Chapter 13
Bacterial Infections of the Spine

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Infections of the Spine

The heterogeneity of clinical syndromes associated with spine infections reflects the structural complexity of the spinal column. Historically, all infections of the osteoarticular elements of the spine were categorized as vertebral osteomyelitis. Spinal epidural abscesses were investigated as a distinct entity, and not as part of the anatomic continuum of an evolving infectious process.

The majority of spine infections arise from hematogenous seeding during episodes of bacteremia. A minority is related to direct inoculation of pathogenic microorganisms during spinal instrumentation. Unlike the hematogenous seeding of the long bones in the pediatric population, which has seen a significant decrease in the antibiotic era, spine infections in the adult population are on the rise.

The reason is likely multifactorial, and includes an expanding elderly population with significant comorbidities subject to frequent invasive procedures, predisposed thereby to recurrent bacteremic episodes. The widespread availability of advanced imaging likely adds to the increase in diagnosis of spine infections. Despite recent advances in our understanding of spine infections, well defined clinical presentations and easier access to cross sectional imaging, the diagnostic delay of this potentially life-threatening infection remains unacceptably long. Once the diagnosis is established, the main therapeutic dilemma remains whether to operate or not. In recent years, the conservative approach with antimicrobial therapy only, has proven

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safe and successful for an increasing number of cases. Patients with overt neurologic deficits and spinal instability require surgery, in addition to antimicrobial therapy.

Anatomy of Spine Infections

Intervertebral discs (IVD) link adjacent vertebral bodies, represent the main amphiarthrodial joints of the spinal column and occupy one third of its height. They are composed of the outer thick ring of fibrous cartilage called annulus fibrosus, the inner gelatinous core or nucleus pulposus and the hyaline endplates. In children, the IVD is vascularized, with numerous capillaries originating from interosseous arteries of the vertebral body traversing the endplates. In adults, the vascular channels obliterate, making the IVD the largest avascular structure of the human body [1].

Vertebral bodies are the main weight bearing elements of the vertebral column. They incorporate physiologic equivalents of metaphyseal plates located along the bone-cartilage interface and supplied by terminal arteriolar archades. Metaphyseal equivalents are targets of hematogenous bacterial seeding, responsible for establishing the nidus for osteomyelitis [2].

Facet joints are diarthrodial, meniscoid containing, synovial joints interlocking adjacent vertebral bodies posteriorly. Facet joints are part of the weight bearing tripod of the spine, comprised of the anterior column and bilaterally symmetric facets posteriorly. Along with the IVD, they transfer load and constrain spine movement [3].

Epidural space is a potential space between the periosteum of the vertebral column and the spinal dura mater. It extends from the foramen magnum to the sacral hiatus. It contains fat, spinal blood vessels, lymphatics and nerve roots with their dural sleeves which extend into paravertebral space [4].

Pathophysiology of Spine Infections

In adults, the infections of the axial skeleton are caused by hematogenous seeding. The blood vessels supplying the vertebral end plates are terminal, and therefore bacteria laden platelet clots lodge in the end arteriolar arcades causing a septic ischemic infarct in bone. As the IVD is an avascular structure which receives nutrients through diffusion from the adjacent vertebral end plate, the infection spreads to engulf the IVD as well (Fig. 13.1). In children, the IVD is vascularized and can be an isolated target for hematogenous bacterial seeding, causing primary discitis without involvement of adjacent vertebral end-plates. Facet joints of adults can be a target for hematogenous seeding as well. As in other synovial joints of the body, it is unclear whether the lack of a basement membrane in the synovium is the entry point for bacteria or the obliterated blood vessels of the closed growth plates

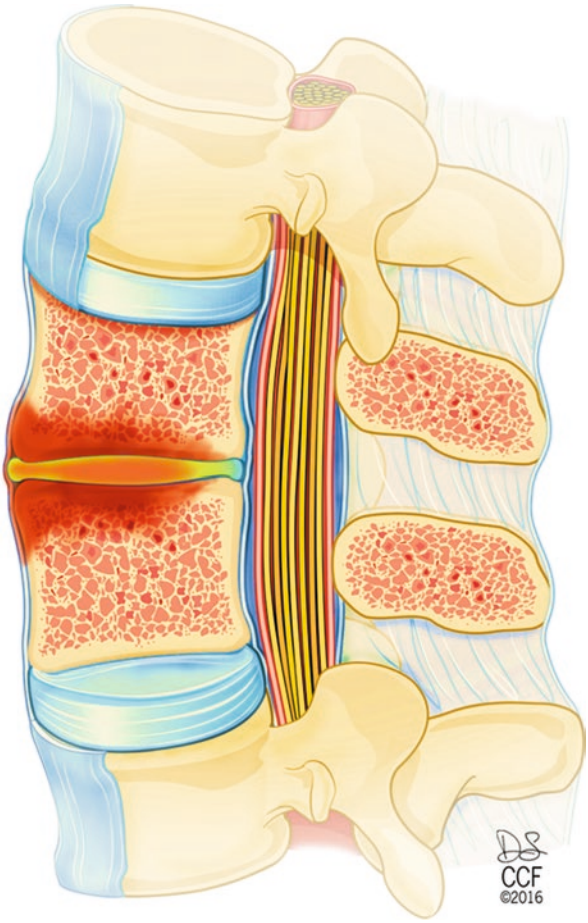

Fig. 13.1 Illustration of early spondylodiscitis, involving the intervertebral disc and two adjacent vertebral endplates. (Reprinted with permission Cleveland Clinic Center for Medical Art & Photography © 2016–2020. All Rights Reserved)

