REVIEW ARTICLE

Spinal infection: state of the art and management algorithm

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Abstract

Introduction Spinal infection is a rare pathology although a concerning rising incidence has been observed in recent years. This increase might reflect a progressively more susceptible population but also the availability of increased diagnostic accuracy. Yet, even with improved diagnosis tools and procedures, the delay in diagnosis remains an important issue. This review aims to highlight the importance of a methodological attitude towards accurate and prompt diagnosis using an algorithm to aid on spinal infection management.

Methods Appropriate literature on spinal infection was selected using databases from the US National Library of Medicine and the National Institutes of Health.

Results Literature reveals that histopathological analysis of infected tissues is a paramount for diagnosis and must be performed routinely. Antibiotic therapy is transversal to both conservative and surgical approaches and must be initiated after etiological diagnosis. Indications for surgical treatment include neurological deficits or sepsis, spine instability and/or deformity, presence of epidural abscess and upon failure of conservative treatment.

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Conclusions A methodological assessment could lead to diagnosis effectiveness of spinal infection. Towards this, we present a management algorithm based on literature findings.

Introduction

Spinal infection is an ancient entity with some descriptions dating from the Iron age [1]. In 1779, Pott made the first detailed description of tuberculosis infection in the spine, and a century later, Lanneloung, in France, reported for the first time the term pyogenic osteomyelitis of the spine in medical literature [2].

When infection affects the intervertebral disc, the term to describe this condition is usually spondylodiscitis [3]. If invades the endplates or the vertebral body, the infection is more correctly designated for vertebral osteomyelitis or spondylitis [4]. However, at the time of diagnosis in many cases, the infection has already compromised these two structures; therefore, both terms are frequently used [3].

Due to the low specificity of signs and symptoms at clinical presentation, a significant delay usually occurs until the establishment of diagnosis and treatment. Literature data report a delay of 2–6 months between first symptoms and diagnosis [3, 5, 6], leading in some cases to catastrophic outcomes.

In this paper, we propose an algorithm for diagnostic assessment as well as current treatment options and their therapeutic outcomes based on an extensive literature review.

Epidemiology

Spine is susceptive to infection, accounting for 2–7 % of all cases of musculoskeletal infections [7]. Its incidence varies between 1:100,000 and 1:250,000 in developed countries and its estimated mortality rate ranges between 2 and 4 % [3, 5]. Numerous studies refer to a bimodal distribution with a peak below 20 years and another between 50 and 70 years of age, representing in this group, approximately 3–5 % of all cases of osteomyelitis [4, 8]. Furthermore, a 2:1–5:1 male/female ratio has been reported [9, 10].

Known predisposing risk factors include previous spine surgery, a distant infectious focus, diabetes mellitus, advanced age, intravenous drug use, HIV infection, immunosuppression, oncologic history, renal failure, rheumatological diseases, and liver cirrhosis [11–13].

In recent years, an increased incidence has been observed, due to a combined effect between an increase in susceptible populations (particularly history of previous spine surgery) and an improved accuracy in diagnosis [14]. Nowadays, postprocedural discitis represents up to 30 % of all cases of pyogenic spondylodiscitis and has been related to almost all spine surgery techniques [15, 16].

Etiology

Spine infections occur by three major agents: bacteria, causing pyogenic infections; tuberculosis or fungi, responsible for granulomatosis infections; or by parasites, which are the less common etiology. In the past, tuberculosis infection was the major cause of spinal infections, however, due to the success on diagnosis and treatment of lung tuberculosis, its incidence has decreased during the last 50 years. Nowadays, the majority of spinal infections are bacterial monomicrobial [17, 18] caused by *Staphylococcus aureus* with an incidence between 30 and 80 % [4, 14, 18]. Gram-negative bacteria such as *Escherichia coli* are responsible, in some series, for up to 25 % of spinal infections [4]. *Mycobacterium tuberculosis* is particularly common in HIV positive patients, reaching in this susceptive group up to 60 % of identified pathogens. Anaerobic agents are also a cause of infections, especially in penetrating spine trauma [19]. Despite the efforts to identify the infectious agent, one-third of these have never been identified [20, 21]. However, particular attention should be given to some endemic areas such as Eastern Europe and Mediterranean countries, where both brucellosis and tuberculosis still have a high incidence [22]. Turunc et al. [23], in a prospective study including a total of 75 spondylodiscitis patients, found that 13 of them (17.3 %) were caused by tuberculosis, 32 (42.7 %) by brucellosis, and 30 (40 %) by other bacterial agents.

Pathophysiology

Classically, there are three routes of pathogen spread: hematogenous, direct external inoculation, and spread from contiguous tissues.

