Following debridement, anterior column reconstruction was performed using a fibular allograft as a structural strut graft. Postoperatively, a plaster-of-Paris body jacket was applied to provide external spinal support during the healing period.

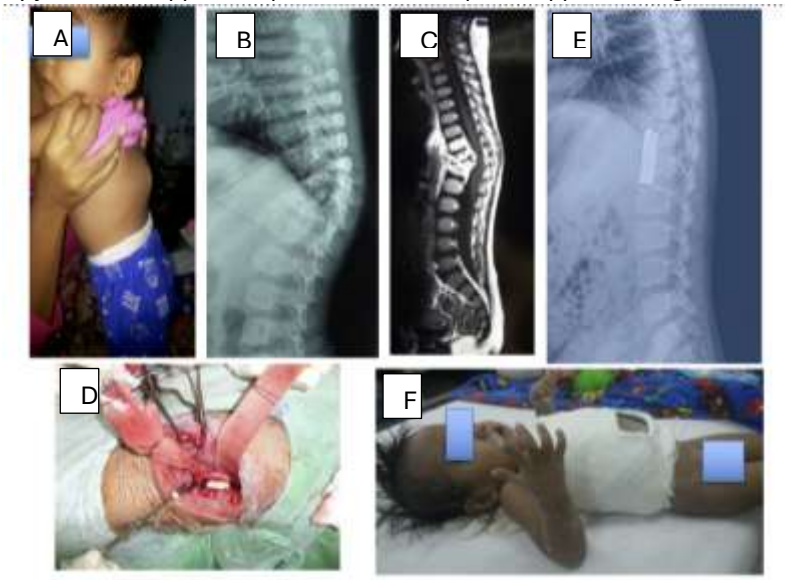


Figure 3. Sequential clinical, radiological, and operative findings in the third patient.

(A) Preoperative clinical photograph demonstrating the prominent hump and poor nutritional status. **(B)** Preoperative lumbosacral radiograph showing extensive destruction of the Th10–Th12 vertebral bodies. **(C)** Sagittal magnetic resonance imaging demonstrating a large intracanal abscess with associated destruction of the Th10–12 vertebral segments and significant spinal canal compromise. **(D)** Postoperative radiograph demonstrating anterior reconstruction with a structural graft. **(E)** Intraoperative photograph demonstrating exposure and debridement of the diseased vertebral segments through a thoracophrenicolumbotomy approach, followed by anterior reconstruction using a fibular allograft as a structural strut graft. **(F)** Postoperative clinical photograph demonstrating the patient supported in a plaster-of-Paris body jacket following surgery.

The patient's neurological and functional status gradually improved following surgery. She regained the ability to bear weight and walk independently approximately two months after surgery. No further deterioration in neurological function was observed during postoperative follow-up.

Case 4

A 2.5-year-old girl presented with a clinical picture similar to that of the third patient, characterized by progressive refusal to walk and a history of a gradually enlarging lump over the lower back. The patient remained able to move both lower extremities; however, she experienced discomfort and pain when encouraged to stand or walk. Neurological examination was limited by her young age and limited cooperation, although upper motor neuron signs were present.

Plain lumbosacral radiographs demonstrated marked destructive changes involving the L2–L3 vertebral bodies. Magnetic resonance imaging revealed extensive destruction of the L2–L3 segments associated with a large intracanal abscess and significant spinal canal compromise.