facilitate bacterial entry through microscopic infarcts. Posterior spread of infection from the affected IVD and vertebral bodies into the epidural space results in an epidural abscess (Fig. 13.2). If infection spreads antero-laterally, it extends into the retropharyngeal space in the cervical spine, into the space limited by the endothoracic fascia in the thoracic spine, along the costovertebral joints and ribs, or into the psoas muscles in the lumbar spine causing psoas muscle abscesses. Spread of infection from the facet joints anteriorly extends into an epidural abscess. Posterior spread decompresses into the paravertebral musculature (Fig. 13.3). A simplified classification of spine infections and their nomenclature is presented in Table 13.1.

A minority of spinal infections are caused by direct expansion of infection from adjacent structures, like infected aortic grafts, fistulous tracts and abscesses related to inflammatory bowel disease, or contiguous sites of osteomyelitis in areas of decubitus ulcers.

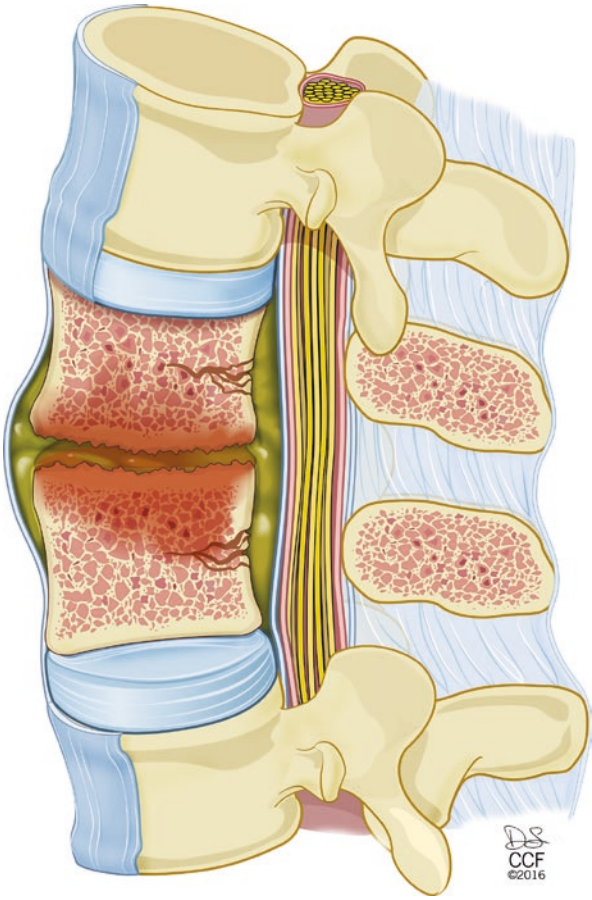

Fig. 13.2 Illustration of advanced spondylodiscitis with associated epidural abscess and prevertebral abscess. (Reprinted with permission Cleveland Clinic Center for Medical Art & Photography © 2016–2020. All Rights Reserved)

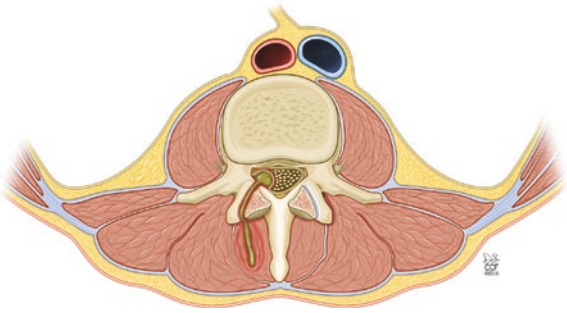

Fig. 13.3 Illustration of septic facet joint with associated epidural abscess and paravertebral abscess. (Reprinted with permission Cleveland Clinic Center for Medical Art & Photography © 2016–2020. All Rights Reserved)

Table 13.1 Nomenclature of spine infections

Nomenclature of spine infections	Pathology	Characteristics
Discitis	Isolated disc infection	Hematogenous bacterial seeding of vascularized disc in children
Spondylitis	Vertebral end plate infection	Earliest osteomyelitis of VB in adults
Spondylodiscitis	Discitis with adjacent vertebral body infection	Extent of most spine infections at presentation
Septic facet joint	Hematogenous septic arthritis of facet joints	Increasingly recognized entity in era of MRI
Epidural abscess	Purulence in epidural space	Contiguous spread of infection from infected disc space or septic facet joint

Epidemiology of Spine Infections

The incidence of spine infections is steadily increasing. Reports on annual incidence of vertebral osteomyelitis range from 1 per 100,000 to as high as 7 per 100,000 inhabitants [5–7]. In a Danish study the incidence tripled from 2/100,000 to 6/100,000 over a period from 1995 through 2008 [5]. A subsequent 2013 report from the Danish Civil Registration system, focused on a 1 year cross section in a single region confirmed a 5.3/100,000 cases in the general population, if adjusted for age >65 however, the incidence increased to 16.5 per 100,000 [8]. According to the Japanese Diagnosis Procedure Combination Database from 2007 to 2010 the incidence increased from 5.3 to 7.4 per 100,000 inhabitants. In Spain the incidence more than doubled from 0.6 to 1.5 per 100,000 from 1991 to 2009 [7].

