33 Tuberculosis

Z. Deniz Olgun, Muharrem Yazici,
David A. Spiegel, Syed Muhammad Awais,
and Binod Bijukachhe

General Principles

Tuberculosis continues to be a major public health problem globally and is commonly encountered in areas with crowding, malnutrition, poor sanitation, and where access to preventive and curative health services is scarce or absent.

Mycobacterium tuberculosis is transmitted through inhalation of airborne droplets disseminated by individuals with pulmonary tuberculosis. The microorganisms are ingested by alveolar macrophages, and the infection is either contained or develops into active disease. Active disease is most common in children younger than 5 years and adults with HIV/AIDS. The incidence of extrapulmonary tuberculosis is increasing due to the increase in the prevalence of HIV/AIDS.

Musculoskeletal involvement is diagnosed in less than 10% of all cases of tuberculosis, and 50% of these patients have spinal involvement. Tissue destruction in tuberculosis is caused by a delayed hypersensitivity reaction, leading to inflammation, tissue exudation, and liquefaction, producing a cold abscess. These can migrate along tissue planes and exit the skin at sites remote from their origin, such as those from the spine draining through the inguinal or gluteal region (Fig. 33.1a, b). Though uncommon, multiple osseous and/or articular sites can occur in patients with significantly impaired host defenses. As the prognosis relates to the stage of disease at the time of presentation, early diagnosis and treatment improves patient outcomes.

Principles of Diagnosis

A diagnosis requires a high index of suspicion, especially in areas where the disease is not prevalent. Bone and joint tuberculosis is usually an indolent, slowly progressive disease, with patients often presenting with nonspecific consti-

Z. D. Olgun (✉)
Department of Orthopedic Surgery, Children's Hospital of Pittsburgh of UPMC, Pittsburgh, PA, USA

M. Yazici
Orthopedics and Traumatology, Hacettepe University, Ankara, Turkey

D. A. Spiegel
Division of Orthopedic Surgery, Children's Hospital of Philadelphia, University of Pennsylvania School of Medicine, Philadelphia, PA, USA

Hospital and Rehabilitation Centre for Disabled Children, Banepa, Kavre, Nepal
e-mail: spiegeld@email.chop.edu

S. M. Awais
Department of Orthopedics, Spine and Traumatology, King Edward Medical University and Mayo Hospital, Lahore, Punjab, Pakistan

B. Bijukachhe
Department of Orthopedics, Grande International Hospital, Kathmandu, Nepal

R. A. Gosselin et al. (eds.), *Global Orthopedics*, https://doi.org/10.1007/978-3-030-13290-3_33

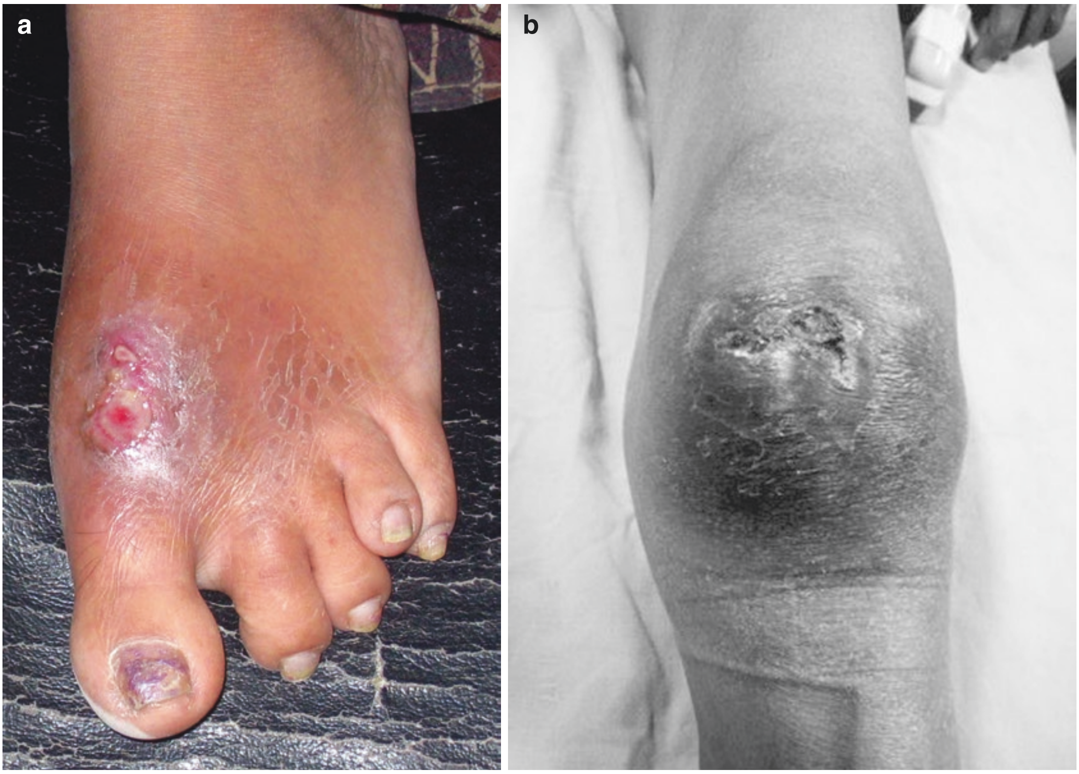

Fig. 33.1 (**a**, **b**) Sinuses often form as a complication of musculoskeletal tuberculosis. (Reprinted with permission from Spiegel et al. [16])

tutional symptoms such as low-grade fevers, night sweats, weight loss, anorexia, anemia, and malaise. Lymphadenopathy is common. Extremity involvement may present with localized pain and increased warmth, soft tissue swelling or effusion, loss of motion, and limp or gait disturbance. The initial evaluation includes a chest radiograph, complete blood count, and ESR. Normal acute phase reactants do not rule out the presence of tuberculosis. The purified protein derivative (PPD) tuberculin skin test is often positive in endemic areas or in patients who have received the BCG vaccination and does not correlate with active disease.

The microbiologic diagnosis of tuberculosis in austere settings depends on the evaluation of sputum smears, and smears and cultures of biopsy specimens, using Ziehl-Neelsen and Auramine O stains. Acid fast bacilli and granulomas seen on direct microscopy lead to the fastest diagnosis but are present in less than 50% of cases. A formal biopsy may be difficult to obtain especially in those with spinal involvement. Cultures are positive in up to 90% but often take 6–8 weeks to become positive.

Treatment Principles

Chemotherapy remains the mainstay of treatment for all forms of tuberculosis and is generally effective in 90% of cases. Surgery is indicated for (1) establishing the diagnosis and (2) treating complications of the disease. Ideally a biopsy and culture should guide therapy, but this is impractical in low-resource environments. Empiric chemotherapy is provided in many cases when the characteristic clinical and radiographic features are present. In previously untreated adults without known drug susceptibility, rifampin and isoniazid should be used throughout the duration of therapy, and another first-line drug, streptomycin or ethambutol, is chosen for the first 2 months along with one second-line drug.

Most patients with active TB are treated with 6–9 months of therapy [1, 2], though some practitioners favor treating spinal disease for 12–18 months. The WHO treatment guidelines should be followed [2], and systems for monitoring compliance, such as DOTS – directly observed therapy, short course – should be in place. A longer duration of chemotherapy may be indicated with documented cases of relapse and in patients who exhibit signs of persistent inflammation, known as slow responders. Specific recommendations are available for patients with recurrent disease and active disease associated with HIV/AIDS. In contrast to abscesses associated with bacterial sepsis, cold abscesses may resolve with chemotherapy, and drainage is not routinely required. Bacterial superinfection should be suspected when a sinus track fails to close following an adequate course of chemotherapy.

Lack of adherence to treatment with chemotherapy commonly leads to the development of resistant strains that are more difficult and costly to treat. DOTS regimens have been developed to counter this but require intense resources, which are often lacking. Screening for drug toxicity is limited, and patient education about side effects and potential complications of treatment is crucial.

Multidrug-resistant TB is defined as resistance to isoniazid and rifampicin, while extensively drug-resistant tuberculosis describes resistance to isoniazid, rifampicin, and several second-line drugs [3]. Most of these resistant cases reflect the failure of the system to provide the correct medications and dosages and to monitor treatment. The incidences of these worrisome entities are on the rise.

Osteomyelitis

Osteomyelitis is the least common form of musculoskeletal TB (5%), and the presentation is similar to subacute hematogenous osteomyelitis. Clinically, patients present with pain and soft tissue swelling, and both abscesses and sinuses are common. Most patients are adequately imaged with plain radiographs.

