ORIGINAL ARTICLE

Spondylodiscitis: Diagnosis and Treatment Options

A Systematic Review

Christian Herren, Norma Jung, Miguel Pishnamaz, Marianne Breuninger, Jan Siewe, Rolf Sobottke

SUMMARY

Background: A recent population-based study from Denmark showed that the incidence of spondylodiscitis rose from 2.2 to 5.8 per 100 000 persons per year over the period 1995–2008; the age-standardized incidence in Germany has been estimated at 30 per 250 000 per year on the basis of data from the Federal Statistical Office (2015). The early diagnosis and treatment of this condition are essential to give the patient the best chance of a good outcome, but these are often delayed because it tends to present with nonspecific manifestations, and fever is often absent.

Methods: This article is based on a systematic search of Medline and the Cochrane Library for the period January 2009 to March 2017. Of the 788 articles identified, 30 publications were considered.

Results: The goals of treatment for spondylodiscitis are to eliminate infection, restore functionality of the spine, and relieve pain. Magnetic resonance imaging (MRI) remains the gold standard for the radiological demonstration of this condition, with 92% sensitivity and 96% specificity. It also enables visualization of the spatial extent of the infection and of abscess formation (if present). The most common bacterial cause of spondylodiscitis in Europe is *Staphylococcus aureus*, but tuberculous spondylodiscitis is the most common type worldwide. Antibiotic therapy is a pillar of treatment for spondylodiscitis and should be a part of the treatment in all cases. Neurologic deficits, sepsis, an intraspinal empyema, the failure of conservative treatment, and spinal instability are all indications for surgical treatment.

Conclusion: The quality of life of patients who have been appropriately treated for spondylodiscitis has been found to be highly satisfactory in general, although back pain often persists. The risk of recurrence increases in the presence of accompanying illnesses such as diabetes mellitus, renal failure, or undrained epidural abscesses.

► Cite this as:

Herren C, Jung N, Pishnamaz M, Breuninger M, Siewe J, Sobottke R: Spondylodiscitis: diagnosis and treatment options—a systematic review. *Dtsch Arztebl Int* 2017; 114: 875–82. DOI: 10.3238/arztebl.2017.0875

Although vertebral osteomyelitis is rare at a rate of 3%–5%, it is the third most common form of osteomyelitis (e1) at >50 years of age. Spondylodiscitis is characterized by marked heterogeneity, which limits its scientific evaluation and recommendations on its treatment. Differential diagnoses include polymyalgia rheumatica, activated osteochondrosis, vertebral hemangioma, destruction of the spinal column by tumors, fractures, and ankylosing spondyloarthritis.

Propagation and spectrum of pathogens: Three infection pathways are described from a pathogenetic perspective: endogenous, exogenous, and per continuitatem. The hematogenic form is the most common and can be differentiated on the basis of its arterial or venous etiology. Spondylodiscitis is usually a monobacterial infection and more than 50% of cases in Europe are caused by *Staphylococcus aureus*, followed by gram-negative pathogens such as *Escherichia coli* (11%–25%) (1, e2, e3). The most common pathogen worldwide is *Mycobacterium tuberculosis*. Brucellosis should be included in pathogen identification in patients from Mediterranean countries and the Middle East (e4).

Incidence and risk factors: Although the literature reports a low incidence of approximately 5–6/100 000 patient years, data from the German Federal Statistical Office (2015) are clearly higher at an age-standardized rate of approximately 30/250 000 (2, e2). Due to improved diagnostic methods, a growing incidence of cases has been seen (2, e5). Moreover, the rate of surgical procedures in older, polymorbid patients is rising—patients aged over 65 years are affected up to 3.5 times more frequently, while women are affected 0.82 times less frequently (2). Other risk factors include diabetes mellitus, immunosuppression, a history of infections, i.v. drug abuse, and HIV (3).

