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History of spine surgery for tuberculous spondylodiscitis

Introduction

Archaeological studies have shown that tuberculous bacilli have lived with mankind since the beginning of time. Evidence of tuberculous spondylitis has been found in the mummies of Egyptian kings dating as early as in 3400 BC (**Fig. 1**; [1]). In India, the Rig Veda and Atharva Veda (3500–1800 BC) mentioned tuberculosis as "Rajayakshma" [2]. It is interesting to note that the physicians of the Vedic period advised high altitude, fresh air, rest and immobilization for patients with "Yakshma" (tuberculosis) much similar to the philosophy of treatment for pulmonary tuberculosis practiced as recently as in the 1950s [3].

Hippocrates, considered to be the Father of Spine Surgery (100–300 BC), described spinal tuberculosis and tubercular gibbus deformity in his work *On Articulations* ([5]; **Table 1**). In the second century AD, Galen had clearly documented the relationship between tuberculosis and spinal deformity [6]. In their respective works, Hippocrates and Galen described the use of extension–traction devices to correct spinal deformities secondary to tuberculosis, by manual reduction techniques ([7]; **Fig. 2**). Many centuries later in 1779, Sir Percival Pott described tuberculous disease of the spine and its sequelae of paraplegia as "That kind of palsy of lower limbs which is frequently found to accompany a curvature of spine" [8]. Pott also described the classical clinical triad of spinal tuberculosis—*kyphosis, abscess and paraplegia*—which was then referred to as the diagnostic criteria of tuberculosis.

Further knowledge about the infectious origin of the disease was revealed with the identification of the "tubercle" lesion. Laennec (1781–1826) described the "tubercle", the basic microscopic lesion identified in tubercular lesions, by which the disease has been universally known since then [10]. With the bacterial theory having become popular, Sir Robert Koch (**Fig. 3**) was the first to identify *Mycobacterium tuberculosis* as the microbial pathogen responsible for tuberculosis [11]. Bacilli Calmette Guerin (BCG) vaccination for tuberculosis became available in 1945, but the major breakthrough in the management of tuberculosis was the discovery of antitubercular drugs (1948–1951). Selman A. Waksman [12] discovered streptomycin from the fungi *Streptomyces griseus* which inhibited the growth of tuberculous cultures in vitro. The initial massive success of streptomycin against tuberculosis was short lived as drug resistance was soon identified.

» Streptomycin, which was very successful in the 1940s to treat tuberculosis, quickly became ineffective due to resistance

J. Lehman isolated para-aminosalicylic acid (PASA) in 1944 and isoniazid in 1952 [13, 14]. Combinations of drugs—isoniazid, PASA with streptomycin—were used to tackle the problem of resistance. Pyrazinamide (1954), cycloserine (1955), and ethambutol (1962) were subsequently discovered. In 1966, Pietro Sensi isolated rifamycin S from the fungus *Streptomyces mediterranii*, thus, completing the discovery of the major antitubercular drugs [15]. Multidrug chemotherapy enabled excellent disease clearance, achieving high drug concentrations even in infected tissues and abscesses.

The benefits of antituberculous drugs on reducing mortality and morbidity was so spectacular that the management of spinal tuberculosis can be divided into three eras: (1) the pre-antitubercular era, in which patients were treated by ancient traditional methods and various "direct and distant surgical procedures", (2) the early post-antitubercular era, in which patients were treated by surgical excision of disease foci along with antitubercular drugs, and (3) the current post antitubercular era in which all patients are treated primarily with antitubercular drugs and surgery is confined to patients for selective indications.

The pre-antitubercular era

Nonoperative conservative treatment

Recumbence and immobilization by various means, adequate exposure to sunshine, wind, and nutritious food were the basis of treatment of tuberculosis for many centuries (**Table 2**). Ancient Indian medical science described tuberculosis as Yakshma and prescribed constitutional supportive treatment. The Atharvans (1800–1000 BC) treated cases of skeletal tuberculosis with "Sipudru", an herbal preparation, and heliotherapy [1]. In the West, Hippocrates (450 BC) and Galen (131–201 AD) described the use of manual pressure and special traction appliances to correct tubercular kyphotic deformity. Apart from traction devices, plaster casts and forced reduction techniques were used by different surgeons to correct the kyphotic deformity (**Fig. 4**). The infectious origin of the disease and its contagious nature was identified in the 19th century.