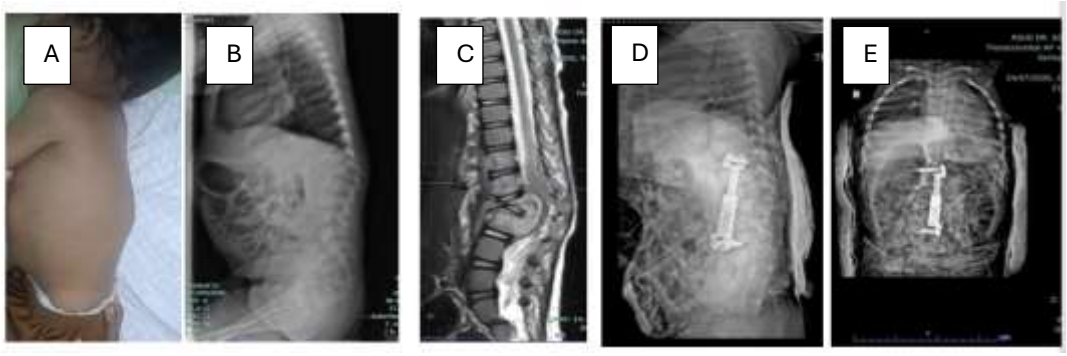


Figure 4. Clinical and radiological findings of the fourth patient.
(A) Preoperative clinical photograph demonstrating the prominent hump. **(B)** Preoperative lateral radiograph demonstrating extensive destructive changes involving the L2–L3 vertebral bodies. **(C)** Preoperative sagittal magnetic resonance imaging demonstrating extensive L2–L3 vertebral destruction with a large intracanal abscess and significant spinal canal compromise. **(D–E)** Postoperative radiographs demonstrating restoration of the anterior spinal column with a tubular cage and bone graft.
Considering the progressive neurological symptoms, extensive vertebral destruction, and intracanal abscess formation, surgical intervention was performed. A lumbotomy approach was used to access and debride the involved vertebral segments and evacuate the abscess. Following adequate debridement, anterior column reconstruction was performed using a tubular cage packed with bone graft to restore structural support and maintain spinal alignment. Postoperatively, a plaster-of-Paris body jacket was applied to provide additional external spinal support during the healing period. The patient demonstrated spontaneous movement of both lower extremities immediately following surgery. Her neurological and functional status continued to improve during follow-up, and she was able to walk independently six weeks after surgery.

Table 1. Comparative Case-Series Results

Characteristics	Case 1	Case 2	Case 3	Case 4
Age	2.5 y	2 y 4 mo	2.5 y	2.5 y
Sex	Female	Male	Female	Female
Initial symptom	Lumbar lump	Lumbar lump + flank mass	Refusal to walk	Refusal to walk
Duration of swelling	4 mo	6 mo	3 mo	4 mo
Neurological presentation	Unable to weight-bear	Complete lower-limb motor loss	Refusal to walk	Refusal to walk
UMN signs	Ankle clonus, increased physiological reflex	Spasticity, preserved reflexes	Ankle clonus	Ankle clonus
Vertebral level	L1–L2	T12–L1	Th10–Th12	L2–L3
Intracanal abscess	Yes	Yes	Yes	Yes
Psoas/paravertebral abscess	Fusiform, surrounding the affected vertebrae	Bilateral psoas + paravertebral	Fusiform, surrounding the affected vertebrae	Fusiform, surrounding the affected vertebrae
Surgical approach	Thoracophrenicolumbotomy	Posterior+anterior	Thoracophrenicolumbotomy	Lumbotomy

Reconstruction	Rib inlay graft	Bone graft	Fibular allograft	Tubular cage + bone graft
Postoperative support	TLSO	TLSO	POP body jacket	POP body jacket
Early neurological response	Gradual	Toe/ankle immediately	Gradual	Lower-limb movement immediately
Independent walking	6 weeks	2.5 months	2 months	6 weeks

DISCUSSION

Spinal tuberculosis remains one of the most destructive forms of musculoskeletal tuberculosis and represents a particularly challenging condition in the pediatric population. Although spinal tuberculosis can occur at any age, its clinical behavior in children differs from that in adults because of the ongoing growth and development of the vertebral column. Pediatric spinal tuberculosis may progress to extensive vertebral destruction, angular deformity, and neurological compromise, with the potential for further deformity even after the infection has become quiescent. Early recognition and appropriate treatment are therefore particularly important in young children [1,2,4].

The present prospective case series describes four children younger than 5 years with destructive spinal tuberulosis associated with intracanal abscess formation and neurological impairment. All patients were approximately 2.5 years of age and presented with a relatively chronic history of a palpable spinal or paravertebral swelling. Interestingly, the neurological presentation varied from refusal to walk with preserved spontaneous lower-extremity movement to complete loss of voluntary lower-extremity movement. This spectrum illustrates the difficulty of recognizing early neurological deterioration in toddlers, in whom formal neurological examination is frequently limited by age, cooperation, and inability to reliably communicate sensory symptoms.