The most recent retrospective review of the epidemiology of vertebral osteomyelitis in the United States calculated the average incidence of 4.7/100,000 cases of vertebral osteomyelitis annually [9]. In contrast to prior European studies, which reported a steady increase in incidence by age, with a peak incidence among patients 70 years of age and older, the majority of cases (49.5%) in the Unites States series are younger than 59 years old. The reason for this discrepant finding remains unclear, but could be related to a combination of increased awareness of practitioners, easier access to more accurate detection methods, i.e. widespread availability of MRI and the ongoing opioid crisis.

Microbiology

The majority of infections of the spine, in keeping with the rest of osteoarticular infections, is caused by gram positive bacteria, Staphylococci and Streptococci. In large series of pyogenic spine infections account for 60–90% of all cases [10–12].

In recent series that focus on presence of epidural abscess, gram positive organisms account for 90% of pathogens [13]. *Staphylococcus aureus* remains the single, most frequently isolated organism in cases of native spine infections [10–16]. The percentage of methicillin-resistant *S. aureus* (MRSA) varies, and seems to correlate with the incidence of IVDA and community acquisition.

Streptococci spp. are the second most frequent pathogen isolated from cases of spine infections [10, 11, 17]. Streptococci are a heterogenous group, encompassing virulent pathogens akin *to Staphylococcus aureus, i.e Steptococcus pneumoniae*, *Streptococcus pyogenes* and *Streptococcus agalactiae* as well as less virulent organisms like viridans streptococci. Interestingly, these low virulent organisms are frequently implicated in cases of coinfections of spine and endocarditis [18].

Coagulase negative staphylococci (CNS) are less virulent pathogens. They are capable of seeding the spine and establishing overt infect during episodes of prolonged bacteremia. Prolonged CNS bacteremia is usually related to artificial material infection, like line infections, prosthetic valve endocarditis cases or intravascular shunts infections [19].

Gram negative bacilli historically accounted for 15–30% of pathogens in series of spine infections [10, 17]. Gram negative spine infections, like *E coli*, Proteus spp. or Klebsiella spp., can be seen following procedures or infections involving the genito-urinary or gastro-intestinal tract [20, 21]. It is unclear why the percentage has decreased in recent series, with gram positive organisms accounting for almost 90% of all microbiologically confirmed infections [13, 16, 22]. Our institution registry concurs with the more recent data, with less than 5% of spinal infections caused by gram negative pathogens (unpublished data). It is unclear whether a true shift in etiology has happened over the past 30 years or whether the extent of gram-negative infections has been overestimated in older case series. From an antimicrobial stewardship point, it is crucial to reevaluate the percentage of gram-negative spine infections and address empirical antimicrobial regimens that were designed to provide coverage for both gram positive and gram-negative organisms. Evidence for a particular choice of empiric antibiotic treatment in culture-negative cases is very limited.

Fungal infections, including Candida and Aspergillus species, present a minority of spine infections mostly limited to patients with injection drug abuse and immunocompromised hosts [23].

Tuberculosis of the spine and Brucella spp infections are found in endemic areas. Hematogenous seeding of the spine usually results in monomicrobial infections. Contiguous infections, originating from pelvic abscesses or overlying dehisced surgical wounds, are frequently polymicrobial.

Risk Factors and Clinical Presentation

Spinal infections remain a diagnostic challenge, since the classical presentation of progressive back pain in a patient with fever is frequently masked by concomitant distant infections or use of anti-inflammatory medications.

A high index of suspicion is required, especially in patients with risk factors for transient bacteremias, including those with chronic indwelling catheters, dialysis – dependent patients, intravenous drug abusers and patients subject to frequent medical procedures. Diabetes, malignancy, alcoholism and immunocompromised status are reported in most studies to be risk factors for spinal infections [10, 12, 14, 24].

The *sine qua non* of spinal infections is back pain, present in more than 80% of cases in most series [25–27]. The features of back pain associated with spine infections differ based on the anatomical location involved and extent of spread. Discitis and spondylodiscitis usually present as indolent midline pain exacerbated by movement that slowly progresses to unremitting, nocturnal pain at rest. In cases of lumbar spine spondylodiscitis with spread of infection into a psoas abscess, the pain can radiate into the side of the involved psoas muscle and can be exacerbated by flexion of the hip, as the psoas muscle is a major hip flexor. In thoracic spine spondylodiscitis, apart from the midline pain, the adjacent costovertebral joint can be involved, and the pain can radiate along the ipsilateral rib, mimicking the pain of herpes zoster, pleurisy or pancreatitis [28]. Cervical spondylodiscitis with anterior prevertebral spread of infection can present with neck pain associated with dysphagia and dysphonia [29]. Involvement of the posterior elements, as in the case of isolated hematogenously seeded facet joints, present more acutely, frequently as distinctly unilateral pain [30].