The patients were treated in special hospitals called sanatorium where the average time of hospitalization varied between 1 and 5 years (**Fig. 5**). The word *Sanatorium* in Latin, means an establish-

Fig. 1 ▲ Evidence of post-tubercular kyphosis in an Egyptian mummy. (From [4])

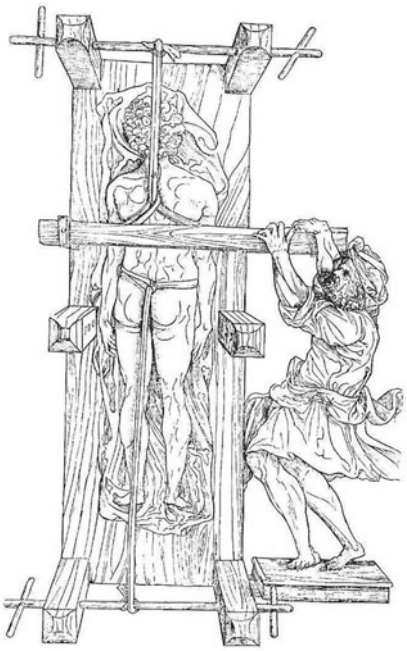

Fig. 2 ▲ Traction appliance used by Hippocrates in ancient times to correct tubercular kyphosis. (From [9])

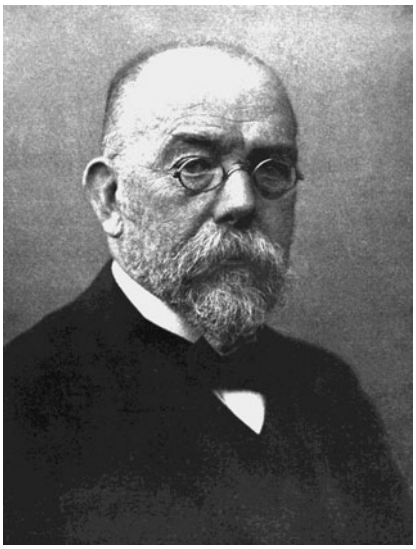

Fig. 3 ▲ Sir Robert Koch discovered *Mycobacterium tuberculosis*. ©picture alliance/dpa

Fig. 4 ▲ Calot's forced redression. (From [16])

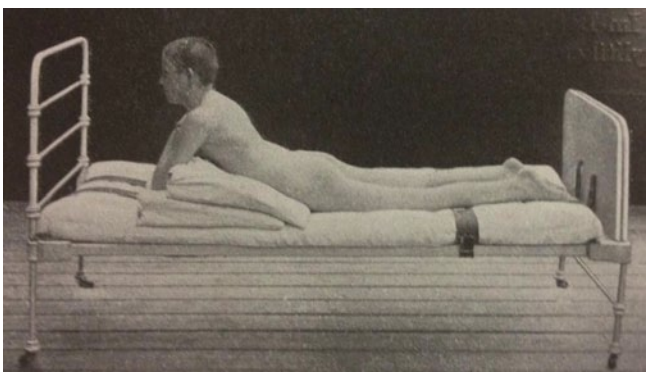

Fig. 5 ▲ Photograph of patient afflicted by spinal tuberculosis being treated at a sanatorium. (From [19])

ment providing therapy. The England-based health practitioner George Bodington was the first to propose sanatorial treatment for tuberculosis patients to provide affected patients with a nutritious diet, physical activities, and fresh air [17].

» A nutritious diet, fresh air, and high altitude of treatment in a sanatorium were advantageous, but high mortality persisted

Physicians of the 19th and early 20th century enhanced these principles and described the advantages of treating tuberculosis patients with sanatorial treatment [18]. Despite the modest usefulness provided by good diet, fresh air, high altitude of sanatorial treatment, the disease continued to be associated with high mortality. Even many eminent persons like Robert Luis Stephenson, John Keats, Somerset Maugham, and Voltaire succumbed to tuberculosis.

In the absence of chemotherapy, the natural course of skeletal tuberculosis passed through three overlapping stages. In the first "stage of onset", the affected joint is warm, tender, and swollen with severe pain. In the second "stage of destruction", the disease progresses with gross destruction of bones and joints with deformity, subluxation, contractures, and abscess formation. Many abscesses that ruptured ended with sinuses with secondary pyogenic infection. In due course, patients developed severe cachexia, dissemination of bacilli (military tuberculosis, tuberculous meningitis), which resulted in death for 50–60 % of patients. Tuberculosis was hence described as *phthisis* (from the word *phthinein* which means *to decay*) and as *consumption* because the patients slowly succumbed to the disease.

Patients with either better immunity or lesser disease load entered the third "stage of repair and ankylosis". As the dis-

ease healed, the abscesses and the sinuses gradually resorbed while the destroyed bones remineralized. The involved joint usually healed with fusion in a deformed position. In spinal tuberculosis, kyphosis of varying degrees was the inevitable outcome. Bony fusion was perceived to reduce chances of disease recurrence and further progress of deformity. Hence the primary aim of treatment of skeletal tuberculosis was to achieve the "stage of repair and ankylosis" of the joint or spine in the least disabling position. Without chemotherapy, the results of nonoperative constitutional treatment were unsatisfactory with less than 30 % of treated patients resuming full working capacity. The remaining patients either died or were severely disabled.