Spinal tuberculosis in toddlers: a challenging clinical presentation

The clinical presentation of spinal tuberculosis in young children may be subtle and difficult to recognize. Classical symptoms such as back pain, constitutional symptoms, and neurological complaints may be absent or difficult to identify. Instead, parents may initially notice a spinal prominence, paravertebral swelling, changes in gait, refusal to walk, or regression of previously acquired motor abilities. In the present series, the presence of a progressively enlarging spinal or paravertebral mass was an important clinical clue [12].

Pediatric spinal tuberculosis also has distinct anatomical and clinical characteristics compared with those of adult disease. Children may have more extensive vertebral involvement and are more susceptible to spinal cord compression because of the narrower spinal canal. Paravertebral and psoas abscesses may also extend more extensively, while kyphotic and gibbus deformities are more likely to develop. These characteristics reflect the unique features of spinal tuberculosis in the growing spine and may contribute to extensive disease and neurological compromise in young children. Chatterjee and Banta emphasized that pediatric spinal tuberculosis has a dynamic natural history that differs substantially from adult disease, with rapid destruction during the active phase and potential progression of deformity during subsequent growth. They further emphasized the importance of early diagnosis and long-term surveillance in children [7]. Similar concerns have been highlighted in broader reviews of spinal tuberculosis, in which young age, extensive vertebral destruction, and multiple involved vertebral bodies are recognized as risk factors for progressive deformity [1,4].

In the present series, all four children were younger than 3 years. This extremely young age is clinically relevant because conventional neurological grading systems may be difficult to apply reliably. In toddlers, functional observations such as spontaneous leg movement, ability to bear weight, crawling, standing, and independent walking may provide more meaningful longitudinal indicators of neurological recovery than formal muscle-power grading alone.

Neurological deficit and mechanisms of neural compression

Neurological impairment is one of the most serious complications of spinal tuberculosis. In active disease, neurological dysfunction is most commonly related to mechanical compression of the spinal cord or neural elements by epidural abscess, caseous material, granulation tissue, sequestrated bone, vertebral collapse, or spinal instability. Additional mechanisms include inflammatory myelitis, arachnoiditis, and vascular compromise

[1,4]. Spinal instability may also contribute to neural compromise in cases with extensive vertebral destruction. Involvement of all three spinal columns can result in pathological subluxation and further compromise of the neural elements [13].

The imaging findings in our patients support mechanical compression as an important contributor to the neurological presentation. All four patients demonstrated extensive intracanal abscess formation in association with destructive vertebral lesions. In the second patient, the disease extended extensively into both psoas muscles and the paravertebral soft tissues, with approximately 400 mL of purulent material evacuated intraoperatively. Such extensive abscess formation illustrates the ability of spinal tuberculosis to extend well beyond the primary vertebral focus.

The severity of neurological impairment varied considerably. The second patient presented with complete absence of voluntary lower-extremity movement and spasticity, representing the most severe neurological deficit in the series. In contrast, the third and fourth patients remained capable of spontaneous lower-extremity movement but refused to walk and demonstrated upper motor neuron signs. This variation may reflect different stages of neural compromise rather than fundamentally different disease processes.

Importantly, all four patients demonstrated neurological improvement following surgical treatment. The second patient demonstrated return of toe and ankle movements immediately after decompression and recovery of knee extension within one week. The first and fourth patients achieved independent walking six weeks after surgery, while the third patient achieved independent walking approximately two months postoperatively. The second patient, despite presenting with complete loss of voluntary lower-extremity movement, achieved independent walking approximately 2.5 months after surgery. These observations support the concept that neurological dysfunction associated with active spinal tuberculosis may remain substantially reversible when neural compression is relieved.

Previous pediatric series have similarly demonstrated meaningful neurological recovery following surgical treatment. Srivastava et al. reported neurological improvement in children with spinal tuberculosis and even longstanding neurological deficits, with substantial improvements in Frankel grade following decompression. Although their cohort was considerably older than the children in the present series, their findings support the potential for neurological recovery despite severe preoperative impairment [14].