Fever is an inconsistent finding in spine infection, present on average in 2/3rds of cases, but ranging from 16% to 97% between series [10, 12, 31]. Given the ubiquitous use of anti-inflammatories for back pain, febrile episodes likely remain masked.

Neurological deficits in the form of motor weakness, sensory deficits, radicular pain or cauda equina syndrome, are present in 10–50% of cases and are caused by the development of an epidural abscess [32–34].

Diagnosis

The unacceptably long diagnostic delay in establishing spine infection as the cause of back pain remains a problem even in today's era of widespread MRI availability. Work up for new onset back pain should always include inflammatory markers. Erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) in particular, are helpful in screening for serious causes of back pain, i.e. infection, fractures and metastatic lesions [35]. CRP is the only factor found to significantly shorten the diagnostic delay in pyogenic spine infections [36].

Imaging

Radiographs are frequently the initial examination performed. Changes of spine infection on X-ray lag several weeks following symptom onset and include decreased bone density, disc space narrowing, end plate destruction followed

ultimately by subluxation and instability. The imaging of choice for establishing a diagnosis of spine infection is MRI [37]. MRI findings include disc space narrowing and increased signal on fluid sensitive, or T2 weighted, sequences with enhancement following contrast administration. The endplates show low T1 signal, increased T2 signal and enhancement post contrast administration.

End-plate enhancement is the earliest sign of acute spondylodiscitis on MRI [38]. Paraspinal soft tissue inflammation is seen as increased T2 signal with enhancement and is crucial in differentiating infection from degenerative disc changes [39]. When possible, gadolinium should be administered, as it is essential in differentiating epidural abscess formation from phlegmonous inflammation [40]. Uniform enhancement is seen in phlegmonous inflammatory changes lacking a central liquid component. In contrast, an abscess is seen as a rim enhancing hypointense collection. The central low intensity signal on T1 weighted images represents the necrotic portion of the abscess, while the surrounding rim of granulation tissue is well perfused and enhances following contrast administration [41]. These two distinct MRI patterns correlate with intraoperative findings of gross purulence that can be surgically evacuated in cases of epidural abscesses, versus inflamed granulomatous tissue in phlegmon which cannot [42]. When an MRI cannot be obtained and the suspicion for epidural abscess is high, a CT myelogram is recommended. The block in free contrast flow indicates the level of compression, but can frequently not delineate the extent of an epidural abscess or whether it originates from an infected disc space or a septic facet joint [43]. It is also an invasive procedure associated with risks of infection and bleeding. Typical MRI findings of spondylodiscitis are shown in Fig. 13.4. Typical findings of epidural abscess on MRI are shown in Fig. 13.5.

In cases where MRI is contraindicated, contrast enhanced CT scan, PET scan, or combined gallium/T99c bone scan can help establish the diagnosis [44, 45]. Boney structures are better evaluated on CT compared to MRI, like end plate erosions and extent of destruction of vertebral bodies. CT is the modality of choice for evaluating for possible biopsy to help establish the diagnosis. The addition of intravenous contrast to CT makes soft tissue inflammation and abscesses more conspicuous. Unfortunately, a major limitation of CT is its inability to delineate epidural abscesses [46].

The best alternative to MRI, albeit limited by cost and availability, is FDG-PET-CT. It reliably identifies paraspinal soft tissue inflammation and psoas abscesses, as well as end-plated changes characteristic of spondylodiscitis. Its major drawback is lack of reliable identification of epidural abscesses [47, 48].

A frequently overlooked entity and underreported imaging finding is the septic facet joint. Radiographs are not helpful and typically only show degenerative changes. CT findings include erosive changes in the affected facets that are difficult to differentiate from degenerative changes, unless additional soft tissue inflammation, paraspinal or psoas muscle abscesses are present [49]. MRI is the imaging of choice for establishing a diagnosis of a septic facet joint, as early as 5 days after onset of symptoms [50]. On MRI, fluid in a facet joint with associated edema in the surrounding soft tissues of the paraspinal muscles should raise suspicion for