Surgical treatment without chemotherapy

The disappointing results of nonoperative treatment in the pre-chemotherapy era forced surgeons to explore possibilities of surgical debridement of affected vertebra. Initial attempts were towards drainage of abscesses or sinus tract excision. Peripherally accessible abscesses were aspirated to reduce pressure symptoms and decrease disease load. Neurological deficit, cachexia, and poor lung function were the chief causes of death. It was believed that the peridural abscess and the kyphotic deformity contributed to neurological deficits. Chipault [20] was the first to perform laminectomy for paraplegia due to tuberculosis, in an attempt to improve neurological compression [21]. However, the lamina was the only stabilizing structure in a spine afflicted with tuberculosis because the anterior vertebral bodies are already destroyed. Thus, laminectomy invariably resulted in poor results due to pain, kyphosis, and worsening neurological deficit. Hence, the procedure was abandoned. Seddon [22] ascribed the dismal results of laminectomy in spinal tuberculosis to its inability to provide adequate access for vertebral body debridement and its failure to arrest progression of kyphosis.

The need to retain the posterior stabilizing structures while simultaneously relieving anterior pressure on the spinal cord resulted in the development of "anterolateral decompression" approaches for spinal tuberculosis. Menard [23] proposed the "costotransversectomy approach" to decompress the spinal cord without violating the posterior stabilizing structures [24]. Although the surgical concept was novel, in the absence of chemotherapy, the technique fell into disrepute due to the high incidence of sinus formation and secondary infection. Later Norman Capener (1933) developed the classical "anterolateral decompression" procedure for spinal tuberculosis, which he coined as "lateral rhachiotomy" approach [25]. The technique involved excising a part of the lamina and pedicle unilaterally to enter the spinal canal anteriorly. Necrotic bone tissue and tubercular abscess compressing anteriorly on the spinal cord were removed. Dott and Alexander [26] modified the technique of anterolateral decompression (the original Capener's operation), the approach being a little more anterior or removing a part of the vertebral body to gain access to the spinal canal without performing any laminectomy [21].

» Surgical treatment alone invariably associated with poor results

Although the disease load was substantially controlled by removal of necrotic tissue, the absence of chemotherapy and ineffective microbial control led to problems like worsening kyphosis, sinus formation, and disease reactivation. While the initial results of surgery were promising, the general outcome of surgery was dismal and it was summarized by Calot [28] as "*the surgeon who, so far as tuberculosis is concerned, swears to remove the evil from the very root, will only find one result awaiting him—the death of his patient*". Because "direct operation on the disease area" presented such a gloomy picture, surgeons probed the possibility of "distant operations" without opening the site of the disease. Albee and Hibbs (1911) developed un-instrumented posterior spinal fusion along the facet joints contending that achieving spinal fusion would shorten the period of immobilization. While Albee used tibial grafts between adjacent spinous processes to stabilize the spine [29], Hibbs decorticated the lamina and facet joints of adjacent vertebrae and performed fusion using morselized bone derived from the spinous processes [30]. They believed that achieving fusion would result in less chances of activation of disease (Fig. 6). However, pus, debris, and

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Abstract
For those stricken with tuberculosis, a disease that was present in ancient times, treatment was originally limited to conservative treatment including high altitude, fresh air, rest, and immobilization, manual reduction devices, and surgical procedures. Mortality and morbidity were high until the advent of antitubercular chemotherapy in the 1940s. Today multidrug regimen enable good disease clearance and also make direct surgical debridement without complications possible. Antitubercular drugs have reduced mortality by 72.5%. Surgical intervention is reserved for selected situations.

Keywords
Tuberculosis · *Mycobacterium tuberculosis* · Chemotherapy · Surgical procedures, operative · Antitubercular agents

Geschichte der Wirbelsäulenchirurgie bei tuberkulöser Spondylodiszitis

Zusammenfassung
Früher waren die Behandlungsmöglichkeiten für von Tuberkulose betroffene Menschen bis auf homöopathische Ansätze bzw. manuelle Apparaturen und operative Verfahren außerordentlich begrenzt, und bis zur Einführung der tuberkulostatischen Pharmaka in den 1940er-Jahren waren Morbidität wie Mortalität hoch. Inzwischen erzielen Mehrfach-Kombinationstherapien gute Heilungsraten und ermöglichen ein direktes chirurgisches Débridement ohne Komplikationen. Der Einsatz von Tuberkulostatika hat die Mortalität um 72,5% verringert, und chirurgische Interventionen bleiben ausgewählten klinischen Konstellationen vorbehalten.

Schlüsselwörter
Tuberkulose · *Mycobacterium tuberculosis* · Pharmakotherapie · Operative chirurgische Verfahren · Antituberkulotika

Table 1 Important events in the history of diagnosis of spinal tuberculosis

Year	Described by	Event
1000 BC	–	Healed tuberculosis in Egyptian mummy
500 BC	Hippocrates	Spina luxata, abscess and paralysis and lung affliction in tuberculosis
131–201	Galen	Kyphosis
1573	Dalechamps	Description of destruction of vertebral bodies
1779	Pott	"Pott's triad", Gibbus as a symptom
1783	Pouteau	Connection between vertebral destruction and "Phthysie pulmonaire"
1816	Delpech	Tuberculosis of the lung is the reason for spondylitis
1824	Wenzel, Plattner	Description of tuberculous spondylitis
1882	Koch	Discovery of the tubercle bacillus
1882	Ziehl	Ziehl–Neelsen stain
1891	Koch	Tuberculin skin test
1908	Mantoux	Intradermal tuberculin skin test