The role of paravertebral and intracanal abscess formation

Abscess formation is a characteristic feature of spinal tuberculosis. Tuberculous collections may extend from the vertebral lesion into the paravertebral muscles, psoas muscles, epidural space, and, depending on the level involved, other adjacent anatomical compartments [1,4].

In our series, intracanal abscess formation was present in all four patients and was associated with neurological impairment. This finding is clinically important because an abscess located within the spinal canal can directly compromise the neural elements, particularly when accompanied by vertebral collapse or instability. A recent pediatric case report similarly described concomitant epidural and bilateral psoas abscesses associated with L2–L3 vertebral destruction, further illustrating the potential for spinal tuberculosis to involve multiple contiguous anatomical compartments [15].

The presence of a large abscess alone, however, should not automatically be considered an indication for surgery. Modern management of spinal tuberculosis remains fundamentally based on effective antituberculous chemotherapy, with surgery reserved for complications such as neurological deterioration, significant neural compression, instability, progressive deformity, extensive destructive disease, or selected symptomatic abscesses [1,4,6].

In the present series, the decision to operate was based on the combination of neurological impairment, extensive vertebral destruction, and significant intracanal and/or paravertebral abscess formation. The second patient additionally had extensive bilateral psoas involvement, further supporting the need for surgical source control.

Indications for surgery in pediatric spinal tuberculosis

The role of surgery in spinal tuberculosis has historically been controversial. The development of effective antituberculous chemotherapy established medical treatment as the cornerstone of therapy, and surgery is not required for every patient with spinal tuberculosis. However, surgical intervention remains important when neurological, mechanical, or deformity-related complications develop [1,4,6].

Commonly accepted indications include progressive or severe neurological deficit, spinal instability, significant vertebral destruction, progressive or severe kyphotic deformity, failure of medical treatment, diagnostic uncertainty, and selected large or symptomatic abscesses [1,4]. In children, the threshold for considering surgical

intervention may be lower because progressive vertebral destruction can produce severe angular deformity during subsequent growth [2,4]. Basu and Maddali further reported that major vertebral destruction, a type C stabilization pattern, and worsening deformity or neurological deficit were associated with the need for surgical intervention. They also emphasized the importance of identifying children at risk of progression and maintaining close long-term follow-up [16].

All four patients in this series met clinically significant indications for surgical intervention. Each had neurological impairment associated with substantial vertebral destruction and intracanal abscess formation. Thus, the surgical objective was not simply eradication of infection, but also restoration or preservation of neurological function and mechanical stability.

This distinction is particularly relevant in toddlers. A strategy that achieves infection control but leaves a severely unstable or progressively collapsing anterior spinal column may expose the child to progressive deformity during growth. Conversely, overly aggressive instrumentation in a very young child also introduces technical and biological concerns. Therefore, surgical reconstruction must be individualized according to the location and extent of vertebral destruction, remaining spinal stability, neurological status, and anticipated growth.

Surgical strategy and reconstruction

The four cases demonstrate different reconstructive strategies according to the anatomical location and severity of the disease. Two patients underwent anterior access through thoracophrenicolumbotomy or lumbotomy, with debridement and anterior column reconstruction. One patient underwent posterior decompression and fusion combined with anterior bone graft reconstruction, while another underwent anterior reconstruction using a tubular cage packed with bone graft.

There is currently no universally accepted surgical approach for pediatric thoracolumbar spinal tuberculosis. A recent systematic review and meta-analysis comparing combined anterior-posterior and posterior-only approaches in pediatric thoracolumbar tuberculosis found improvement in neurological function with both approaches and concluded that available evidence remains insufficient to establish clear superiority of one approach over another [6,17]. Evidence from pediatric lumbar spinal tuberculosis further supports an individualized surgical strategy. Wang et al. reported favorable long-term outcomes following one-stage posterior instrumentation combined with anterior debridement and reconstruction using allogenic strut bone in 16 children with multilevel lumbar spinal tuberculosis. At a mean follow-up of 7.8 years, all patients achieved solid bone fusion, with substantial correction of kyphosis and significant improvement in neurological function [18].