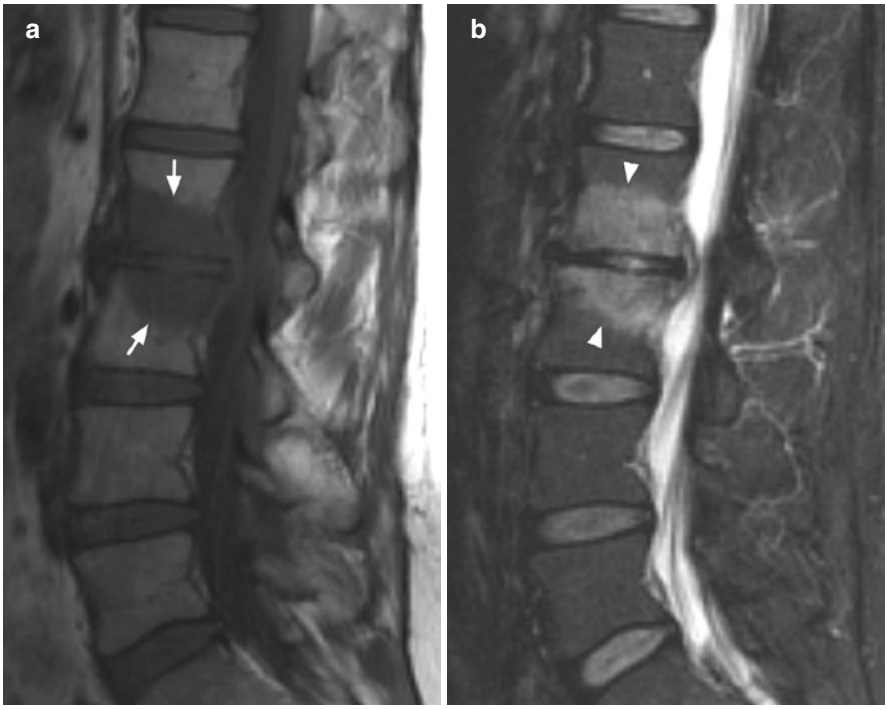

Fig. 13.4 (**a**) Findings of spondylodiscitis on T1W MRI imaging, arrows pointing to edema in adjacent vertebral bodies as hypo-intense signal area. (**b**) Findings of spondylodiscitis on STIR MRI, arrowheads pointing to edema of adjacent vertebral bodies as bright signal area

infection. Edema is more conspicuous on fat suppressed fluid sensitive sequence, T2WI or STIR (Fig. 13.6). The addition of gadolinium is preferred as it can delineate the presence of an epidural abscess originating from the culprit septic facet joint. The reported frequency of epidural abscesses originating from septic facet joints ranges from 25% to 60% and typically, though not uniformly, involve the posterior epidural space, forming a dorsal epidural abscess [30, 51].

Establishing Microbiological Etiology

Every effort should be made to confirm the microbiological etiology prior to initiating antibiotic therapy.

Blood cultures should be routinely obtained in patients with back pain who are febrile or have imaging findings suspicious for infection. They are positive in roughly 60% of bacterial spine infection cases, the yield ranging from 30% to 72% [52]. Empiric antibiotics should be withheld until the microbiological diagnosis is established in all but critically ill patients with signs of sepsis. In patients with

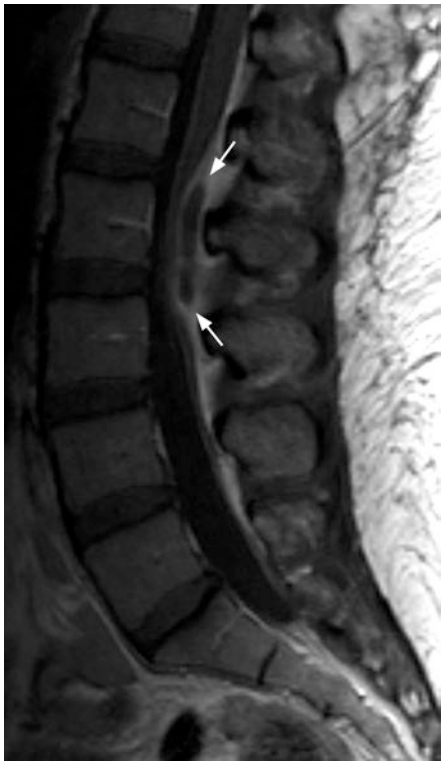

Fig. 13.5 Findings of epidural abscess on gadolinium-enhanced T1W MRI, arrows delineating the proximal and distal end of the dorsally located epidural abscess

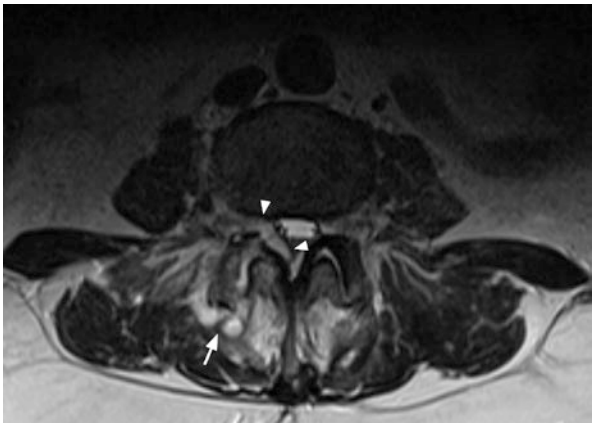

Fig. 13.6 Findings of a right sided septic facet joint on T2W MRI, arrowheads pointing to epidural extension and arrow pointing to paravertebral spread of infection

negative blood cultures or a single set isolate of a contaminant organisms like coagulase negative Staphylococcus, a CT guide or open biopsy is indicated. The yield of biopsy ranges from 30% to 75% and is compromised by prior administration of antibiotics [53–55]. Given the indolent course, side effects of empiric antimicrobial therapy and increased awareness of the need for antimicrobial stewardship, it is