In children, the intraosseous arteries have extensive anastomosis with some vessels penetrating the intervertebral disc [24]. For this reason, a septic embolus from hematogenous spread does not cause bone infarction, and the infection is located essentially within the disc. The adult intervertebral disc is avascular and undergoes, around the third decade of life, an involution of the intraosseous anastomosis [25]. Therefore, as the adult ages, the release of septic emboli leads to the formation of extensive vascular bone infarcts and spread of infection to adjacent structures leading to the classic spondylodiscitis imaging: erosion of vertebral endplates, osteolytic lesions, and compression fractures, which can lead to spine instability, deformity, and risk of spinal cord compression [25, 26]. An infection can lead to an uncontrolled spread beyond the bone structures and access the surrounding tissues, causing paravertebral and psoas abscesses. When spreading into the spinal canal, it can cause epidural abscesses, subdural abscesses, and meningitis. Spreading to the posterior structures is very rare because of its deficit vascular supply and occurs more frequently in fungal and tuberculosis spondylodiscitis [25].

Pyogenic spondylodiscitis caused by hematogenous spread affects mainly the lumbar spine (58 %), followed by thoracic (30 %) and cervical (11 %) [25, 27], reflecting to some extent the vascular supply of these structures. Tuberculosis lesions preferentially affect the thoracic spine, often involving more than two levels, which differentiates it from pyogenic spondylodiscitis [27]. Direct inoculation pathway is frequently iatrogenic: postsurgical lumbar procedures, after lumbar puncture or epidural procedures [15]. Contiguous spread is rare and may occur in the context of adjacent infection, including esophageal ruptures, retropharyngeal abscesses, or infections of aortic implants [28].

Diagnosis

Clinical findings

Diagnosis is generally difficult and requires a high level of suspicion. For this reason, a significant delay usually occurs between the first symptoms and diagnosis. This diagnosis should be supported by clinical, laboratory, and imaging findings (Fig. 1) [3, 5].

Nonspecific back or neck pain are generally the first clinical features, however, up to 15 % of patients could be

Fig. 1 Spinal infection management algorithm: step 1. *ESV* erythrocyte sedimentation velocity, *CRP* C-reactive protein, *WBC* white blood cell count, *MRI* Magnetic resonance imaging
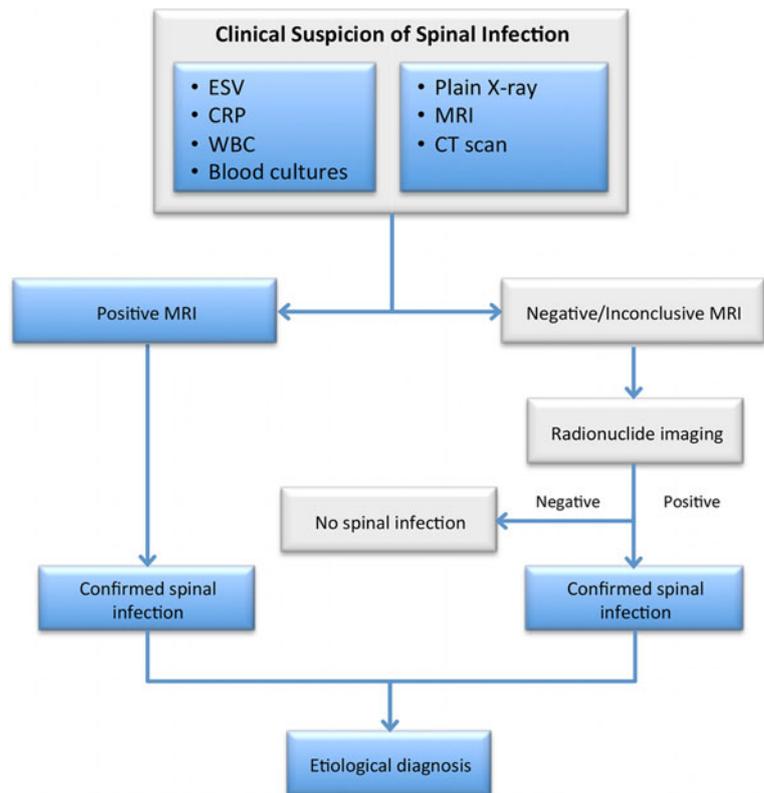
pain free [12]. With this insidious onset, patients have constant pain that worsens at night, often associated with radicular pain to the chest or abdomen [14]. Fever is less common [29] occurring in about 48 % of patients with pyogenic spondylodiscitis and in about 17 % of tuberculosis spondylitis cases. Dysphagia and torticollis are symptoms that may be caused by cervical location [30].

Symptoms associated with neurological deficits, such as leg weakness, numbness, and incontinence, are present in about one-third of patients [9]. These are often associated with late diagnosis [31], cervical infection [30], presence of epidural abscess, tuberculosis infection [32], and late diagnosis. During physical examination, it is important to look for kyphosis deformities, swelling, and tumefactions, which are often associated with tuberculosis spondylitis [33]. Yet, it has been recognized a frequent association of pyogenic vertebral osteomyelitis and infectious endocarditis. Pigrau et al. [31] found among 91 cases of pyogenic vertebral osteomyelitis, 28 of them (30.8 %) had infectious endocarditis. This should not be underestimated during clinical evaluation: in patients with Gram-positive infections and cardiac infection risk, or symptoms such as new heart murmur, peripheral stigmata, or other metastatic foci; it is strongly recommended to perform an echocardiography [34, 35].