Table 2 Important events in the history of treatment of spinal tuberculosis

Year	Described by	Event
500 BC	Hippocrates	Extension traction appliance for kyphosis correction
131–201	Galen	Active correction (breathing exercise) chest binders and jackets
1771	Aurran	Horizontal bed rest for a period more than 6 month
1779	Pott	Abscess–incisional drainage
1823	Shaw	Advised no manipulation of the kyphosis
1840–1850	Nelaton	Injection of fluid mixtures in a chronic draining fistula
1853	Taylor	Verticalization of spine with brace
1860	Bauer	Immobilization in water beds
1874	Sayre	First plaster jacket treatment for tuberculosis

Table 3 Results of Medical Research Council (MRC) trials conducted in various centers on the various treatment regimens for tuberculosis

Centre	Conclusions
Masan, Korea—MRC 1973	The standard drugs were potent for florid spinal tuberculosis in children and bed rest was not necessary
Pusan, Korea—MRC 1973	Streptomycin is not necessary and plaster-of-Paris jacket offers no benefit
Bulawayo, MRC—1974	Debridement is not a good surgical procedure and clinical diagnosis assisted with radiographs was sufficient to start the treatment as was later confirmed by histopathology and or bacteriology in 83 % of patients
Hong Kong, MRC—1974	Radical anterior excision is a better surgical procedure with positive histopathology and/or bacteriology in 85 % of patients
Madras, MRC—1978	Ambulatory treatment with rifampicin and isonicotinic acid hydrazide for 9 months was found to be superior to an ambulatory 6-month regimen or 6-month regimen with radical resection within 1 month of starting chemotherapy

necrotic bone remained enmeshed and the disease flared up when the immunity dropped. Furthermore, posterior fusion often failed in patients with extensive vertebral damage, and hence the posterior "distant" surgery fell out of repute.

Early post-chemotherapy era

Radical excision surgery

The antitubercular drugs were developed in the 1940s which tremendously changed the management of spinal tuberculosis. Streptomycin was introduced in 1943 and subsequently other drugs including p-aminosalicyclic acid (1944), isoniazid (1952), and rifampicin (1966) were developed which achieved spectacular success in the control of disease. Although the drugs were effective in disease control, patients with significant abscess and kyphosis formation still required surgical debridement. Fortunately, the availability of effective antitubercular drugs made direct surgery on the diseased area possible without dissemination of infection or sinus formation. This resulted in renewed enthusiasm for surgical intervention in spinal tuberculosis.

The surgical philosophy proposed was "universal excision surgery" of the affected vertebra in conjunction with antitubercular drugs. Surgeons had assumed that the drugs did not penetrate into osseous tuberculous lesions and hence wide surgical excision of infected tissue was mandatory. Surgical debridement of tuberculous infection was classically performed through a direct anterior approach since the disease was mainly confined to the anterior column. The anterior approach also allowed direct access to debridement, decompression, and adequate reconstruction of the anterior column with rib grafts. The anterolateral extrapleural approach, initiated by Menard [23] and subsequently developed by Griffiths, Roaf, and Seddon was commonly used [22, 31].

» After complete excision of the involved vertebrae, reconstruction with rib or iliac crest grafts required

In the 1960s, Hodgson, popularized the concept of anterior radical debridement and reconstruction using rib strut grafts (The Hong Kong Surgery) for spinal tuberculosis (**Fig. 7**; [32, 33]). His technique was a modification of similar approach originally reported by Ito et al. in the pre-chemotherapy days. Ito et al. [34] published a series of 10 cases of spinal tuberculosis in which they approached the lumbar spine retroperitoneally for debridement followed by fusion. In Hodgson's technique, the debridement should be "radical" and involve complete excision of the whole of the vertebrae in-

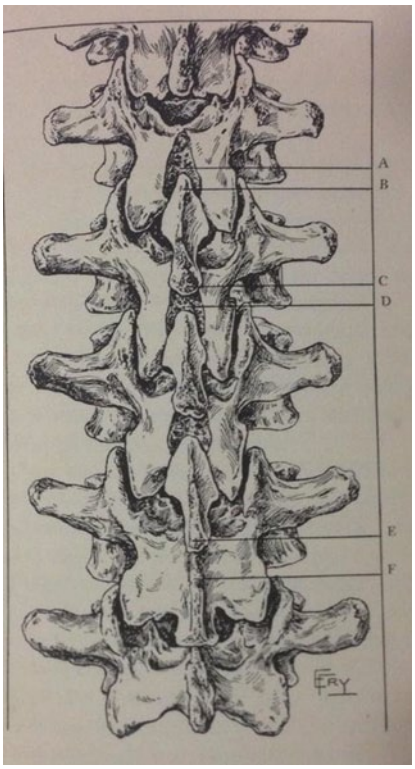

Fig. 6 ▲ Scheme of using spinous processes for solidifying posterior aspect of vertebrae. (From [27]; courtesy of Columbia University Press)

volved. The resultant anterior column defect was usually huge and had to be reconstructed with rib or iliac crest grafts. He published the results of his first 100 cases in 1960 and reported excellent results. Although Hodgson and Stock reported good results, it could not be replicated in all of the other published series of radical anterior surgery.