The differential diagnosis on plain radiographs is extensive and includes chronic osteomyelitis, Brodie's abscess, benign and malignant tumors, and other granulomatous diseases. While a lytic lesion with or without a sclerotic rim is the most common presentation, lesions may be serpiginous, commonly cross the physis, and may readily invade neighboring joints (Fig. 33.2a–d). An aggressive periosteal response can also be observed, and in such cases a biopsy is mandatory.

Sequestrae are unusual but can be present. The entire diaphysis can become sequestered in children due to intraosseous thrombosis. Disseminated skeletal tuberculosis can be observed in compromised hosts, involving combinations of osseous and articular involvement. Tuberculous dactylitis, spina ventosa, occurs in the short tubular bones of the hands and feet. X-rays show multiple layers of subperiosteal new bone, a finding diagnostic for tuberculosis (Fig. 33.2d).

Given this diversity in plain radiographs, a biopsy is helpful in establishing the diagnosis, recognizing that under selected circumstances empiric treatment is considered. While curettage is recommended at the time of biopsy, bone grafting is rarely required as the lesions heal with chemotherapy. In severe and recalcitrant lesions, antibiotic-loaded bone cement (polymethyl methacrylate PMMA) spacers may be considered as well. While rifampin has been shown to be unsuitable for delivery through bone cement, isoniazid and streptomycin have shown beneficial elution parameters [4].

Arthritis

The natural history of TB arthritis progresses over several years, beginning with synovial seeding or direct penetration from a metaphyseal focus and culminating with joint destruction. The host inflammatory response results in synovial hypertrophy and an effusion, although adult patients may present with minimal effusion, called dry or "sicca" arthritis. At this point, plain radiographs demonstrate periarticular osteopenia due to the hyperemic inflammatory response (Fig. 33.3). Granulation tissue develops at the

Fig. 33.2 While TB osteomyelitis is variable in radiographic appearance, (**a**) one common presentation is an ill-defined metaphyseal lucency which crosses the physis. (**b**) In this example there is an expansile lesion with a smooth periosteal reaction. (**c**) TB in the foot typically involves both osseous and articular structures. In this case there is involvement of the navicular, medial cuneiform, and lateral cuneiform, as well as the joints between these tarsal bones. (**d**) Tuberculous dactylitis or spina ventosa. (Reprinted with permission from Spiegel et al. [16])

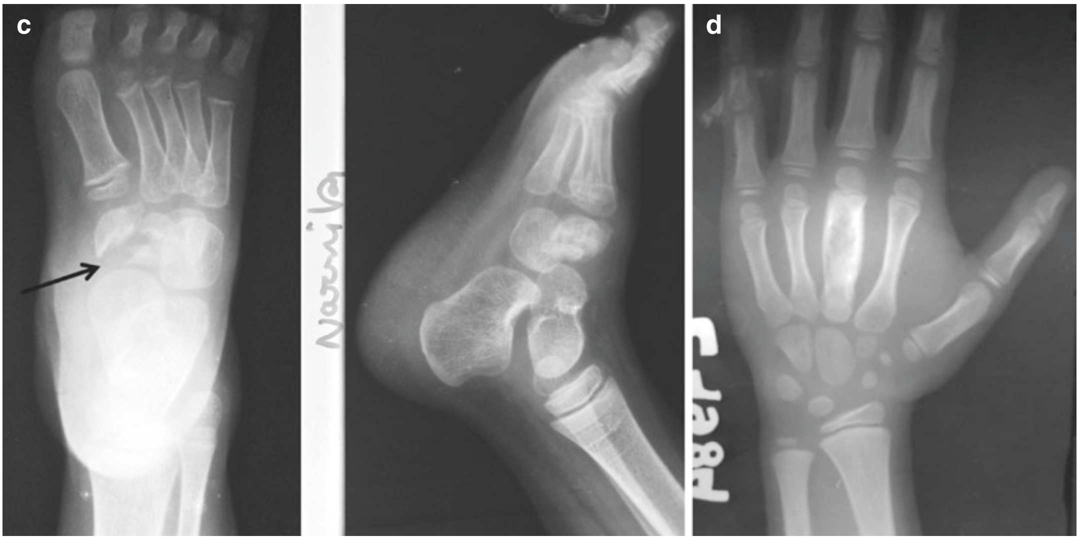

Fig. 33.2 (continued)

joint periphery leading to marginal erosions. As the disease progresses, this tissue extends across the joint surface directly damaging the articular cartilage (Fig. 33.4a, b). Other osseous abnormalities include osteophytes, chondrocalcinosis, and loose bodies. Ultimately, destruction of the joint occurs with or without subluxation or dislocation (Fig. 33.5a–c). Joints may also become ankylosed, often in a nonfunctional position.

The time course and evolution of pathologic changes are similar to that of an untreated chronic inflammatory arthropathy. Less common entities such as pigmented villonodular synovitis may also be confused with tuberculous arthritis, requiring a biopsy.

The clinical consequences are most profound in the larger, weight-bearing joints, especially the hip. Shanmugasundaram has classified the spectrum of morphologic abnormalities associated with mycobacterial hip disease into seven categories [5] (Fig. 33.6).

Other than biopsy, surgical intervention addresses complications of the disease, and procedures include synovectomy with or without joint debridement, osteotomy, arthrodesis, excisional arthroplasty, pelvic support osteotomy, and total joint arthroplasty.

During the early stages of TB arthritis, when changes are potentially reversible, treatment focuses on controlling discomfort with rest and restoring and maintaining ROM and strength. Adjunctive measures such as physical therapy, traction, serial casting, and/or splinting may help achieve or maintain motion, prevent deformity, provide comfort, and enhance strength. Weight-bearing is encouraged when comfort and an adequate ROM allow. The prognosis is excellent in the early stages, and the indications for synovectomy, with or without joint debridement, remain controversial.

Irreversible changes in the joint occur in the later stages, and salvage procedures can improve function. In cases where ankylosis is expected, the goal for some joints (wrist, knee, foot, and ankle) is to maintain a functional position by splinting or casting. When ankylosis would result in a decrease in function, for example, in the elbow, an excisional arthroplasty can be considered (see Chap. 41). When a joint becomes ankylosed in a nonfunctional position, osteotomy can realign the limb.

Fig. 33.3 Tuberculous arthritis. (**a**) Knee joint involvement during later stages is evidenced by significant synovitis with effusion, which may be complicated by flexion contracture and posterior subluxation of the tibia. Plain radiographs demonstrate (**b**) osteopenia and (**c**) soft tissue swelling early in the disease process

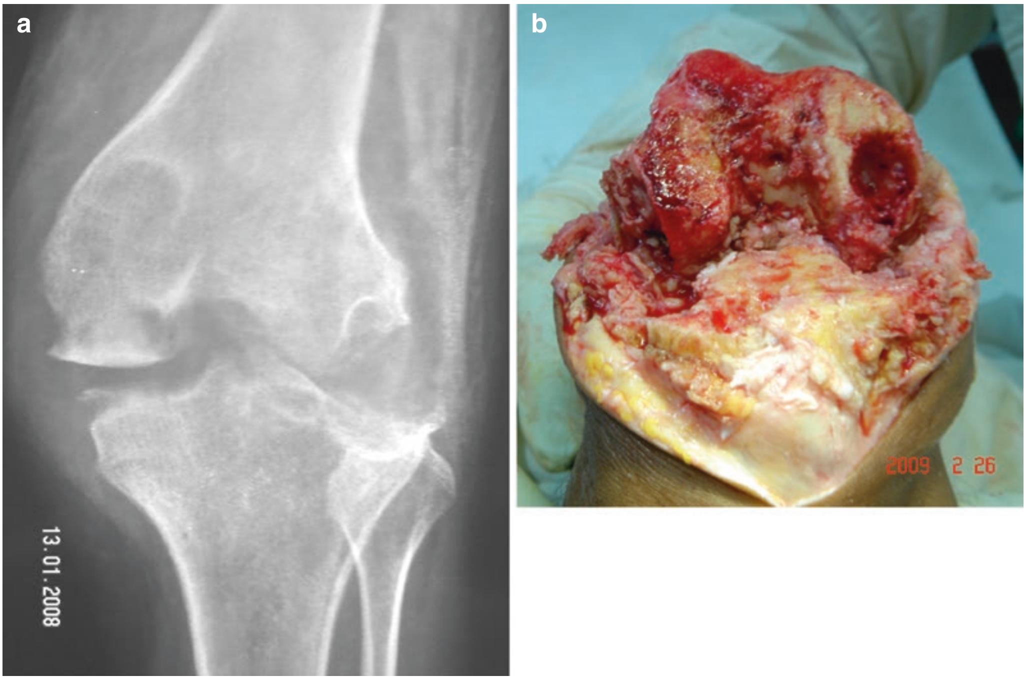

Fig. 33.4 (**a**, **b**) Proliferation of synovial granulation is followed by marginal erosions