Diagnosis is based not only on radiological findings, but also on clinical, laboratory, and microbiological findings. It is not uncommon for this to cause a delay of 2–12 weeks between diagnosis and treatment initiation (4). The prognosis of spondylodiscitis without accompanying neurological deficits is good if antibiotic therapy and surgical management, if necessary, are initiated promptly (5). Nevertheless, the overall mortality rate in

Department for Trauma and Reconstructive Surgery, University Hospital RWTH Aachen: Dr. med. Herren, Dr. med. Pishnamaz

Department I for Internal Medicine, University Hospital Cologne: PD Dr. med. Dipl. chem. Jung, Dr. med. Breuninger

Center of Orthopedic and Trauma Surgery, University Hospital Cologne: PD Dr. med. Siewe, Prof. Dr. med. Sobottke

Center for Orthopaedics and Trauma Surgery, Rhein-Maas Klinikum GmbH, Würselen: Prof. Dr. med. Sobottke

Flowchart showing the publications included

the case of inadequate treatment is given as up to 20% in the literature (6, 7).

Methods

Based on the article *Aktuelle Diagnostik und Therapie der Spondylodisitis* (Current Diagnosis and Therapy of Spondylodisitis) published by Sobottke et al. in 2008 (3), a systematic review of the English literature (Medline, Cochrane Library; 2009–2017) was performed using the following search terms: “vertebral osteomyelitis,” “spinal infection,” “discitis,” “spondylodiscitis,” “pyogenic osteomyelitis,” AND “spine,” “diagnosis,” and “therapy.”

Titles and abstracts were reviewed and included on the basis of diagnostic/therapeutic recommendations. Case reports and all articles containing the term “ankylosing spondylitis” were excluded. Of the 788 articles identified, 30 publications were considered (Figure 1) and summarized in two overview tables according to the Oxford evidence grading system (Table 1 and eTable) (e6).

Results

Patient history and symptoms

There is a direct association between the occurrence of post-invasive spondylodiscitis and prolonged surgical time and dorsal instrumentation (e5, e10–e12). According to Sobottke et al., spondylodiscitis occurs in 22.2% of conservatively treated and 50.4% of invasively treated (e.g., catheterization, fine-needle aspiration) patients. Other aspects to be considered are summarized in Table 2.

Laboratory and microbiological tests

Blood testing includes leukocyte and C-reactive protein (CRP) counts. Although blood sedimentation rate

(BSG) is often cited as an easy parameter to determine, it is non-specific (e13, e14). However, response to antibiotic therapy can be effectively followed-up using CRP/BSG (10). An acute disease course is characterized by increased inflammatory markers (75%–98%), whereas these can be virtually normal in the chronic course. Leukocytosis is not necessarily present, whereas increased CRP is seen in 90%–98% of cases (4, e15). Jean et al. showed that an increased CRP can shorten the time to diagnosis compared with other laboratory parameters (9). The procalcitonin (PCT) level plays a minor role as a parameter of sepsis in the primary diagnosis of spondylodiscitis, is more cost-intensive than CRP determination, and is not suitable as a follow-up parameter (11).

In addition, at least two blood culture pairs (aerobic/anaerobic) are obtained. The pathogen can be identified in 25%–59% of blood cultures (4), whereas a pathogen detection rate of as much as 70% is described in patients not previously treated with antibiotics (e12). Since a focus of infection, such as in the case of bacterial endocarditis, requires targeted therapy, the search for the focus is an important part of the diagnostic work-up. In addition, the primary source of infection can be found in approximately 50% of infections.

Material can be obtained for further histopathological investigation by means of computed tomography (CT)-guided fine-needle biopsy or removed surgically. The presence of granulomas can point to specific pathogens. Pathogen detection is 19%–30% when using CT-guided fine-needle biopsy due to the small amount of tissue available, whereas detection can be achieved in 41% using histopathological methods (13, e16). More recent literature shows that pathogen detection can be improved using a combined magnetic resonance imaging (MRI)/CT investigation involving superimposition of the respective image data prior to fine-needle biopsy (14, 15). According to Kim et al., the pathogen detection rate is 2.28 times higher following soft tissue investigation compared with bone tissue (16), whereas in their retrospective analysis (126 tissue biopsies), Chang et al. demonstrated that there is an approximately significant difference in specificity/sensitivity in relation to the type of biopsy tissue (sensitivity/specificity end plate vs. paravertebral soft tissue: 38%/86% vs. 68%/92%, $p = 0.09$; disc vs. endplate: 57%/89% vs. 38%/86%; $p = 0.05$) (16, 17).