» Un-instrumented bone grafts often associated with displacement, breakage, and late recurrence of kyphotic deformity

The complications reported in various studies included vascular complications, prolonged surgeries, neurological deficits, the problems of huge anterior bone defects, and the general morbidity of anterior approach in patients who invariably had poor pulmonary function [35]. Radical resection of lesions in children also destroyed the anterior growth plate, accentuating risks of worsening of kyphosis [36, 37]. Thoracotomy in patients with spinal tuberculosis who were anemic, with coexistent pulmonary infection, weak intercostal muscles and kyphosis was a major surgical undertaking with potential complications.

In a series of 91 patients treated by thoracotomy for anterior debridement of spinal tuberculosis, seven died of respiratory failure. Adendorff et al. [35] observed increased mortality after thoracotomy, especially in those with severe neurological deficit. They showed that when paraplegia was moderate; there was a mortality of 6%, which increased to 11%, when it became severe. Another problem of radicular anterior debridement, especially when three or more vertebrae are involved, was the large anterior vertebral defect. Though the defects were reconstructed with un-instrumented rib grafts and iliac crest grafts, graft-related complications such as displacement, breakage and late recurrence of kyphotic deformity were reported in up to 45% of cases [38]. Rajasekaran et al. [39] observed that graft-related complications were very common in patients with involvement at two or more levels. Graft failure was attributed to the thin ribs, their curvature, and the small surface area of contact with the adjacent normal vertebral end plates. They recommended that long grafts must be protected by posterior instrumentation.

Modern post-antitubercular chemotherapy era

Middle path regimen

While the morbidity of radical excision surgeries were increasingly being recognized, several surgeons observed that the potential for repair and regeneration of the diseased vertebrae with multidrug combination chemotherapy was significant [40]. As the remarkable effects of chemotherapy in providing optimal disease control were increasingly acknowledged, surgeons were able to be less aggressive in their surgical resection, wherein only the diseased vertebral segments were removed. Tuli from India [41] endorsed the middle path regimen: all patients treated with antitubercular chemotherapy, and surgery advised only in patients at risk of neurological deficit or significant kyphosis. He noted that operative excision and debridement should be less aggressive, being limited to removal of sequestrated vertebrae or discs, and the offending tissues compressing the spinal cord, while chemotherapy was used to treat the disease.

» Middle path regimen: all patients treated with antitubercular chemotherapy with surgery only in special cases

To resolve the debate over radical excision versus debridement and antitubercular chemotherapy alone, the British Medical Research Council (MRC) Working Party on Tuberculosis of the Spine initiated a series of studies from 1965 in Korea, Zimbabwe, Hong Kong, and Madras. Patients were randomly allocated to the drug treatment group, debridement group, or radical debridement plus anterior spinal fusion group [42–44]. All patients were given two or three drug combination chemotherapy for 18 months. In the debridement group, the abscess, sequestrum, and loose disc fragments were removed to achieve spinal cord decompression and no fusion was performed. The radical surgery group was treated with radical debridement of the anterior necrotic tissue and reconstruction with autogenous rib, iliac, or fibula grafts. After 5, 10, and 15 years, equivalently favorable outcomes were achieved in all three groups (**Table 3**). With the success reported with middle path regimen, the indications for surgery became very selective. All patients are treated with antitubercular chemotherapy and surgery is advised to prevent and correct spinal deformities, manage neural complications, and to improve quality of function [45].

Evolution of surgical techniques

Direct anterior debridement and reconstruction

Initially, an anterior approach for debridement of spinal tuberculosis was preferred because it provided direct access to involved vertebrae for debridement, allowed direct decompression of the cord, and enabled anterior reconstruction. The posterior approach for decompression