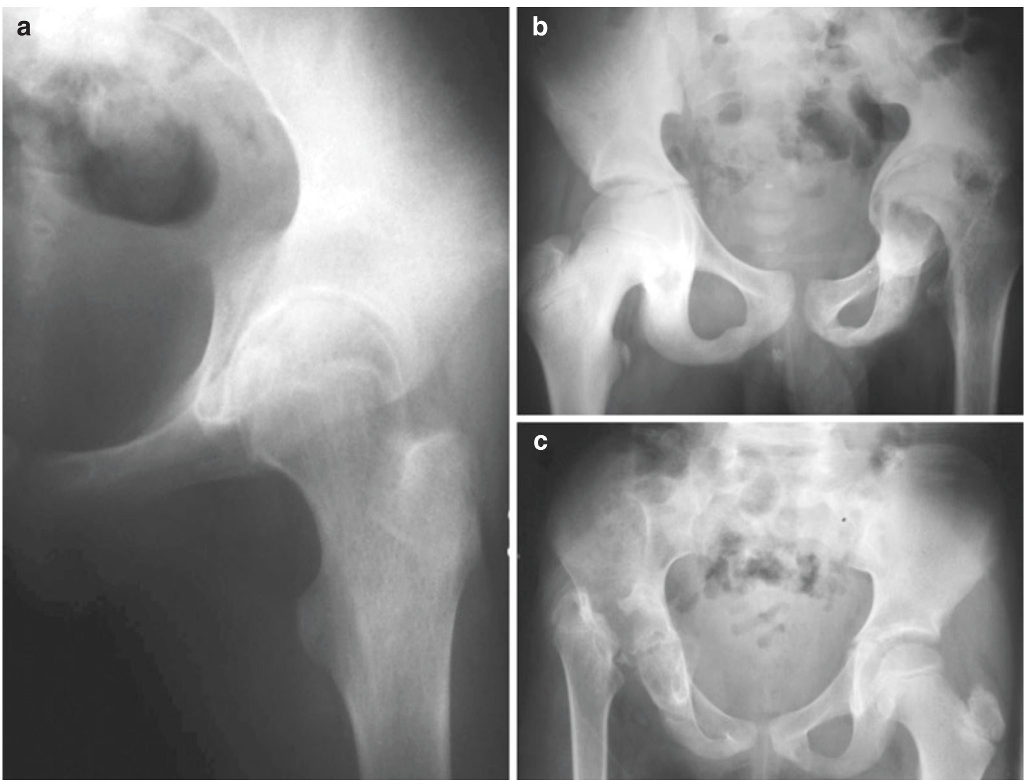

Fig. 33.5 Ultimately, there are destructive changes within the joint, for example, (**a**) narrowing of the joint space, (**b**) protrusion with destruction of the femoral head and acetabulum, and (**c**) loss of the femoral head and neck

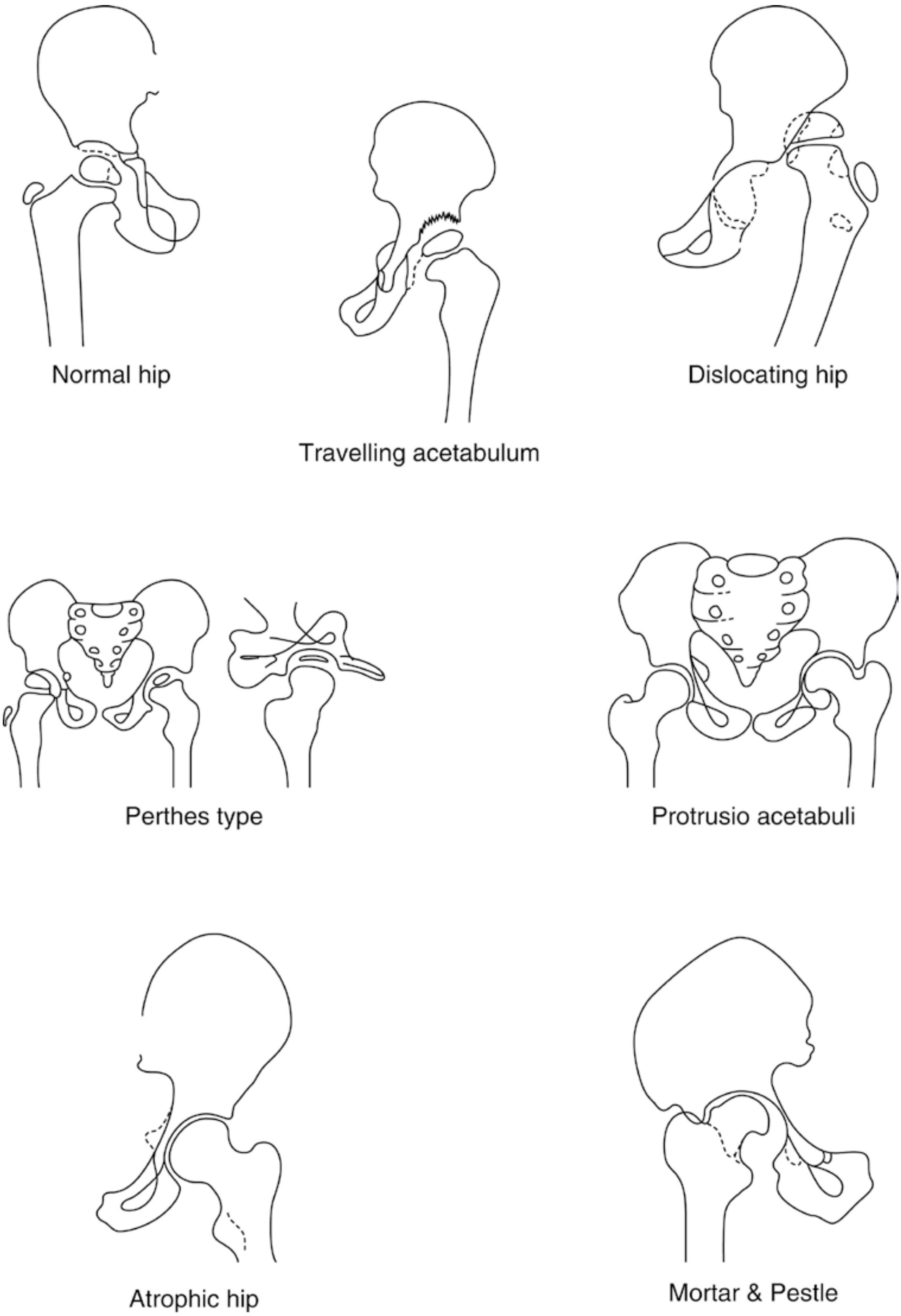

Fig. 33.6 Shanmugasundaram has classified the spectrum of morphologic abnormalities associated with hip disease. Generalized hyperemia, likely associated with a mild form of avascular necrosis, presents as the "Perthes" type in which there is coxa magna. Involvement of the acetabular roof is classified as a "traveling acetabulum," while the "protrusio" type occurs with lesions in the acetabular floor. Destructive changes on both the femoral and acetabular sides of the joint commonly result in joint incongruity "mortar and pestle." The "atrophic" subtype involves symmetric thinning of the joint space and may be confused with rheumatoid arthritis. The joint may also become dislocated, "dislocating" subtype

With hip involvement, the context will determine whether the goal is stability or motion. Hip arthrodesis can reliably reduce pain and restore alignment but produces increased stresses at the knee and lumbar spine that can lead to degenerative changes over the long term (Fig. 33.7a–d). Excisional arthroplasty will improve motion at the expense of stability, and the resulting gait disturbance can be significant. When the hip has autofused in a nonfunctional position and arthrodesis is an acceptable solution, an osteotomy can reposition the limb (Fig. 33.8a–d). Pelvic support osteotomy should be considered when retention of motion is desirable. When the resources are available, total joint arthroplasty is an option, along with prophylactic chemotherapy to reduce the risks of disease reactivation.