deemed reasonable to withhold therapy for up to 2 weeks in stable patients [56]. A standard biopsy specimen should include an aspirate from the disc space or adjacent paraspinal collections, and a core specimen of the affected end plates. Samples are sent for both microbiology and pathology. Routine bacterial and fungal stains and cultures are done. In cases of exposure history, mycobacterial stains and cultures are requested. Pathology evaluation can be helpful in culture negative cases, where the presence of white blood cells indicates pyogenic osteomyelitis, or granulomatous lesions point towards mycobacterial etiology or Brucellosis [57]. Pathology can also be helpful in culture negative cases where imaging findings are equivocal and cannot differentiate between infection and non-infectious etiology. The absence of white blood cells on pathology can point away from infection in favor of degenerative Modic changes, ankylosing spondylitis, neuropathic-Charcot joint deformities of the spine or hemodialysis-associated spondylo-arthropathy [58]. Occasionally, crystal deposits can be found on histology, establishing a diagnosis of gout or pseudogout in the spine, entities indistinguishable from infection on both imaging and clinical presentation [59].

Cases where no pathogen is identified, either from blood cultures or tissue obtained by biopsy, are deemed as culture negative and placed on empiric antibiotic therapy. Recent guidelines recommend a second CT guided or open biopsy attempt at establishing the pathogen [56]. The yield of a second biopsy ranges from 0% to 60% and its applicability has been a topic of intense debate [60]. Though post-biopsy blood cultures had shown some promise as an adjunct tool to establish a microbiologic diagnosis, its overall low yield has made it an obsolete diagnostic test [61].

Broad-range PCR has emerged in recent years as an additional tool available in cases where microbiological cultures are not sufficiently sensitive, as in patients who have previously received antibiotics or when fastidious organisms are present. Limitations of these advanced diagnostic techniques are high rate of false positive results and lack of susceptibility testing to guide treatment [62, 63].

Treatment

Once the diagnosis of spine infection is established and the microbiological cause is confirmed, antimicrobials can be initiated. The goal of treatment is to eradicate infection, relieve back pain and prevent further complications, like cord compression and progressive bone loss leading to an unstable spine. Uncomplicated cases of spine infection, including discitis, spondylodiscitis, septic facet joints without significant boney erosions and epidural abscesses without significant neurologic deficits, are treated conservatively with good outcome. Six weeks of targeted antibiotic therapy suffices in most cases [64]. More extensive infections with spread into paraspinal tissue and associated psoas muscle abscesses may benefit from extended courses of up to 8–12 weeks [65]. Initial intravenous antibiotic regimens can safely be switched to oral antibiotics with high bioavailability once the CRP has decreased by 50%, if the pain has resolved and no residual neurological deficits are present

[66]. The therapeutic response is monitored clinically and with serial inflammatory markers. End of treatment cross-sectional imaging is not recommended if pain has resolved and inflammatory markers have normalized [56]. MRI findings can lag up to 4–6 weeks behind clinical improvement, and persistence of findings on imaging can create a conundrum for the treating physician and the patient. Only in cases where back pain persists or recurs, or inflammatory markers fail to improve, should repeat imaging be performed [67].

Some patients will require surgery. Surgical indications include acute neurological deficits caused by cord compression from epidural abscesses and mechanical instability of the vertebral column due to loss of bone stock to infectious osteolysis (Figs. 13.7 and 13.8). Occasionally, unremitting pain and prolonged bacteremia can present a relative surgical indications. Historically, the treatment of choice for all epidural abscesses was surgical decompression [68, 69]. Currently, the dilemma is whether or not to proceed with surgical decompression of an epidural abscess. Over the past two decades, conservative management of epidural abscesses, with antibiotics alone has become a viable option for an increasing number of patient. Epidural