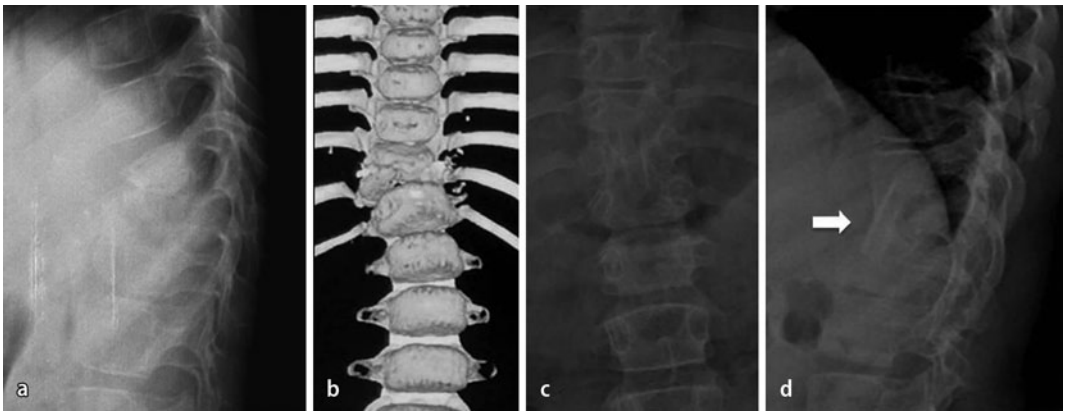

Fig. 7 ▲ Anterior radical excision surgery for spinal tuberculosis. **a** Lateral radiograph and **b** coronal CT of thoracolumbar spine showing destruction of T12–L1 vertebra and kyphosis. The patient was treated by removal of infected bone, abscess, necrotic granulation tissue, and reconstruction with fibular strut grafts (*white arrow*) as seen in the anteroposterior and lateral postoperative radiographs (**c**, **d**)

without instrumentation was not popular as it removed the healthy posterior vertebral elements and resulted in spinal instability. Midcervical lesions were typically treated by standard anterior cervical approaches (Smith Robinson approach) with excellent results, which still remain the standard approach for cervical tubercular lesions. In the thoracic spine, radical debridement and reconstruction were accomplished through transthoracic, extrapleural anterolateral, or posterolateral approaches (e.g., costotransversectomy). For the lumbar spine, debridement and reconstruction was typically performed through a lateral retroperitoneal approach.

After debridement, grafting was necessary to reconstruct the anterior column of the spine and promote solid bony arthrodesis. Autografts acquired from the ribs, iliac crest, and fibula were commonly used [46, 47]. In an MRC study with 119 patients, fusion rates, non-union rates, and mean kyphotic angles were lower in those who underwent radical anterior debridement with autologous grafting compared to those with debridement alone. The pioneers of anterior radical surgery, Hodgson and Stock originally used iliac crest block grafts to achieve union after debridement. While cancellous grafts incorporated quickly, cortical rib and fibular grafts slowly remodeled. Bradford and Daher [48] used vascularized rib grafts and demonstrated significantly earlier incorporation and higher fusion rates. Subsequently fibular and femoral ring allografts were used to substitute or supplement autografts. Govender and Parbhoo [49] used fresh-frozen humeral allografts for the reconstruction of the anterior column after debridement and reported good fusion rate.

Metallic implants in active spinal tuberculosis

In situations where the defect was extensive and incorporation was slow, kyphosis further worsened and sometimes resulted in graft breakage and dislodgement. To provide a stronger anterior column support, metallic cage or mesh type devices containing non-structural autograft were tried and successfully used. The use of metallic cages with bone grafts biomechanically enabled better deformity correction, reducing the risk of graft subsidence. There was an initial apprehension to use metal implants in active infection, but it was shown by Oga et al. [50] that the tubercle bacilli unlike pyogenic organisms does not adhere to metal and form a biofilm.

» Metal implants provide immediate stability and protect against development of kyphotic deformity

In their original study, Oga et al. studied 11 patients with thoracic, thoracolumbar, and lumbar spinal tuberculosis treated by debridement, anterior fusion, and combined posterior instrumentation surgery. Despite the use of instrumentation, there were no cases of persistence or recurrence of infection after surgery, and instrumentation provided immediate stability and protected against development of kyphotic deformity [51, 52].

The adherence properties of *Mycobacterium tuberculosis* to stainless steel was evaluated experimentally and was found to have very weak adherence and lacked biofilm formation [50]. Thus, after reconstruction with grafts alone or with cages, anterior instrumentation with a plate or rods is commonly used. Despite extensive usage, the disadvantages of anterior surgery in tuberculosis were lurking and included the morbidity of the approach, compromised lung function, graft-related complications and biomechanical concerns of using instrumentation in soft infected bones [53–56].

Combined anterior and posterior approaches

The last few decades have witnessed tremendous changes in concepts regarding the surgical approach to the focus of infection and the method of reconstruction using combined anterior and posterior approaches (**Fig. 8**). Children <10 years with extensive vertebral damage and those with thoracic disease were observed to be at particular risk of progressive kyphosis even after successful anterior reconstruction because of persistence of growth in the posterior elements [37, 57, 58]. Posterior in situ arthrodesis either prophylactically or as a salvage pro-