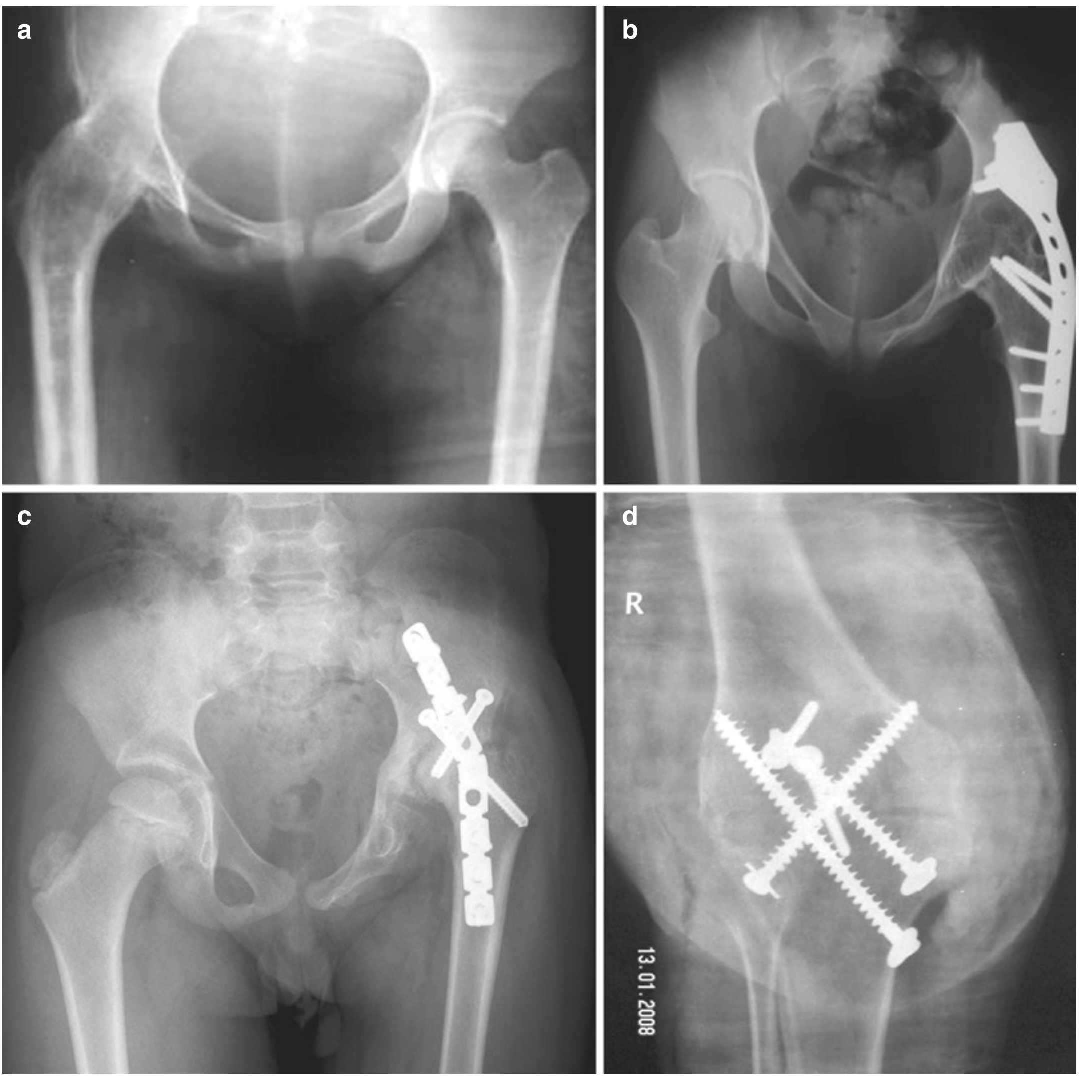

Fig. 33.7 Many options are available for salvage in the late stages of TB arthritis. (**a**) Arthrodesis provides excellent pain relief but may be undesirable depending on the demands of daily living. Arthrodesis of the hip can be achieved with debridement and spica cast application in younger children; fixation is required in adolescents and adults. (**b**) Internal fixation with a cobra plate via a posterior approach or (**c**) an anterior approach with screw and plate fixation. (**d**) This knee fusion was performed with screw fixation alone

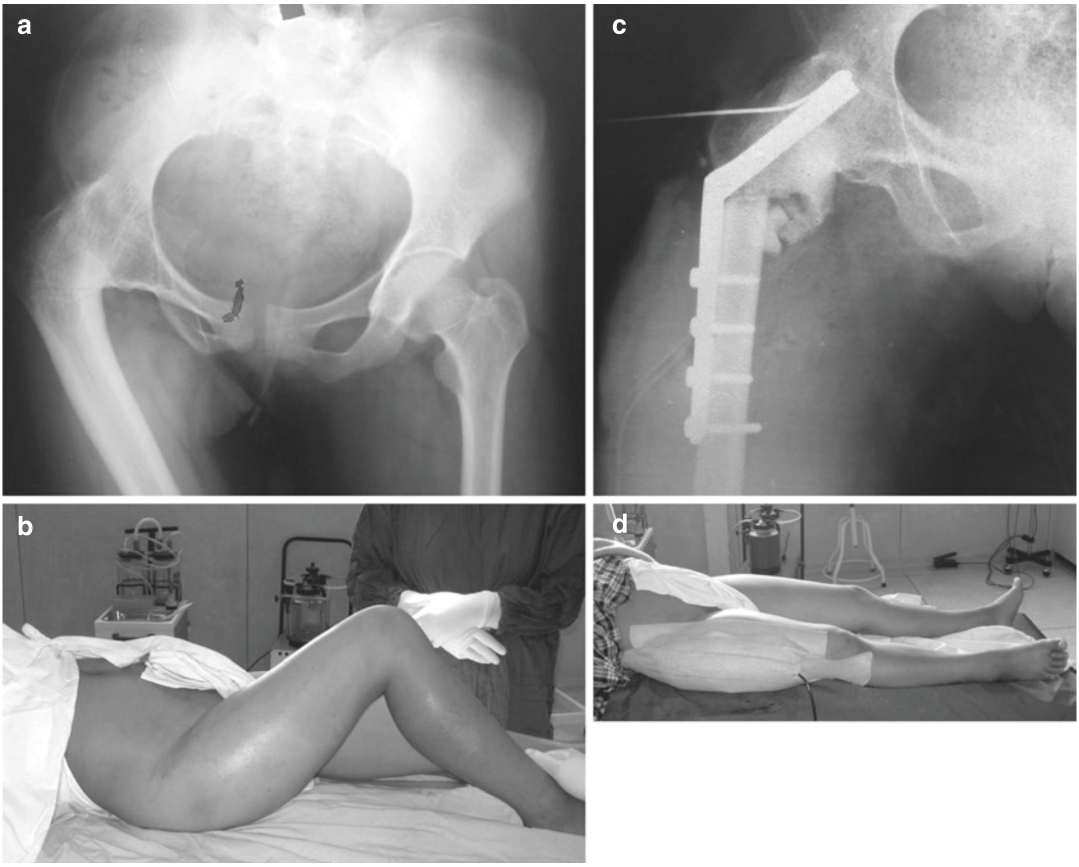

Fig. 33.8 (**a**, **b**) This adolescent presented with an awkward gait owing to spontaneous fusion of her right hip in severe flexion and adduction. (**c**, **d**) A realignment osteotomy was performed to place the extremity in a more favorable position. The inequality in limb lengths can be addressed at a later stage if her discrepancy is symptomatic

TB arthritis of upper extremity joints is uncommon. Involvement of the shoulder results in a fixed adduction contracture. Arthrodesis can eliminate pain and instability. Surgical treatment options for the elbow include synovectomy, but once destructive changes are present, excisional or fascial arthroplasty, or rarely arthrodesis (in a heavy laborer), may be required (see Chap. 41). Wrist involvement often spreads to the carpal bones and tendon sheaths, producing a flexion deformity. Early management includes splinting or immobilization. While synovectomy and debridement may be helpful before significant destructive changes have occurred in the wrist, most cases require arthrodesis for salvage.

Spondylitis

The spine is involved in approximately 50% of cases of osteoarticular TB. The main surgical concerns are preservation of neurologic function and prevention and treatment of kyphotic deformities. Much of the recent literature on this subject has come from centers with state-of-the-art capabilities, and the challenge is to adapt this knowledge to austere settings.

Pathophysiology and Natural History

Tuberculosis reaches the spine by hematologic dissemination from a pulmonary or genitourinary source, often through Batson's venous plexus, and commonly affects the thoracic or thoracolumbar spine. Direct extension from the lungs is rare. Three patterns of infection have been defined: paradiscal (most common), central, and anterior.