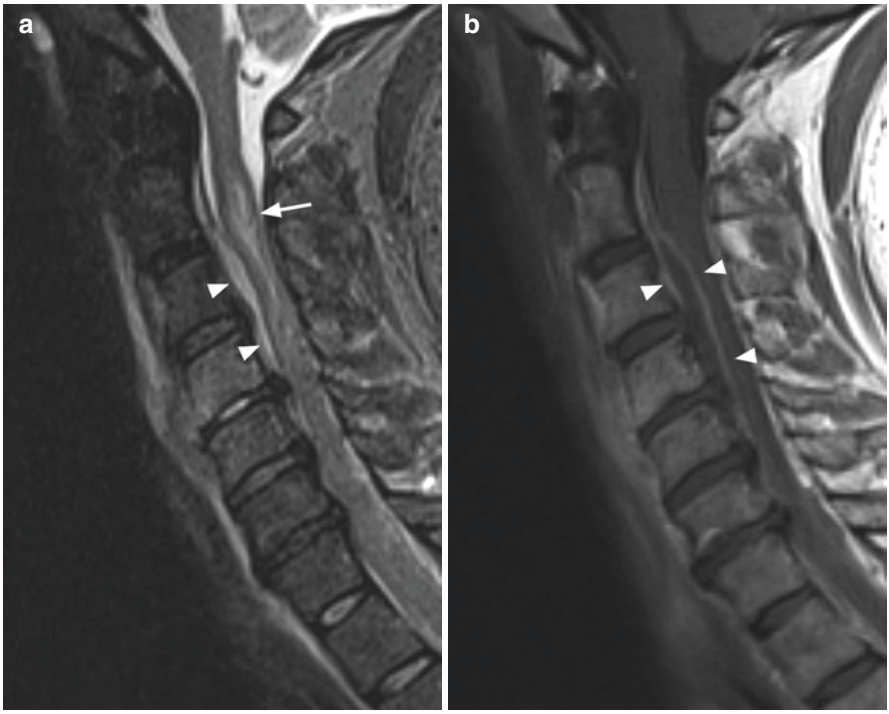

Fig. 13.7 (**a**) Findings of cervical spondylodiscitis associated prevertebral and epidural extension on STIR MRI. Arrowheads delineate epidural collection causing cord compression with marked cord edema, arrow pointing to bright signal in spinal cord. (**b**) Typical finding of a ventrally located epidural abscess on gadolinium-enhanced T1W MRI. Arrowheads delineating rim enhancement of the abscess

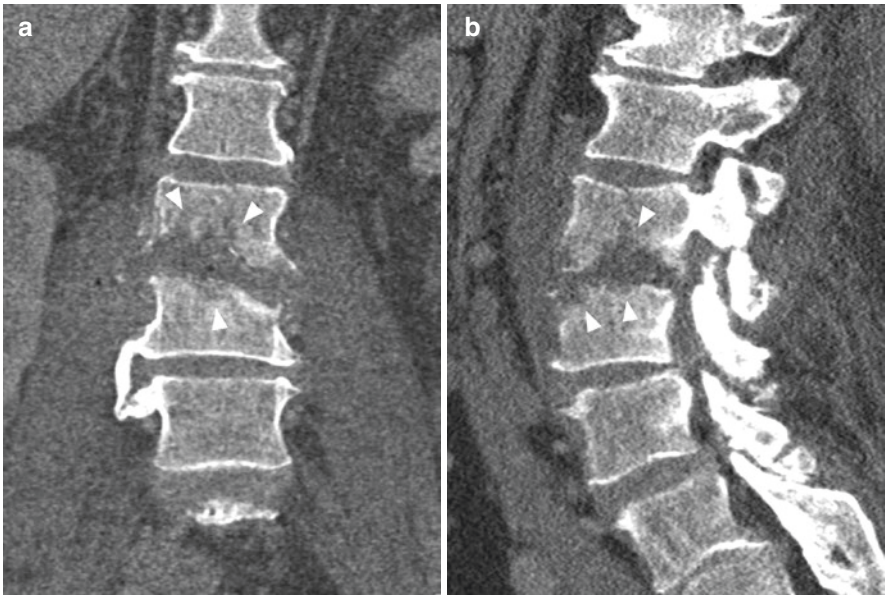

Fig. 13.8 (**a**) Coronal CT imaging findings of advanced vertebral body destruction due to spondylodiscitis. Arrowheads pointing to extensively eroded vertebral endplates. (**b**) Sagittal CT imaging findings of advanced vertebral body destruction with fracture of proximal vertebral body (arrowheads)

abscesses of known causative organism and without neurological deficits can safely be managed conservatively, with antibiotics alone [70, 71]. Patients with neurological deficits should undergo immediate decompression, as it is not known at which point in time the deficits become irreversible [71]. It is acceptable to proceed with conservative management in cases of mild neurological deficits with close follow up. The failure rate of conservative management ranges from 30% to 40% [72, 73]. The outcome of delayed surgery following conservative management failure is suboptimal. It is therefore important to be able to predict which patients are at risk for failure. Numerous algorithms for non-operative management failure of epidural abscesses have been published, all based on retrospective cohort studies [16, 72, 74]. Models are based on the presence of risk factors like diabetes, neoplasm, old age, presence of methicillin-resistant *Staphylococcus aureus*, elevated CRP and white blood cells. Most of the models were not validated in subsequent cohorts and are of limited clinical utility.

Isolated case reports of CT-guide aspiration of epidural collections, as an adjunct to conservative management, confirm its feasibility but the practice is not widespread in clinical setting [75, 76]. The concept is based on aspiration and irrigation of multilevel epidural abscesses under CT guidance. Only dorsally located epidural abscesses with a confirmed liquid component on MRI and absence of significant bony destruction associated with spondylodiscitis qualify for percutaneous drainage [77]. Routine CT guided procedures can provide therapeutic support. Psoas

abscesses associated with lumbar spondylodiscitis, if not multiloculated and with diameters greater than 3 cm, can be successfully drained to decrease infectious load. The optimal therapeutic approach to septic facet joints is unknown. Most are treated in accordance with vertebral osteomyelitis guidelines. If they are associated with an epidural abscess, the presence of neurological deficits determines the therapeutic approach. Occasionally, a septic facet joint can be the source of prolonged bacteremia, especially with *Staphylococcus aureus*. Aspiration under CT guidance of purulent content from the facet joint space can relieve symptoms and help manage source control [30].

Surgical management involves radical debridement of all infected tissue and reconstruction of lost bone support. Debrided bone defects are filled in with bone grafts or, in recent years, titanium mesh cages.