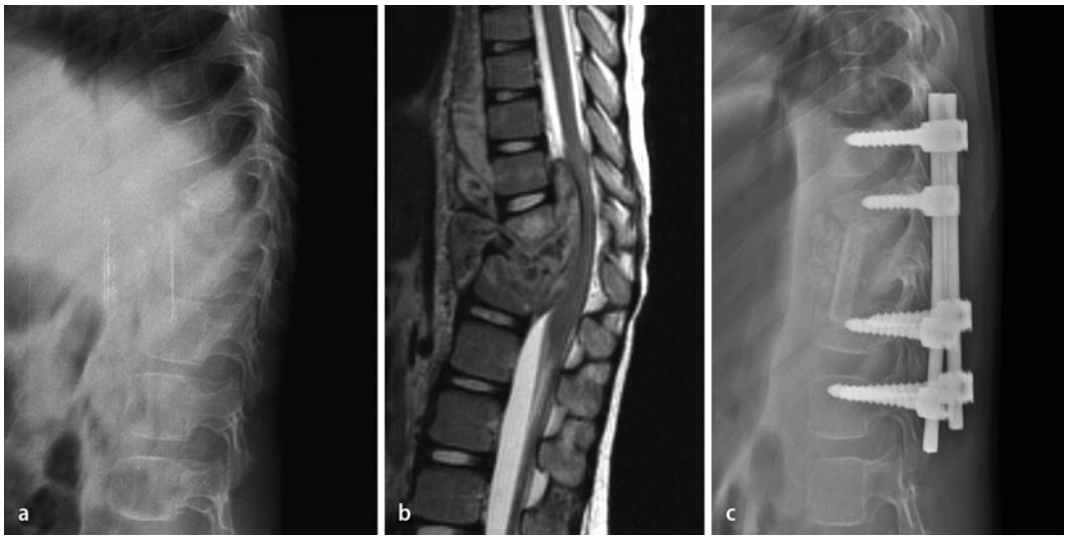

Fig. 8 ◀ Combined anterior and posterior reconstruction in a 12-year-old child with thoracolumbar tuberculosis. **a**, **b** Lateral radiograph and sagittal T2 MRI shows vertebral destruction, kyphosis, and epidural abscess formation causing cord compression, which has been treated by anterior decompression, debridement, reconstruction with fibular struct graft, and supplemental posterior pedicle screw stabilization

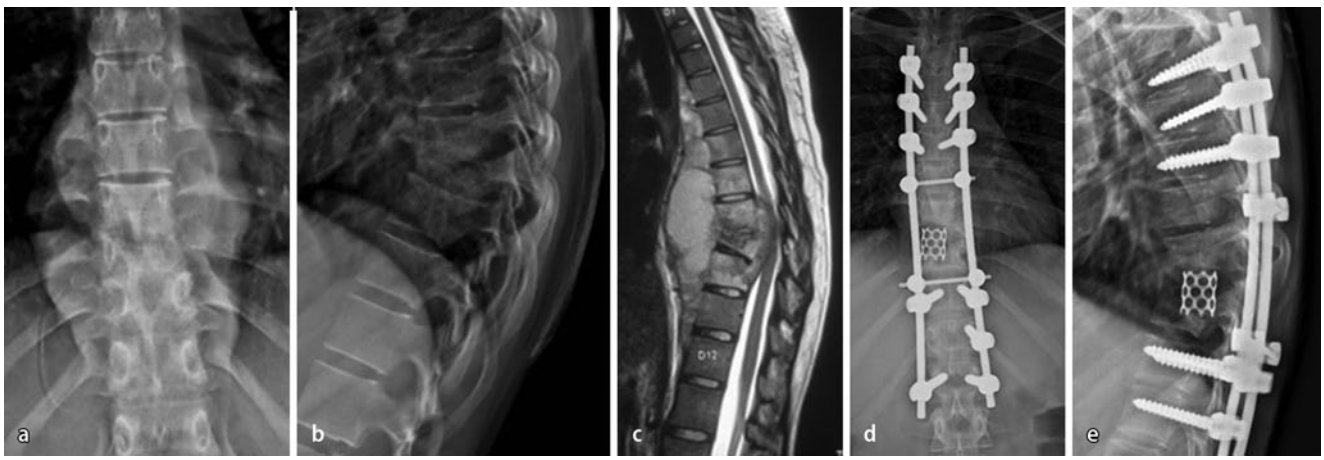

Fig. 9 ▲ **a**, **b** An 18-year-old girl with acute tubercular kyphosis seen as vertebral destruction and kyphosis from T7–9. **c** Sagittal MRI shows prevertebral abscess formation and epidural cord compression. **d**, **e** She was treated using posterior stabilization and anterior reconstruction through a costotransversectomy approach