Bacilli lodge in the well-vascularized vertebral endplates and can spread beneath the anterior longitudinal ligament, the psoas sheath, or spinal canal, sparing the disk spaces early in the disease. While involvement of the anterior portions of the vertebral bodies results in multilevel spinal abscesses, involvement of the central portion of the vertebra can lead to loss of anterior column support and progressive collapse into kyphosis. Isolated posterior involvement is rare, as is panvertebral disease. Loss of stability may occur due to pathologic fracture or circumferential disease. Cold abscesses can present as a soft tissue mass in the axilla (Fig. 33.9), flank, groin, or buttock and spontaneously exit the skin as a sinus.

The natural history of spinal disease is described in three stages [6]. Stage one lasts from 1 to 12 months. The second stage may last up to 3 years and is characterized by abscess formation and bony destruction. The third or healing stage occurs when the vertebrae ankylose (Fig. 33.10). Approximately 30% of patients do not survive to this last stage. Nonunion suggests either recurrence of active disease or superinfection by pyogenic bacteria, both of which are associated with an unfavorable outcome.

Ten percent of patients present with neurologic involvement, most commonly Pott's paraplegia [7]. Cord compression in "early-onset" paraplegia is due to pus, granulation tissue, and/or sequestrae. In contrast, "late-onset" paraplegia is most often due to direct bony compression over the sharp internal gibbous, calcified caseous material or fibrous tissue bands around the spinal cord. The prognosis is much better for early-

Fig. 33.9 This adult female developed a swollen lump in her left axilla that is mildly erythematous and non-tender. It proved to be a cold abscess from spinal tuberculosis

Fig. 33.10 This teenager was treated medically for TB but developed a severe kyphosis, with progressive collapse and fusion at the apex

onset paraplegia, except when there is direct dural invasion. A kyphotic deformity may progress despite successful treatment of active disease, even after skeletal maturity, and lead to paraplegia.

Patient Evaluation

Back pain is the most common presenting symptom and is generally less severe when compared with pyogenic spondylitis. The pain follows an indolent course, often increasing noticeably at night and becoming gradually worse as the spine becomes mechanically unstable. Gait changes and subtle neurologic abnormalities due to myelopathy can be seen at the time of presentation. Constitutional symptoms are often present. The physical examination should include a meticulous neurologic examination; skin examination for masses, cold abscesses, enlarged lymph nodes, or sinuses; and the evaluation of spinal alignment.

Highly elevated white blood cell counts, CRP levels over 5 mg/dl, ESR levels over 40 mm/h, and levels of alkaline phosphatase (ALP) over 120 IU/l are more commonly associated with pyogenic spondylodiscitis, while the laboratory results for TB are both less marked and specific. This makes a high index of suspicion based on the presence of active TB of other organs, a history of longer diagnostic delays, and involvement of more than three spinal levels important in the differential diagnosis [8].

The radiographic differential diagnosis includes brucellosis, atypical mycobacteria, fungal, pyogenic discitis, vertebral osteomyelitis, and both primary and secondary spinal tumors. Plain radiographs are usually all that are available in austere settings.

Generally, two or three spinal levels are involved, and noncontiguous sites are reported. Localized osteopenia is the first sign and may be associated with loss of definition at the vertebral endplates. The disk space is commonly preserved early in the disease but becomes obliterated later. Scalloping of multiple anterior aspects of vertebral bodies, aneurysmal syndrome, can be observed. A loss of vertebral body height commonly occurs due to tissue destruction and collapse (Fig. 33.11). Radiologic findings suggestive of an abscess include fusiform soft tissue swelling (Fig. 33.12) or asymmetry or loss of the psoas shadow.

Destruction of the anterior vertebrae at multiple levels leads to a progressive kyphosis (Fig. 33.13a–c). Factors influencing kyphotic development include thoracic location, pediatric patients, and the pretreatment angle of kyphosis (Cobb angle). Rajasekaran et al. have identified four radiological features that may predict progression of kyphosis: (1) facet dislocation, (2) lateral translation, (3) retropulsion of the vertebral body, and (4) toppling of one vertebra over another [9, 10] (Fig. 33.14). They suggest that two or more findings require stabilization. Multilevel involvement with disk space sparing is seen with metastatic disease; however there are no paraspinal abscesses. It is difficult to distinguish tuberculous spondylodiscitis from that caused by atypical mycobacteria or fungi on radiologic and clinical findings alone.

Although rarely available in the settings where spinal TB is most common, MRI remains the most valuable imaging modality, showing abscess formation (Fig. 33.15a–d) and the involvement of structures around the spine. MRI is also the only modality that helps distinguish spondylitis of different etiologies.

Treatment

The goal of the treatment is to eradicate the disease, prevent or treat any deformity, and preserve or improve neurologic function. The prognosis depends on the timing of diagnosis and the efficacy of treatment.

Outpatient chemotherapy is as effective as surgical debridement in uncomplicated cases [11], even those with stable, mild paraparesis. There is no added benefit from bed rest or immobilization, as these are ineffective in preventing deformities when instability is already present. Adequate medical management may not prevent kyphotic deformities and the cosmetic, func-

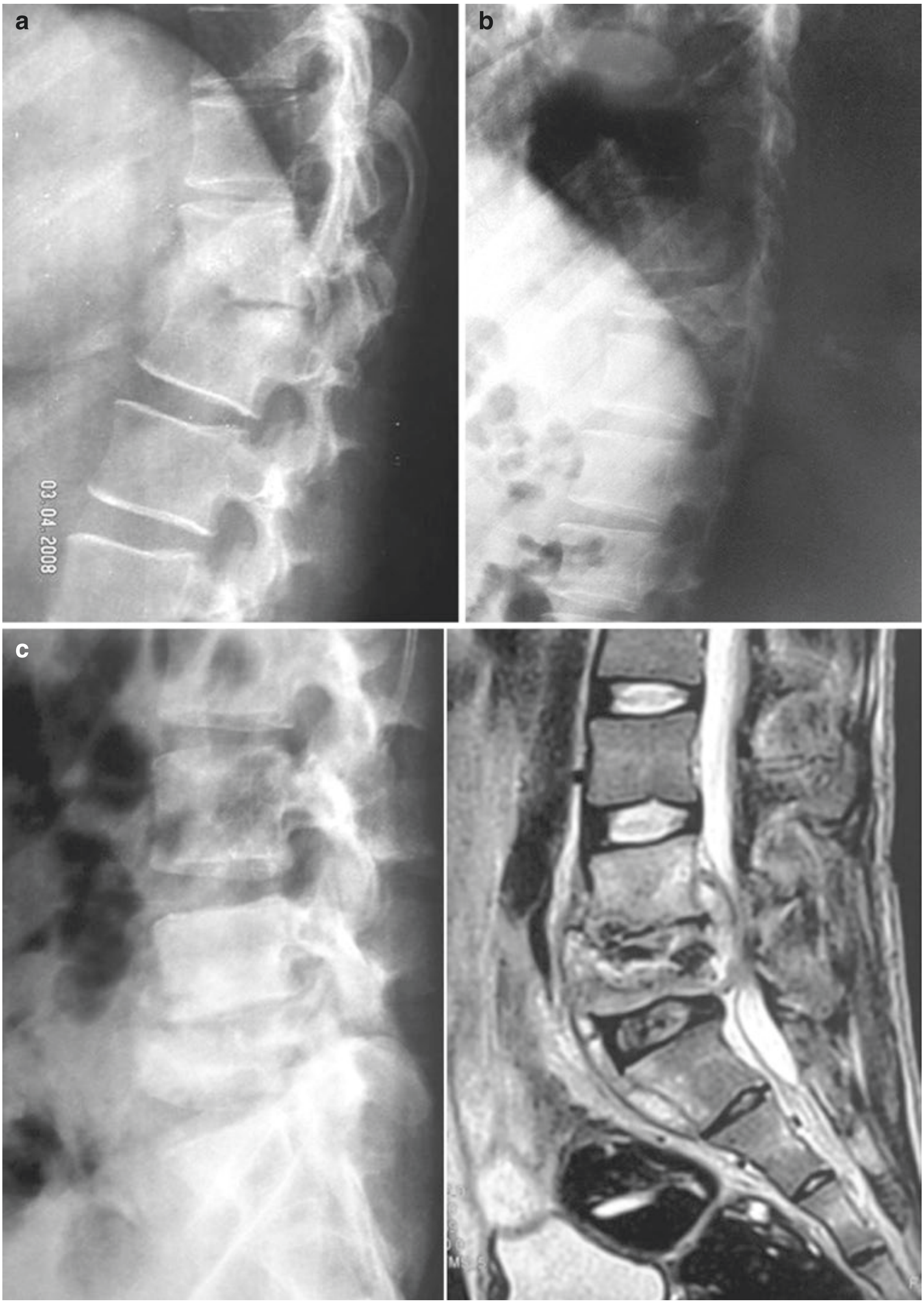

Fig. 33.11 (**a**) TB of the spine usually involves the anterior portion of the vertebra. Inflammation and bony resorption predispose to a progressive kyphotic deformity. (**b**) In some patients the central portion of the vertebra is more involved, resulting in central collapse, giving the appearance of vertebra plana. (**c**) Collapse of the L4 vertebra into L5 (plain radiograph on *left*, MRI on *right*), with the MRI demonstrating abscesses and retropulsion of debris/caseous material

tional, and neurologic complications that follow. Radiographic changes can progress for more than a year after treatment is started and should not be mistaken for the failure of medical treatment.