In pediatric ages, clinical presentation is very nonspecific. Symptoms may include irritability, refusal to crawl, sit or walk, abdominal pain, or incontinence [36, 37]. Fever is rare in children [37], and the most frequent sign found on physical examination is the loss of lumbar lordosis [38]. Development of neurological deficits is extremely rare [36].

Laboratory findings

There are several markers routinely used in clinical practice that are critical for diagnosis and further evaluation of treatment response [39]. Erythrocyte sedimentation rate (ESR) is a sensitive marker of infection, yet with low specificity. Furthermore, ESR is also used as a marker of therapeutic response, for instance, Carragee et al. [39] found that a 25 % reduction of its initial value after 1 month of treatment was a good prognosis marker. However, in 9/18 (50 %) of those with no change in the ESR had good outcome [39]. Thus, in patients responding to therapy, a raised ESR should not lead to unnecessary invasive procedures and/or prolonged therapy. The C-reactive protein (CRP) is also elevated in more than 90 % of spondylodiscitis cases [17, 40], and some authors consider this marker the best monitor of treatment response, once it returns to normal after adequate treatment and faster than ESR [41, 42]. The WBC (white blood cells) count is the least useful of all inflammatory markers, due to its low sensitivity [17, 40].

Once a spinal infection is suspected, it is recommended to obtain blood and urine cultures before antibiotic

initiation [21, 43]. According to the main monomicrobial pattern of pyogenic spondylodiscitis, about up to 59 % of positive blood cultures identify the causative microorganism [4]. Aerobic cultures are performed routinely, while anaerobic were discouraged in the late 80s due to decreasing incidence of anaerobic bacteremia. Consequently, nowadays not all centers are capable to perform anaerobic cultures. Unfortunately, anaerobic bacteremia has reemerged as a significant clinical problem and its detection is highly recommended once it increases positive rate of blood cultures [44, 45].

Despite a suspicious history, associated positive blood cultures, and imaging findings consistent with a clinical diagnosis of spinal infection, the definitive diagnosis only can be achieved by microscopic or bacteriological examination of the infected tissues. Several reports emphasize its importance in patients whose blood cultures were negative or inconclusive [17, 18, 23, 46]. However, due to the fact that biopsy is superior to blood cultures in pathogen detection, we routinely perform biopsies in suspicious cases (Fig. 2). Gasbarrini et al. [47] published recently a comparative study where they conclude that percutaneous CT-guided needle biopsy is the mainstay of diagnosis for spinal lesions of unknown etiology and its accuracy has been reported up to 70 %. Nevertheless, the diagnostic yield of CT-guided needle biopsy is variable between centers, depending on the expertise of the radiologist, the number of samples sent, and the absence of previous antibiotic therapy; thus some authors reserve open biopsies for cases with CT-guided negative cultures [27]. Regarding our personal experience, in cases of patients with absolute indication for surgical treatment, open biopsy is our first choice as biopsy method once allows a greater amount of tissue to be harvested. Higher tissue yield and consequently more specific results are obtained than with percutaneous CT-guided needle biopsy (Fig. 2). For those without criteria for surgery and given the importance of histological diagnosis, CT-guided biopsy is a true option. The role of biopsy in children is not consensual. Some authors recommend it routinely, while others defend its performance only in cases of refractory to empirical treatment or in suspected fungal or mycobacterial infection [36, 48]. The specimens should be submitted to microbiological analysis, such as Gram smear, aerobic and anaerobic cultures, and fungal culture particularly for tuberculosis infections, AFB smear, polymerase chain reaction, and tuberculosis culture. Once Mycobacterium tuberculosis grows slowly (6–8 weeks [49]), a valuable aid for a faster diagnosis is the use of interferon-gamma release assays (IGRA) measured from whole blood plasma, providing results in less than 24 h. In addition, according to Kumar et al. [50], in a study with 70 patients followed for spinal TB infection, the sensitivity of the AFB smear and culture (together) was

59 % and the further addition of IGRA data resulted in a sensitivity of 88 %. Histopathology, per se, has a complementary value to microbiological culture in distinguishing pyogenic from granulomatous diseases [51–53] and is mandatory if tumor lesions are suspected [54–56].

Imaging

Plain radiographs should be performed in an initial evaluation for suspected pathology of the spine. Although it has low specificity (57 %) in spondylodiscitis diagnosis, it will reveal, in advanced cases, irregularity of vertebral endplates with eventual fragmentation and low intervertebral disc height [57]. It is also important to identify any coronal or sagittal malalignment resulting from the disease process.