In addition to foregoing the morbid procedure of harvesting bone graft, Titanium is more resistant to bacterial adherence compared to other metals, and results in higher fusion rates and better sagittal alignment [78–80]. A significant shift in management occurred when it became evident that placement of metal into an actively infected spine did not compromise outcome [79, 81]. Neither the use of Rifampin or chronic suppressive antibiotics are needed following hardware placement in acute cases of spine infection, as they do not impact long term outcome or failure rate [82]. The majority of treatment failures happen within the first postoperative year, thus continuing chronic suppressive antibiotics beyond the initial year is unlikely beneficial [82]. Intraoperative use of topical antibiotic delivery systems have found its applications in surgical management of spine infections. Injectable antibiotic eluting bone graft substitutes have been used successfully to eradicate infection and promote fusion [83].

Outcome

Over the course of the past century, spine infection has evolved from an acute, life threatening illness of the young, with associated high mortality rates, to a more prolonged, indolent disease of the older population, associated with chronic disabling sequelae and lower mortality rates [10]. Estimates of mortality range widely between 1.2% and 20% in prior studies, but is reported as 2.1% in-hospital mortality in the U.S. by Issa et al. [5, 7, 9, 34, 52, 84, 85]. It appears that long-term mortality in spine infections is relates to comorbidities as shown in Table 13.2.

Prior studies of long term functional outcomes of spine infection found significant morbidity and high rates of adverse outcomes [86, 87]. Recent data supports better recovery rates following eradication of infection and restoration of mechanical stability of the spine [88]. Impaired quality of life is attributable to residual pain, paralysis and associated more frequently with female gender. It has been noted previously by Hadjipavlou et al. that residual back pain, attributable to kyphosis or pseudoarthrosis, was more prevalent in cases of spine infection managed non-operatively [11]. Certain features of spine infection may relate to worse outcomes.

Table 13.2 Mortality of spine infections and associated factors

Study	Mortality (%)	Factors associated with mortality
McHenry (2002) [10]	11%	Diagnostic delay, motor weakness, paralysis, nosocomial acquisition
Akiyama (2013) [7]	6%	Older age, diabetes, dialysis, cirrhosis, endocarditis, malignancy
Kehrer (2015) [5]	20%	Epidural abscess, neurodeficits, comorbidities
Kokabu (2017) [88]	3% vs 15%	No comorbidities vs comorbidities

Infections involving the cervical spine seem to have higher mortality compared to lumbar and thoracic locations [89]. Extreme elevation of inflammatory markers, i.e. CRP values above 100 mg/L on presentation was found to relate to higher mortality [22]. Though spine infections caused by MRSA where associated with prolonged bacteremia and more frequent recurrences, compared to MSSA infections, the overall mortality did not differ significantly [90]. Most importantly, a diagnostic delay exceeding 60 days was associated with poor outcome [91].

Summary

Infections of the spine are becoming an increasing occurrence in developed countries with an aging population. Advanced instrumentation predisposes patient to frequent transient episodes of bacteremia. The spectrum of spinal infections is a result of hematogenous bacterial or rarely fungal seeding of vertebral end plates and facet joints. Unopposed infection spreads into adjacent anatomic structures of the spine and causes phlegmons or abscesses in the epidural space, paraspinal and psoas muscles and prevertebral soft tissue spaces. Back pain is universally present as the main complaint, but given its ubiquitous nature adds to the pitfalls of diagnosing a spine infection in a timely manner. Though significant progress has been made in the treatment of spine infections, the diagnostic delay remains unacceptably long. CRP is the sole inflammatory marker that aids in establishing a diagnosis of serious causes of back pain and shortens the diagnostic delay in infections of the spine. The imaging of choice for diagnosing spine infections is Gadolinium enhanced MRI. FGD PET CT scan is a viable option in patients with contraindications to MRI. CT myelograms are used for locating a spinal epidural abscess if MRI not feasible and clinical suspicion is high. The most frequent etiologic agents are gram positive bacteria, namely Staphylococcus aureus. A minority of cases are caused by enterobacteriaceae. Fungal infections are mostly restricted to injection drug use and severely immunocompromised patients. In today's era of antimicrobial stewardship, a concerted effort has to be made to establish the microbiological diagnosis. In hemodynamically stable patients, empiric antimicrobial therapy should be withheld until a microbiological agent is recovered either from blood cultures or CT guided biopsy samples. Targeted antibiotic therapy can be initiated thereafter. The standard

duration of therapy in uncomplicated cases is 6 weeks. Response to therapy is monitored clinically and by following serial inflammatory markers. Initial antibiotic therapy is administered intravenously, but a switch to highly bioavailable oral agents is acceptable in cases of clinical improvement and with down-trending inflammatory markers. End of treatment imaging studies are not recommended. Repeat imaging is reserved for cases with suboptimal therapeutic response, with ongoing symptoms or persistently elevated inflammatory markers. An increasing number of spine infections are managed conservatively, with antibiotic therapy only. In the acute setting, onset of neurologic deficits and mechanical instability of the spine require surgical intervention. Following completion of therapy, residual mechanical instability may be the cause of chronic pain and is eventually managed surgically as well. A number of models predicting the failure rate of conservative management as a tool to assess the need for early surgery are available. Their applicability in real time clinical setting remains to be determined.

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