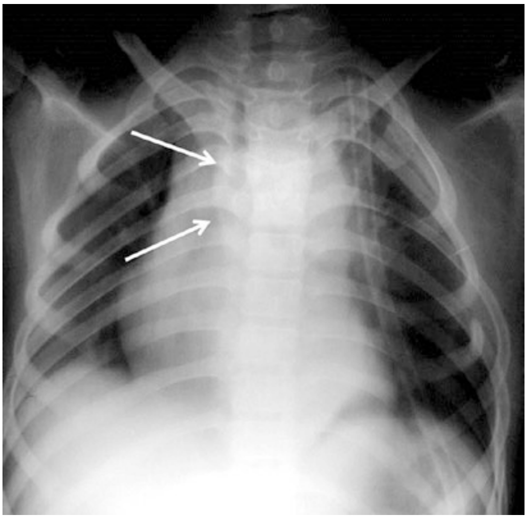

Fig. 33.12 Thoracic paraspinal abscesses appear as oval soft tissue densities adjacent to the spine on a chest radiograph (*arrows*), sometimes with calcifications within the wall of the abscess

Surgical treatment is reserved for establishing the diagnosis and treating complications of the disease, such as progressive or profound neurologic deficits, or patients with or at high risk for progressive kyphotic deformity. In the past surgical treatment for TB spondylitis consisted of thorough debridement of necrotic tissue; decompression of the neural elements; microbiologic assessment of specimens, if not done previously; and stabilization by instrumentation and fusion. Though stabilization can be accomplished using a variety of approaches (Table 33.1), in the last 10 years, there has been a shift toward posterior-only procedures, even with extensive bone destruction and/or deformity (Fig. 33.17a–c). The posterior approach offers less morbidity and independence from requiring other specialties providing exposure. The original "Hong Kong" procedure that involved anterior debridement and strut grafting (Fig. 33.16a–e), to restore anterior column integrity, is used less commonly since the introduction of three-column fixation through transpedicular screws, and pure anterior approaches have been largely abandoned.

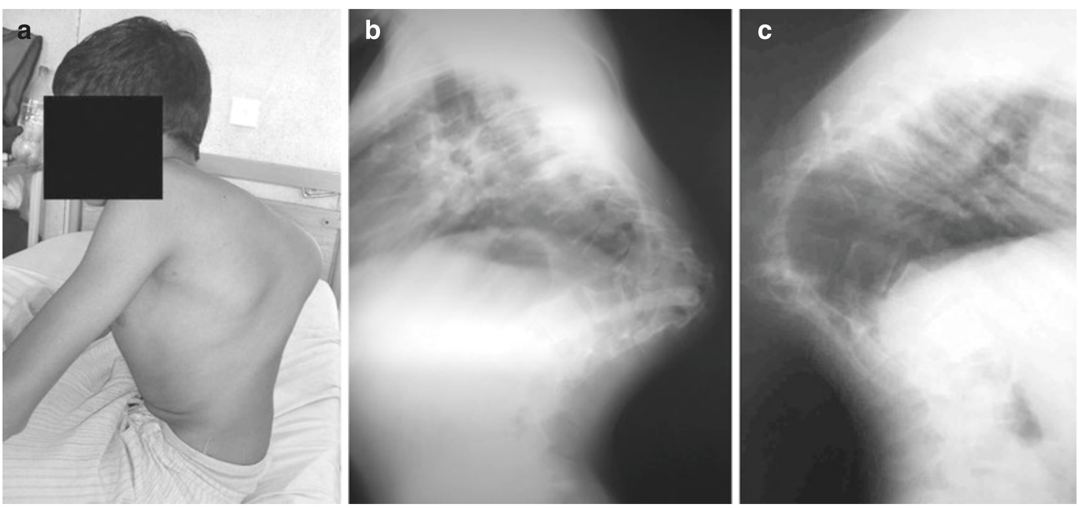

Fig. 33.13 (**a**–**c**) The treatment of severe kyphotic deformities is technically difficult, and treatment is associated with a high risk of complications, especially in patients with "healed disease"

Fig. 33.14 This child developed spinal instability, including two of the four Rajasekaran criteria, lateral vertebral translation and "toppling over"

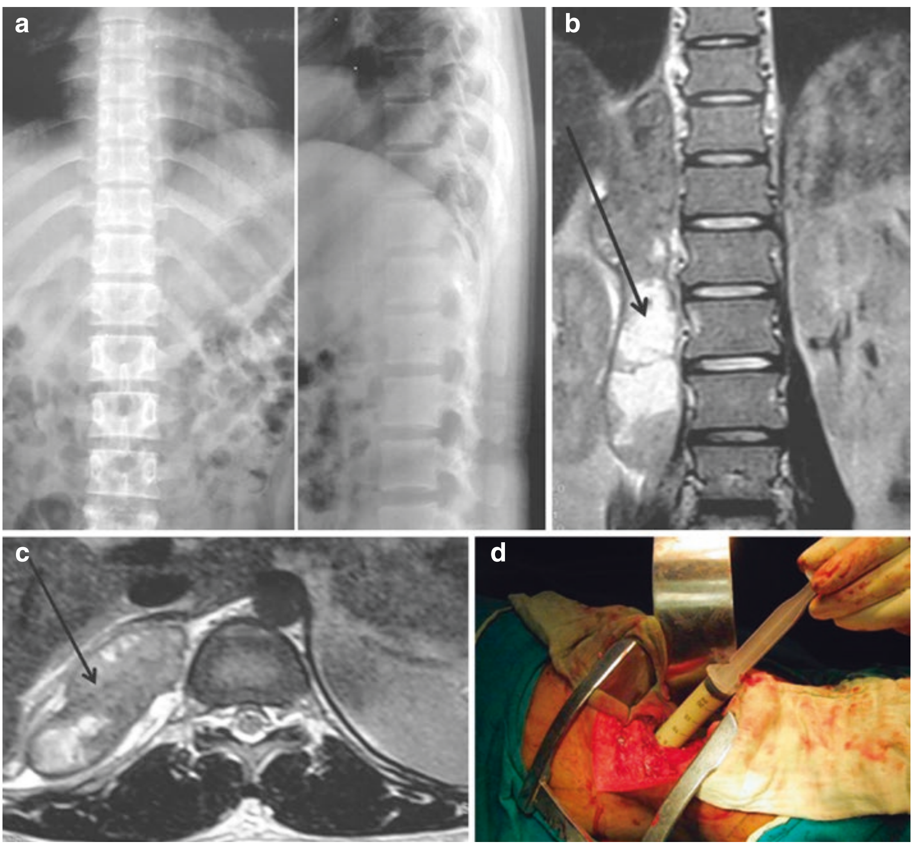

Fig. 33.15 (**a**) This patient had no evidence of an abscess or bony destruction on plain radiographs; however (**b**, **c**) an MRI scan revealed a large abscess adjacent to the lumbar spine, *arrows*. (**d**) An extraperitoneal approach was used to drain the abscess