Computed tomography (CT) remains the best test for evaluation of bony changes, including early changes of vertebral endplates, the presence of bone necrosis, and pathological calcifications suggestive of tuberculosis [57]. CT is also routinely used in percutaneous CT-guided needle biopsy [51–53].

Magnetic resonance imaging (MRI) is considered the gold standard modality for spondylodiscitis imaging diagnosis [58–60] due to its high sensitivity (96 %), specificity (94 %), and greater capacity to provide detailed anatomical information about surrounding soft tissues and epidural space [59]. The characteristic changes consist of a hypointense signal of the disc and vertebral body on T1-weighted images and a hyperintense signal of the same structures (due to edema) on T2-weighted images. Gadolinium enhancement of the intervertebral disc, vertebral body, and surrounding soft tissues increases the accuracy of MRI, especially when other changes are subtle and also help in the differentiation of infectious lesions from degenerative (T2 hypointensity favoring Modic endplate changes) and tumor lesions (T1 hypointense relatively to normal bone marrow) [61, 62]. MRI also plays an important role in the distinction between tuberculosis spondylitis and pyogenic spondylodiscitis [63]. Tuberculosis spondylitis has an extensive bone destruction pattern with relative sparing of the intervertebral disc, heterogeneous enhancement of the vertebral body, and large paravertebral abscesses. Table 1 summarizes several imaging features that can strongly support differential diagnosis of spinal infection etiologies.

Nevertheless, once different appearances occur at different stages, there is no pathognomonic finding on MRI that reliably distinguishes among spinal infections etiologies or from a possible neoplasm. Therefore, we emphasize the importance of complementary diagnosis methods (Figs. 1, 2—Spinal infection management algorithm).

Kowalski et al. [64] suggest that certain MRI findings may persist or even worsen during treatment, despite the

Fig. 2 Spinal infection management algorithm: step 2. *Antibiotic is adjusted according to the subsequent bacterial culture results
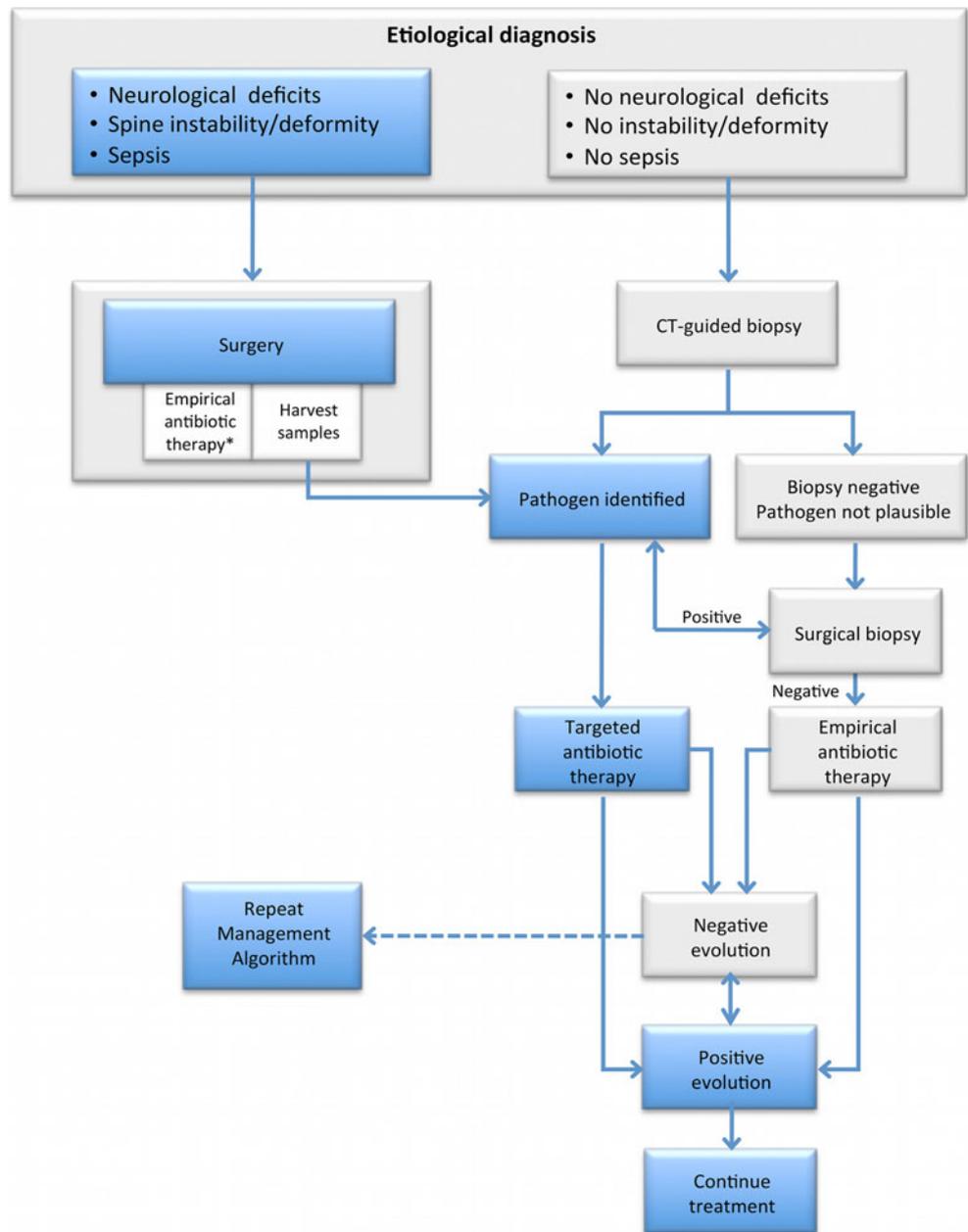
clinical improvement, and may lead to unnecessary invasive treatments. Changes compatible to resolution of the infection appear later and consist in the loss of gadolinium uptake and restoration of bone. Therefore, despite the increasing use of follow-up MR imaging to monitor response to treatment in patients with spinal infection, the study of Kowalski does not support the routine use of follow-up MR imaging in patients who are clinically responding to therapy [64, 65].