Conversely, Xu et al. demonstrated that a posterior-only approach using a polyetheretherketone (PEEK) cage combined with single-segment instrumentation could also provide satisfactory outcomes in children with mono-segment lumbar tuberculosis. However, their study included a highly selected population and excluded patients with severe kyphosis, extensive multilevel disease, pedicle involvement, or large paravertebral or psoas abscesses. These findings suggest that posterior-only reconstruction may be appropriate for anatomically limited disease, whereas more extensive vertebral destruction or abscess formation may require a different surgical strategy [19].

The choice of surgical approach should therefore be individualized. Anterior surgery provides direct access to the diseased vertebral bodies, facilitates removal of infected and necrotic tissue, permits evacuation of anterior and paravertebral collections, and allows reconstruction of the anterior spinal column. Posterior surgery offers effective neural decompression and stabilization and may avoid the morbidity associated with anterior thoracic or thoracoabdominal exposure [4,7].

In our series, the anterior approaches were selected in patients with substantial vertebral body destruction requiring direct debridement and anterior column reconstruction. Structural grafting was performed using different techniques, including a rib-derived inlay graft, fibular allograft, and tubular cage packed with bone graft. These variations reflect the individualized nature of reconstruction in very young children.

The use of structural grafts in pediatric spinal tuberculosis has a long surgical precedent. Historical pediatric series demonstrated favorable long-term results following lesion removal and anterior grafting, although modern surgical practice has evolved substantially with the availability of improved implants, imaging, and antituberculous therapy [8].

An important consideration in toddlers is the balance between achieving immediate mechanical stability and minimizing disruption of future spinal growth. Because the children in this series were approximately 2.5 years old, long-term radiological follow-up is particularly important to assess spinal alignment, vertebral growth, fusion, and potential development of late deformity.

Neurological recovery following decompression

One of the most notable findings of this series was the rapid postoperative neurological improvement despite severe preoperative disease. The second patient, who had no observable voluntary lower-extremity movement preoperatively, regained toe and ankle movement immediately after surgery and knee extension within one week. The first and fourth patients achieved independent walking six weeks after surgery, while the third patient achieved independent walking at approximately two months. Despite the severity of the initial neurological deficit, the second patient subsequently achieved independent walking approximately 2.5 months after surgery. The rapid recovery observed in several patients suggests that at least part of the neurological deficit was related to potentially reversible mechanical compression rather than irreversible spinal cord injury. This is consistent with the pathophysiology of early-onset neurological deficit in active spinal tuberculosis, in which epidural abscess, inflammatory tissue, vertebral debris, and instability can produce dynamic or static neural compression [1,4].

Previous pediatric surgical series also support the potential for neurological recovery after decompression. In a series of 13 pediatric patients with longstanding neurological deficits, surgical intervention was associated with meaningful improvement in neurological grade, including improvement among patients with severe preoperative deficits [15]. Although direct comparison with our patients is inappropriate because of differences in age, disease duration, and methodology, these findings reinforce the potential for neurological recovery even after substantial impairment.

The present series additionally suggests that functional recovery may be a particularly valuable outcome measure in toddlers. For a child younger than 3 years, restoration of independent standing and walking may provide a more clinically meaningful measure of recovery than a conventional numerical motor score that is difficult to obtain reliably.

Medical treatment remains fundamental

Although surgery was central to the management of these four patients, it should not be considered a replacement for antituberculous therapy. Tuberculous spondylitis remains an infectious disease, and adequate antituberculous chemotherapy is essential for eradication of the infection and prevention of recurrence. Current WHO guidance emphasizes individualized management of extrapulmonary tuberculosis in children, with osteoarticular tuberculosis requiring appropriate antituberculous treatment and clinical monitoring [2,9].

The role of surgery in this series should therefore be viewed as treatment of the complications of active spinal tuberculosis—particularly neural compression, extensive abscess formation, vertebral destruction, and mechanical instability—while antituberculous therapy addresses the underlying infectious process [20]. Antituberculous therapy should be initiated promptly following confirmation of spinal tuberculosis and should not be delayed by the need for surgical intervention, as surgery serves as an adjunct to medical treatment rather than a replacement for it [9].