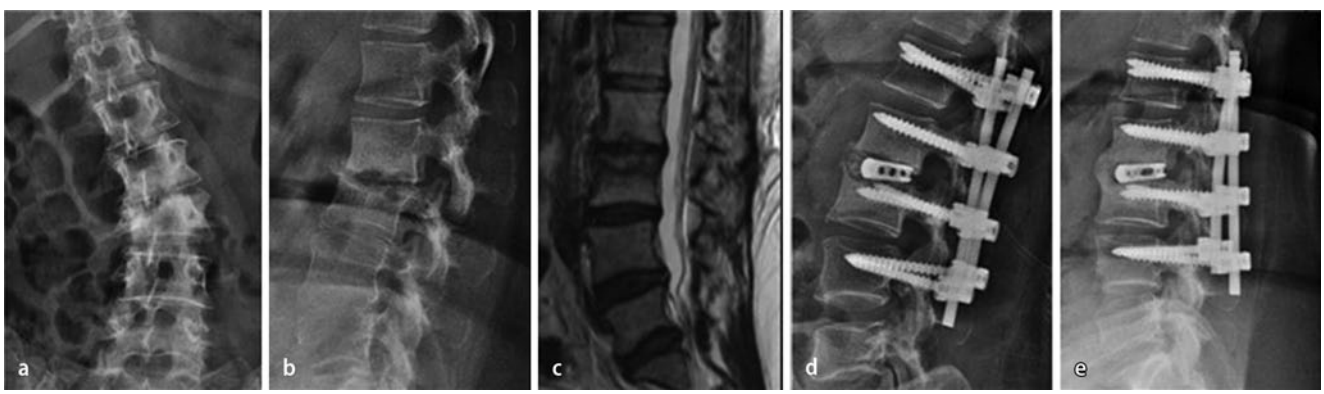

Fig. 10 ▲ **a**, **b** Anteroposterior and lateral radiographs show asymmetric collapse of L2–3 disc space and adjoining vertebrae. **c** Sagittal MRI shows the eroded disc space. **d** Posterior kyphosis correction with transforaminal reconstruction, which healed at 9 months (**e**)

cedure was advocated by several authors to prevent late kyphosis.

In adults, patients with thoracic lesions, marked preoperative kyphosis, and the use of rib grafting alone without instrumentation have also been associated with more severe late deformity after anterior surgery. This led to the advocacy of combined anterior debridement and reconstruction with supplemental posterior stabilization which nullified some of the disadvantages of isolated anterior surgery.

Moon et al. [59] described a two-stage procedure in which posterior instrumentation was performed first followed by anterior decompression and bone grafting 2–3 weeks later. Combined approaches can also be performed in a single stage with equivalent results. Sundararaj et al. [60] performed a single stage combined approach through two separate incisions and observed that the mean duration of the combined anterior and posterior single session surgery was 5 h with a mean blood loss of 1000 ml. However, the need to perform two surgeries on a physiologically compromised patient was a major deterrent for surgeons to opt for the combined approach in many patients.

All-posterior approaches

Recently the advances in spinal instrumentation techniques with the use of pedicle screw system and development of newer surgical approaches like transpedicular decompression and anterior reconstruction through the posterior approach have led surgeons to use an "all-posterior" approach for spinal tuberculosis. In an all-posterior approach, the spine is accessed and stabilized posteriorly with pedicle screws to segments above and below the lesion. Through the same posterior approach, the anterior column is reached through a transpedicular, transforaminal or a costotransversectomy approach (**Fig. 9**).

The safety of using a titanium pedicle screw system even in the presence of abscesses has enabled the extensive use of this system even in active spinal tuberculosis. Posterior alone surgery for spinal tuberculosis has become increasingly popular because of its advantages of familiarity of the approach, lower morbidity, excellent exposure for circumferential spinal cord decompression, easy instrumentation at multiple levels, better control of deformity correction, and simultaneous safe anterior reconstruction.

» Titanium pedicle screw system possible even in active spinal tuberculosis

In patients with early disease with less deformity, posterior transpedicular decompression with stabilization alone has been shown to provide immediate pain relief, prevent severe deformity, and neurological sequelae. Chacko et al. [61] treated 11 patients through transpedicular decompression alone without instrumentation and demonstrated good functional outcomes. In another study, Sahoo et al. [62] treated 18 patients with a posterior transpedicular decompression and screw fixation. Kyphosis improved from 17.7° to 11.6° at final follow-up.

In patients with advanced vertebral body destruction, the transpedicular/extrapedicular route can also be used to place bone grafts or an interbody cage to achieve deformity correction and anterior vertebral reconstruction. Zhang et al. [63] treated 14 patients with thoracic tuberculosis with one-stage all-posterior pedicle screw fixation, debridement and interbody fusion and reported significant improvement in kyphotic angles without any recurrence. Unlike the thoracic spine, where a posterolateral access is necessary to reach the anterior column, a direct transforaminal approach is used in the lumbar spine for debridement, decompression, and cage insertion (**Fig. 10**). In a study of 15 patients, Zaveri et al. [64] performed transforaminal debridement and interbody fusion along with posterior stabilization. All patients had good healing of the disease and there was no recurrence reported in their final follow-up.

Conclusion

Tuberculosis is an ancient disease. Management in ancient era was limited to constitutional treatment and manual reduction devices. The mortality and morbidity of the disease was high until the advent of antitubercular chemotherapy. Multidrug regimen enabled good disease clearance and also made direct surgical debridement possible without complications. It took many years before the effect of chemotherapy could be appreciated in skeletal tuberculosis. Konstam [65] aptly wrote "often it seems to me as if surgeons generally did not appreciate the full power of the new antitubercular drugs". Bosworth [66] showed that the mortality was reduced by 72.5 % by antitubercular drugs. Tuberculosis currently remains a disease that is predominantly treated with drug therapy, while surgical intervention is reserved for select situations. When indicated, direct anterior, all-posterior, or combined anteroposterior approaches can be used for debridement of diseased tissue, spinal cord decompression, and vertebral stabilization.

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Compliance with ethical guidelines

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