Sequential bone/gallium imaging and 67 Ga-SPECT are currently the radionuclide procedures of choice for spinal infections, but the observed lack of specificity have lead to an increase interest in [18F]Fluoro-2-deoxy-D-glucose (FDG) PET, as a promising technique in the absence of

spinal instrumentation as degenerative changes and fractures usually do not produce intense FDG uptake [66, 67]. Despite its increasing importance, radionuclide imaging in spinal infections should be reserved for cases of uncertain diagnosis or when MRI is inconclusive.

Treatment

The key principles for successful treatment of spinal infections are antibiotic therapy for eradication of the underlying infection; fixation of the affected segment to preserve or restore the spinal structure and stability; and debridement and decompression of the spinal canal in the

Table 1 Imaging features that can strongly support differential diagnosis of spinal infection etiologies [23, 61, 68–70]

	Pyogenic	Tuberculous	Brucellar	Fungal
Spine segment	Lumbar	Thoracic/thoracolumbar junction	Lower lumbar	Lumbar
Vertebral body (VB)	Early stage: anterior aspect of VB classically VB T1 hypo- and endplate T2 hyperintensity Late stage: VB destruction; T2 hyperintensity and homogeneous enhancement; Adjacent VB involvement	Early stage: anterior aspect of VB three patterns: para discal (more common)—discal involvement and contiguous spread to adjacent VB, T1 hypointensity and T2 heterogenous hyperintensity. Anterior—anterior scalloping of VB and large subligamentous abcesses Central—vertebra plana deformity; IVD not involved Late stage: T1 variable intensity with bone healing	Relatively preserved VB	Involvement: serrated margins of vertebral endplates without severe VB destruction
Disc space involvement	Present: early stage involvement T2 hyperintensity and enhancement	Variable: from disc space sparing up to severe destruction	Present	Typically spared; lack of T2 hyperintensity
Paraspinal/epidural space involvement	If present: inflammation and/or small abscesses with thick and irregular rim enhancement	Present: large paraspinal abscesses; thin and smooth rim enhancement	Typically not present: lack of paraspinal abscess	Present: Small paraspinal abscesses thick and irregular rim enhancement
Posterior elements	Typically not involved	Can be involved	Typically not involved	Can be involved Rib heads also
Anterior subligamentous spread	Uncommon	Present: can be more extensive than the vertebral involvement	Uncommon	Common
Adjacent vertebral levels involvement	Present: endplate destruction	Present: high bone destruction	Uncommon	Uncommon
Multilevel involvement	Uncommon	Common: skip lesions	Uncommon	Common: skip lesions

presence of neurological deficits or epidural abscesses [4, 71].

Spine infections are infrequently emergency situations at presentation and for this reason, antibiotic therapy should be initiated only after a definitive etiologic diagnosis (Fig. 2).

In the presence of sepsis or the impossibility of an etiologic diagnosis, empirical antibiotic therapy should be considered. The antibiotic spectrum must be extended to cover *S. aureus* and *E. coli*, the commonest pathogens for pyogenic spondylodiscitis, and obviously take into account the local epidemiology and the possibility of colonization by resistant organisms [4]. In cases of bacteremia caused by methicillin-resistant *S. aureus* (MRSA), the drug of choice is usually vancomycin; however, its efficacy is doubtful. To ensure therapeutic concentration levels in the bone, the American Society of Infectious Diseases (ASID) recommends maintaining vancomycin concentrations above 15–20 mg/L.

In confirmed tuberculosis spondylitis, specific tuberculostatic therapy should be initiated. The guidelines from British infection society (BIS) recommends that the treatment of all forms of central nervous system (CNS)

tuberculosis should consist of four drugs (isoniazid, rifampicin, pyrazinamide, ethambutol) for 2 months followed by two drugs (isoniazid, rifampicin) for at least 10 months [72]. In atypical infections, a consensual therapeutic regime has not been yet established [4].