External immobilization and the growing spine

Another notable aspect of this series was the use of postoperative external immobilization. Thoracolumbosacral orthoses were used in some patients, while plaster-of-Paris body jackets were applied in others. In very young children, external immobilization may provide additional support during the early healing period, particularly when the spinal reconstruction involves limited internal fixation or when instrumentation is intentionally minimized.

Historically, cast and brace immobilization formed an important component of conservative management of spinal tuberculosis. However, contemporary treatment has shifted toward mobilization with effective chemotherapy and selective stabilization rather than prolonged immobilization [1]. In the present series, external support was used as an adjunct to surgical reconstruction rather than as definitive treatment.

The long-term implications of spinal tuberculosis in toddlers remain particularly important. Because spinal growth continues for many years after treatment, apparently satisfactory early postoperative alignment does not necessarily indicate the final outcome. Progressive kyphosis and other growth-related deformities may occur during subsequent childhood, particularly when vertebral growth plates have been damaged. Moon et al. demonstrated that growth-plate damage was an important factor associated with progressive spinal deformity in children with spinal tuberculosis [21]. Long-term clinical and radiological surveillance is therefore warranted, particularly in very young children [2,4].

Clinical implications

The present series highlights several practical considerations. First, a progressive spinal or paravertebral swelling in a toddler should prompt evaluation for spinal infection, particularly in tuberculosis-endemic regions. Second,

refusal to walk or loss of previously acquired walking ability may represent an important neurological warning sign, even when formal neurological examination is unreliable. Third, MRI is essential for defining the extent of vertebral destruction, epidural disease, and paravertebral or psoas abscess formation. Finally, when neurological deficit is accompanied by significant neural compression and extensive spinal destruction, early surgical decompression and appropriate reconstruction may provide substantial neurological recovery.

The four cases also demonstrate that the surgical strategy should not be rigidly standardized. Rather, the approach and reconstruction should be tailored to the anatomical level, extent of vertebral destruction, abscess distribution, neurological status, and mechanical stability of the affected segment.

Limitations

This study has several limitations. First, the sample size was small, comprising only four patients, which limits the generalizability of the findings and precludes meaningful statistical analysis. Second, the patients were managed with different surgical approaches and reconstruction techniques, reflecting individualized clinical decision-making but preventing direct comparison between techniques. Third, formal neurological scoring systems were difficult to apply consistently because of the very young age of the patients. Functional recovery, particularly restoration of independent walking, was therefore used as an important clinical endpoint. Finally, longer-term follow-up is necessary because these patients remain at risk for growth-related spinal deformity even after successful control of the infection.

Nevertheless, the rarity of spinal tuberculosis with severe neurological compromise in children younger than 5 years makes this case series clinically relevant. The rapid neurological recovery observed in all four patients provides useful evidence regarding the potential reversibility of neurological impairment when severe neural compression is addressed appropriately.

CONCLUSION

Spinal tuberculosis in children younger than 5 years may present with extensive vertebral destruction, large intracanal and paravertebral abscesses, and significant neurological impairment. In toddlers, recognition of neurological deterioration can be challenging because conventional neurological assessment is frequently limited by age and cooperation. Therefore, changes in walking ability, weight-bearing, and spontaneous lower-extremity movement may provide important clinical indicators of neurological compromise.

In this prospective case series, all four patients demonstrated substantial neurological and functional improvement following surgical management combined with antituberculous therapy. Even the patient who presented with complete loss of voluntary lower-extremity movement demonstrated early postoperative motor recovery. These findings suggest that severe neurological impairment associated with active spinal tuberculosis in very young children may remain substantially reversible when significant neural compression is promptly addressed.

Surgical treatment should therefore be considered in selected pediatric patients with neurological deficit, significant neural compression, extensive vertebral destruction, spinal instability, or large symptomatic abscess formation. The surgical approach and reconstruction should be individualized according to the anatomical level and extent of disease, neurological status, and mechanical stability. Because these patients remain at risk for progressive deformity during growth, long-term clinical and radiological follow-up until skeletal maturity is essential. Larger multicenter studies with longer follow-up are needed to better define the optimal timing, surgical approach, reconstruction strategy, and long-term outcomes of spinal tuberculosis in children younger than 5 years.

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