Table 33.1 Surgical procedures used in the treatment of spinal tuberculosis

Surgical procedures	Indications/advantages	Disadvantages
Costotransversectomy	Abscess drainage in medically debilitated patients	Cannot decompress or perform an arthrodesis
	Less morbidity	
Lateral extrapleural approach (extracavitary)	Decompression and fusion Extrapleural	Greater challenge if instrumentation is planned
Anterior decompression and fusion with or without instrumentation	Direct visualization	Requires thoracotomy and/or taking down of the diaphragm
	Can perform wide decompression or debridement	Higher risk graft failure/nonunion if >2 segments spanned disk spaces and no instrumentation
	Does not destabilize posterior structures	Difficult to visualize apex in sharp angular kyphosis
Anterior and posterior decompression and fusion	Circumferential disease	Higher morbidity and/or risk of complications
Posterior spinal fusion followed by anterior spinal decompression and fusion	Neurologically normal with high risk of future deformity progression stabilize prior to debridement and grafting	Two stages required
Isolated posterior spinal fusion	Mild kyphosis with significant growth remaining	Posterior tethering, gradual restoration of alignment (reduction in kyphosis) with continued anterior spinal growth
Laminectomy	Isolated disease of posterior elements (rare) extramedullary or intradural disease	Risks destabilizing the spine if there is anterior column involvement
Posterior approach for debridement, grafting, and instrumentation	Eliminates need for anterior procedure	Technically demanding
	Shortens the spine	Higher risk of complications
Anterior +/− posterior release, traction, then instrumentation/ fusion	Severe deformities with healed disease	High risk of complications
		Three to four procedures required
		Resource intensive
Resection of internal gibbus (apex of kyphotic deformity)	Severe deformities with healed disease, neurologic dysfunction	Very high risk of complications such as paralysis or neurologic deficit

Most surgeons prefer a posterior stabilization extending two to three segments above and below the pathology. In cases where bone destruction is not extensive and only drainage is required, an ultrasound or CT-guided biopsy can be followed by posterior instrumentation and fusion if instability is suspected. Good results have been reported with effective chemotherapy and the posterior-only approach without extensive debridement, calling the need for debridement into question [12]. Some authors have suggested a posterior approach initially, reserving the anterior approach only for patients who fail to improve. In the setting of neurologic deficit, posterior decompression in the form of laminectomy should be considered (Wang et al.). Posterior trans-pedicular instrumentation also appears to provide better correction and maintenance of kyphosis [13].

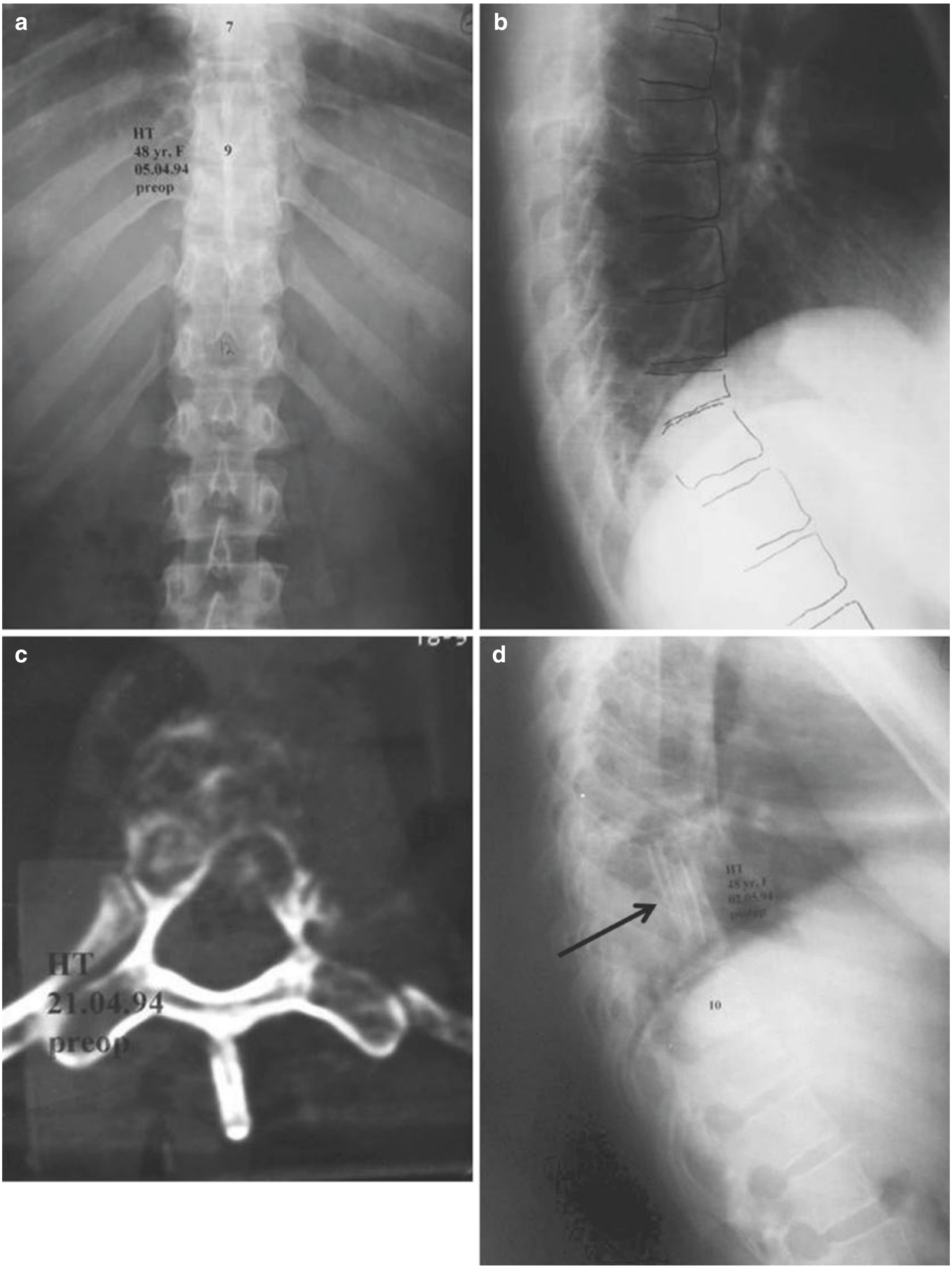

Fig. 33.16 Hodgson and colleagues popularized the anterior debridement and strut grafting for spinal tuberculosis. (**a**–**c**) This adult patient initially had involvement at three adjacent levels with mild collapse at a single level and (**d**, **e**) was treated by the Hong Kong procedure. Several strut grafts (*black arrows*) were placed from T8-T9, across the diseased vertebrae, following spinal cord decompression and debridement of abscess and bony debris

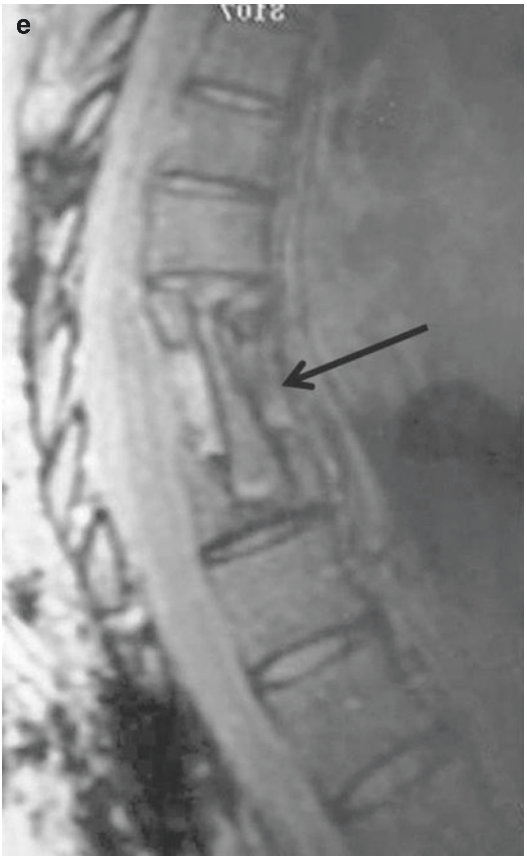

Fig. 33.16 (continued)

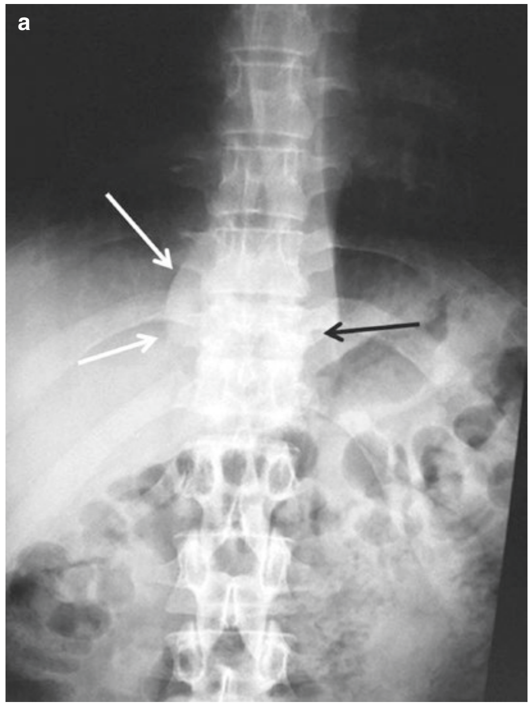

Fig. 33.17 (**a**, **b**) This 24-year-old male had severe collapse of a lower thoracic vertebra with relative preservation of the superior and inferior disc spaces (*black arrow*), a paraspinal abscess (*white arrows*), and was (**c**) treated by a posterior-only approach involving decompression/debridement, placement of a cage for anterior column support, and segmental posterior instrumentation extending two vertebrae above and two below the involved vertebra