Regarding fungal spondylodiscitis, it is generally difficult to identify the fungal agent, and antimycotic therapy is often complicated. Although there is no consensus in the literature, man authors recommend surgery as first approach [4, 71, 73].

The literature provides no clear guidance regarding the duration and route of administration of antibiotic therapy. Generally, an initial parenteric administration is advised, during a range of 3–8 weeks period [74]. Long duration therapy has not been directly related to better outcomes. For instance, Roblot et al. [34], in a retrospective study of 120 patients, found no difference in the risk of relapse amongst patients treated for 6 weeks or longer. After this initial period, antibiotic therapy could follow on with oral administration based on individual response and type of pathogen involved. In nonspecific pyogenic spondylodiscitis, oral antibiotic therapy is recommended for an additional period of 6 weeks to 3 months [4, 5]. Given the high

bioavailability and good diffusion of fluoroquinolones, clindamycin, rifampicin, and fusidic acid, some reports indicate exclusively oral antibiotherapy, avoiding the inconveniences of parenteric treatment [34, 75]. In addition, due to these facts, an early conversion from parenteric to oral therapy can be performed. In this scenario, before early oral conversion, endocarditis must be excluded [31]. In tuberculosis spondylitis, the treatment should be continued for a period of 10–24 months, to allow adequate healing and prevent recurrence [4].

It has been proposed that a weekly reduction of 50 % in CRP is suggestive of a favorable evolution, and accepted criteria for discontinuing the antimicrobial treatment includes improvement or resolution of the symptoms and normalization of ECR or CRP [76].

Conservative treatment

In patients without a formal indication for surgery (neurological deficits, spine instability, and intractable pain) or with high surgical risk, conservative treatment is a real valid option [4, 18, 23].

The controversy arises in the presence of minor neurological deficits [31, 77, 78]. In Pigrau et al. series, only 13 % of the patients required surgery, even though 29.7 % of patients had neurologic symptoms. In our opinion, the conservative approach in this particular scenario is desirable if there is no spinal instability. Neurological symptoms are minor and expected to improve with specific antibiotic therapy.

Immobilization is one of the milestones of a successful conservative approach. The immobilization of the affected segment is necessary when pain is significant and there is no risk of instability. It also eliminates the need for prolonged bed rest. Cervical spine immobilization can be achieved using a collar or a halo-fixator. For the thoracic or lumbar spine, a thoracolumbar brace allows the load distribution to the unaffected joints and reduce the pressure on the affected vertebra [4, 18]. Known risks related to immobilization include up to 50 % non-union rate at an involved disc, which may lead to kyphosis deformity and chronic pain syndrome [3]. If a patient demonstrates increasing pain and deformity in spite of improvement of laboratory indices, then surgical management should be considered.

Even with a conservative approach, the CT-guided percutaneous drainage can be effective for patients with pyogenic spondylodiscitis and a secondary psoas abscess.

Surgical management

Early surgical treatment should be performed in the presence of neurological deficits or sepsis [18]. Absolute surgical indications also include spinal instability due to extensive bone destruction, severe kyphosis, intracanal spinal lesion with mass effect, unknown etiologies associated with active tumor, and in failure of conservative treatment [4, 79]. Some authors also recommend surgical treatment in the presence of epidural abscess even without associated neurological deficits, especially in the cervical and thoracic region [80]. The relative indications consist of the presence of uncontrolled pain and inexistent conditions for conservative treatment [5].

Despite indication for surgery in the presence of neurological deficits, age and presence of concurrent medical conditions may affect surgical decision [20]. According to Yoshimoto et al. [81] in a review of 45 cases of pyogenic spondylitis in elderly, 42 % of patients with paralysis on admission were not submitted to surgery due to poor general condition. Yet, paralysis was improved in 73 % of these patients with conservative treatment [81].

The main goals of surgical treatment of spinal infections include (1) early decompression of the spinal canal and stabilization of the involved vertebral segment, in the presence of neurological deficits [3, 4, 82, 83]; (2) aggressive tissue debridement, including drainage of paravertebral abscesses; and (3) sample harvesting for microbiological and histological analyses.

Regarding the surgical strategy itself, recommendations are controversial [3, 84]. Any standard approach can be used (anterior, posterior, combined, or minimally invasive approaches), whereas the choice is related mainly to the presence of neurological deficits, the location of the infection, and degree of associated bone destruction (Table 2).

In cervical spinal infections, an anterior approach is recommended with appropriate debridement, decompression (eventual corpectomy), and fusion with bone graft, associated with anterior plate stabilization. In multilevel intervention, this should be complemented with posterior instrumentation [82]. Eventually, if the involvement was mainly epidural with no severe destruction of the vertebral body, it is acceptable to proceed toward posterior decompression and fusion [71, 82].