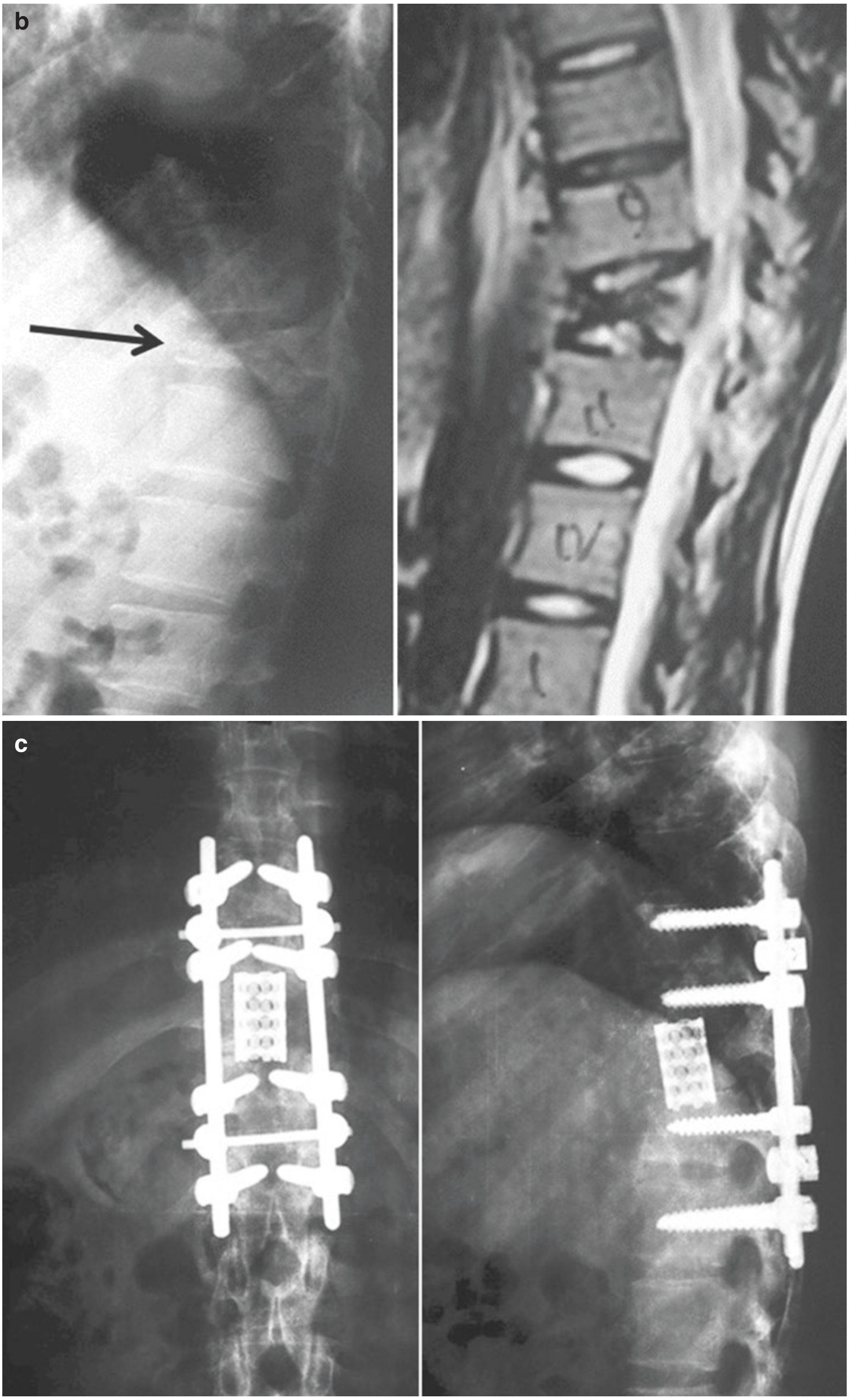

Fig. 33.17 (continued)

References

1. Parthasarathy R, Sriram K, Santha T, et al. Short-course chemotherapy for tuberculosis of the spine. A comparison of ambulant treatment and radical surgery: ten year report. J Bone Joint Surg Br. 2001;81B:464–71.
2. World Health Organization. Treatment of tuberculosis guidelines. 4th ed. Geneva: World Health Organization; 2010. Available at http://whqlibdoc.who.int/publications/2010/9789241547833_eng.pdf. Accessed 19 Apr 2012.
3. Holtz TH, Cegielski JP. Origin of the term XDR-TB. Eur Respir J. 2007;30:396.
4. Lee JH, Han CD, Cho SN, et al. How long does antimyobacterial antibiotic-loaded bone cement have in vitro activity for musculoskeletal tuberculosis? Clin Orthop Relat Res. 2017;475(11):2795–804. (Open Access).
5. Shanmugasundaram TK. Bone and joint tuberculosis. Madras: Kothandaram and Co.; 1983.
6. Tuli SM. Tuberculosis of the spine: a historical review. Clin Orthop Relat Res. 2007;460:29–38.
7. Hodgson AR, Skinsnes OK, Leong CY. The pathogenesis of Pott's paraplegia. J Bone Joint Surg Am. 1967;49:1147–56.
8. Kim CJ, Song KH, Jeon JH, et al. A comparative study of pyogenic and tuberculous spondylodiscitis. Spine. 2010;35:E1096–100.
9. Rajasekaran S. The natural history of post-tubercular kyphosis in children: radiological signs which predict late increase in deformity. J Bone Joint Surg Br. 2001;83:954–62.
10. Rajasekaran S, Shanmugasundaram TK. Prediction of the angle of gibbus deformity in tuberculosis of the spine. J Bone Joint Surg Am. 1987;69:503–9.
11. Jutte PC, Van Loenhout-Rooyackers JH. Routine surgery in addition to chemotherapy for treating spinal tuberculosis. Cochrane Database Syst Rev. 2006;25(1):CD004532.
12. Qian J, Rijiepu A, Zhu B, et al. Outcomes of radical debridement versus no debridement for the treatment of thoracic and lumbar spinal tuberculosis. Int Orthop. 2016;40(10):2081–8.
13. Wu W, Lyu J, Liu X, et al. Surgical treatment of thoracic spinal tuberculosis: a multicenter retrospective study. World Neurosurg. 2018;110:e842–50.

Suggested Reading

Martini M, Adjrad A, Bouddjemaa A. Tuberculous osteomyelitis. A review of 125 cases. Int Orthop. 1986;10:201–7.

Mehta JS, Bhojraj SY. Tuberculosis of the thoracic spine. A classification based on the selection of surgical strategies. J Bone Joint Surg Br. 2001;83:859–63.

Shi T, Zhang Z, Dai F, et al. Retrospective study of 967 patients with spinal tuberculosis. Orthopedics. 2016;39(5):e838–43.

Spiegel DA, Singh GK, Banskota AK. Tuberculosis of the musculoskeletal system. Tech Orthop. 2005;20:167–78. (Open Access) (https://globalhelp.org/products/tuberculosis_of_the_musculoskeletal_system/).

Tuli SM. Tuberculosis of the skeletal system: bones, joints, spine and bursal sheaths. 5th ed. Bangalore: Jaypee Brothers Medical Publishers; 2016.

Rajasekaran S. Kyphotic deformity in spinal tuberculosis and its management. Int Orthop. 2012;36(2):359–65. (Open Access).

Rajasekaran S. Natural history of Pott's kyphosis. Eur Spine J. 2013;22(Suppl 4):634–40. (Open Access).

Rajasekaran S, Rajoli SR, Aiyer SN, Kanna R, Shetty AP. A classification for kyphosis based on column deficiency, curve magnitude, and osteotomy requirement. J Bone Joint Surg Am. 2018;100(13):1147–56. (Open Access).