In the thoracic spine, as stability is maintained mostly by the rib cage and with physiologically restricted mobility, stability issues may not be a significant priority. Therefore, in the presence of an epidural involvement without anterior disc or bony destruction, a posterior approach with decompression and instrumentation is usually the first option. A purely anterior approach for decompression and fusion (using a transthoracic, posterolateral, or thoracoscopic approaches) is reserved for monosegmental lesions without involvement of posterior elements [85]. Even in this situation, consideration for adjunctive posterior stabilization is often considered. In advanced anterior bone

Table 2 Summary of the most relevant features of spinal infections' surgical treatment—clinical series published in the last 5 years

Reference	Number of patients	Follow-up (M)	Neurologic deficitis (%)	Etiology	Spine segment	Surgical approach	Anterior reconstruction	Mortality (%)	Neurologic improvement (%)	Union rate (%)	Loss of correction
Zhang et al. 2012 [87]	14	50.1 (42–64)	100.0	TB	Lumbar	Combined (two-staged)	Allograft (fresh frozen ICBG)	0	100.0	100.0	1.9°
Shousha et al. 2012 [88]	30	28.4 (6–54)	40.0	PY	Cervical	Single anterior (17) Combined (13)	CAGE (17) Autologous ICBG (10)	10	58.0	100.0	(–)
Masuda et al. 2011 [89]	30	26.2 (3–60)	90.0	PY (19) TB (11)	TL	Combined (two-staged)	Bone graft	0	56.7	100.0	(–)
Koptan et al. 2011 [90]	30	66 (24–84)	60.0	TB	Cervical	Single anterior	CAGE (16) Autologous ICBG (14)	0	94.4	93.0	(–)
Erturer et al. 2010 [91]	20	52.7 (37–94)	55	TB	TL	Combined (single-staged)	CAGE (allgograft)	0	90.9	100	0.8°
Chen et al. 2010 [92]	16	24 (–)	31.3	PY (10) TB (1)	Lumbar	Single anterior (12) Combined (4)	Autologous ICBG	12.5	80.0	85.7	0°
Hempelmann et al. 2010 [93]	18	21 (12–42)	38.9	PY	Lumbar	Posterior (PLIF)	Autologous ICBG	17	100.0	100.0	(–)
Hirakawa et al. 2010 [94]	10	48.2 (24–101)	60.0	TB	Lumbar	Combined (two-staged)	Autologous bone	0	66.7	100.0	5.1°
Okada et al. 2009 [95]	52	35.9 (24–120)	80.8	PY (25) TB (27)	Cervical TL	Single anterior (15) Posterior (7) Combined (30)	(–)	0	90.4	(–)	1.9° PY 2.4° TB
Zaveri et al. 2009 [96]	15	41 (26–69)	86.7	TB	Lumbar	Posterior (PLIF)	CAGE (autologous bone)	0	100.0	86.7	1°
Lu et al. 2009 [97]	36	21 (10–39)	72.2	PY (30) TB (6)	Cervical TL	Combined (27) Single anterior (5) Posterior (4)	CAGE (autograft or allograft)	2.7	92.0	(–)	(–)
Robinson et al. 2008 [98]	22	36 (32–47)	22.7	PY (12) TB (1)	Cervical TL	Single anterior (3) Combined (19)	CAGE (autologous bone)	9	(–)	100.0	3.7°
Pee et al. 2008 [99]	60	35.8 (26–50)	26.7	PY	Lumbar	Combined (single-staged)	CAGE (37) Autologous ICBG (23)	0	68.7	95.0	(–)
Korovessis et al. 2008 [100]	24	56 (31–116)	58.3	PY (20) BC (4)	Cervical TL	Combined (single-staged)	CAGE (autologous bone)	0	85.6	100.0	0.6°

TB tuberculous, *PY* pyogenic, *TL* thoracolumbar, *PLIF* posterior lumbar interbody fusion, *ICBG* iliac crest bone graft

destruction and collapse, it is recommendable an anterior approach for debridement, decompression, and fusion with bone graft complemented with additional posterior instrumentation [71, 82, 83].

At the thoracolumbar juncture, decompression and stabilization are recommended in the presence of a neurological deficit or extensive epidural invasion. In cases of monosegmental spondylodiscitis with moderate anterior bone involvement and minimal kyphosis deformity, a posterior lumbar interbody fusion may be sufficient [86]. Many surgeons prefer, however, not to invade the posterior tissues with exposure to purulent tissue and would prefer an initial anterior debridement followed by a posterior stabilization procedure.

In the presence of an extensive anterior bone destruction and collapse with segmental kyphosis, a double approach (performed in one or two stages) with anterior debridement and interbody fusion associated with posterior instrumentation results in faster fusion, improved correction of the kyphotic deformity and its maintenance, as well as earlier patient mobilization [18, 101–103]; yet, opinions diverge about the best option for anterior interbody fusion (Table 2). Classically, bone grafting with tricortical iliac autograft is recognized as a safe procedure, with excellent and consistent outcomes [103–105]. Structural bone allograft can be used as an alternative, avoiding donor site morbidity and reducing operative time [97]. Furthermore, recent publications have demonstrated improved fusion rates when combining recombinant human bone morphogenic protein-2 (rhBMP-2) with structural bone graft [106–108]. A drawback that surgeons must keep in mind when using bone allografts, although not frequent, is the risk of provoking an immune reaction or that it could become a source for infection transmission [103].

Structural bone grafting persists as a standard procedure in several centers, majorly due to the concern about risks of introducing hardware in an infected field [109]. Nevertheless, several recent publications show that metallic implants can be safely used in spinal infections (Table 2) [96–98, 100, 109–112]. Despite the importance in distinguishing the different risks of using metallic implants in pyogenic or tuberculous infection, enthusiastic outcomes have been published on the use of hardware in both cases. Erturer et al. [91], in a series of 20 patients with tuberculous spondylitis submitted to anterior interbody fusion using titanium mesh cage, reported solid fusion in all patients with maintenance of kyphosis correction, as well as no recurrence of tuberculosis infection [91]. Regarding pyogenic spondylodiscitis, Liljenqvist et al. [102] reported a 100 % fusion rate and infection eradication in a 20-patient series with destructive vertebral osteomyelitis treated by a double approach with anterior column reconstruction using an expandable titanium cage filled with morselized autologous bone graft [102].

With the advent and development of minimally invasive spine surgery (MISS), some techniques have been used successfully in the treatment of spinal infection. At the thoracic segment, thoracoscopic approach has been used in some centers with exciting results and additional advantages such as pain reduction and improved postoperative respiratory function, less damage to the soft tissues, resulting in improved esthetic results, and shorter hospital stay [85]. In the lumbar segment, posterior percutaneous instrumentation is already regularly used in patients who underwent double approach.

Prognosis

With the advent of antibiotics, improved techniques of management, and early recognition, mortality associated with spinal infections has significantly decreased to <5 % in developed countries [12, 20, 21], and early mortality is generally related to uncontrolled sepsis. Despite mortality has declined, the most worrying outcome is the potential for a permanent neurological deficit.

Some retrospective outcome studies present distinct prognostic factors. We summarized those related to a poor outcome in Table 3. Besides age and spine segment, underlying conditions that are associated with poor prognosis, the major prognostic factor was the presence of a motor deficit before treatment and if the neurological deficits are present for longer than 36 h [5, 18]. In our opinion, whenever these patients gather surgical conditions, an operative approach might greatly improve prognosis. In a series by Hadjipavlou et al. [18], 23 % of patients with paralysis on admission recovered completely after surgical decompression.

Table 3 Spinal infections' prognostic factors associated with poor outcomes

Prognostic factor	Poor outcome	References
Age	Older patients	[114–116]
Spinal segment	Cervical/thoracic involvement	[20, 117–119]
Underlying disease	Diabetes mellitus	[114, 116]
	Chronic heart disease	[114]
Clinical presentation	Paralysis	[20, 80, 113, 115, 118–120]
	Bowel/bladder disfunction	[115, 118, 120]
Diagnosis	Delayed	[118, 119, 121]
Pathogen	MRSA	[20, 116]
Length of time for surgery	>36 h	[5, 18, 80, 113, 120, 122]

Despite the presence of neurological deficits on admission, at medium- and long-term follow-up, residual symptoms persist independently of treatment choice and this detrimental outcome is directly related with diagnosis delay [113]. These sequelae are essentially the result of degenerative changes secondary to tissue destruction by the infectious process. McHenry et al. [76] reported in a 253 patients follow-up series, 14 % of patients had a recurrence of their infection of which 75 % occurred in the first year after surgery. In childhood, the prognosis is excellent [36, 48].

Conclusions

Spinal infections remain a rare pathology, although an increased incidence has been reported due to a progressively more susceptible population (particularly history of previous spine surgery and HIV positive populations) and improved diagnostic acuity.

Due to the insidious onset, a high clinical suspicion remains the centerpiece of a prompt diagnosis, which is pivotal to improve long-term outcomes and prevent permanent neurologic deficits. Herein, microbiological and histological diagnosis plays a critical role toward the definition of specific therapeutic management. Therefore, in CT-guided or open biopsy should be considered a first line of investigation in suspected cases.

The treatment of spinal infections is mainly a nonsurgical treatment and comprises a specific antibiotic therapy associated with immobilization that reduces pain and helps preventing segmental instability and deformity. Surgery is indicated for patients with neurological deficits or sepsis, spine instability and/or deformity, presence of epidural abscess, and in failure of conservative treatment. Once spinal infections affect mainly the vertebral body and the intervertebral disc, surgical strategy should include appropriate anterior debridement of the infected tissues and reconstruction of the involved segments with bone construct, posterior decompression of neural elements, and instrumented stabilization. In selected patients, MISS has been used and is showing interesting results.

Conflict of interest None.

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