The most reliable method remains surgical biopsy (e12, e17), with a pathogen detection rate of up to 68%–93%. Molecular biological investigations (polymerase chain reaction [PCR]) can be used to further identify the pathogen in the case of negative cultures after 48-h incubation, especially in patients pre-treated with antibiotics. Species-specific PCR (e.g., for *S. aureus* and *M. tuberculosis*) can further increase sensitivity (12, e1). Using species-specific PCR, Choi et al. were able to detect 46.7% of spondylodiscitis cases overall, whereas only 26.7% could be detected using conventional PCR (12). This was also demonstrated in a retrospective study in which 275 of 427

TABLE 1

Treatment of spondylodiscitis: overview of study outcomes

Type of treatment	Number of patients	Follow-up	Outcome parameter	Key message (year of publication)	Evidence level*
Antibiotic treatment	359	12 months	EQ-5D, cure	6-week antibiotic treatment showed no worse outcome than 12-week antibiotic treatment in pyogenic spondylodiscitis at 1 year (90.9% of patients included per group; difference between groups: 0.05%; 95% CI: [-6.2; 6.3]) (2015) (21)	I
Conservative vs. surgical treatment at >65 years of age	32 (16 conservative, 16 surgical)	42 months	ODI, SF-36, mortality, complications	Surgical treatment at >65 years of age does not show higher mortality (3.1%/12.5% in follow-up) compared with young patients, but the complication rate is higher (21.9% vs. 40.6%); overall, there is no significant difference in SF-36 (39.2 vs. 37.1) or in the VAS for leg pain (1.8 vs. 3.2) (2010) (7)	III
Antibiotic treatment	45	10 months (10–90 months)	Neurological status	Decreasing neurological symptoms (72.7%) with conservative treatment (antibiotic treatment and corset immobilization) at 1-year follow-up in patients >65 years (72.7%, 8 of 11 patients) (2011) (22)	III
Antibiotic treatment	215	39 months	Antibiotic failure	Diabetes (HR 1.69; 95% CI: [1.03; 2.79]), epidural abscess (HR: 1.91 [1.05; 3.45]), further osteomyelitis (HR: 5.17 [2.63; 27.9]), or fever (HR: 1.61 [0.93; 2.79]) are independent factors for antibiotic failure (2017) (23)	III
Surgical treatment	No data	No data	No data	Absolute surgical indication: neurological deficit, paravertebral abscess >2.5 cm, vertebral instability and pronounced kyphosis or bone destruction (2012) (e9)	V
Antibiotic treatment/surgical treatment	32	24 months (6–24 months)	Wound healing, re-infection, deformity, cure	One-stage biopsy, debridement, reconstruction, and stabilization in one procedure resulted in resolution and a lower complication rate (12.5%) in all 32 patients (2014) (24)	III
Abscess drainage (psoas)	20	No data	Successful drainage (yes/no?)	Successful ultrasound-guided drainage placement in 14 of 16 cases and open drainage placement in 4 of 4 cases in patients with HIV-positive (14)/-negative (5) serology and psoas abscess (2016) (25)	III
Abscess drainage (disc)	8	10 months	Resolved (yes/no?)	Percutaneous drainage for 32 days on average (13–70) accompanied by antibiotic treatment of the infection site resulted in resolution in 6 of 8 patients (2012) (26)	IV
Surgical treatment (posterior vs. postero-anterior)	31 (23 vs. 8)	12 months	JOA score, VAS, functional criteria, radiological parameters	An isolated posterior procedure resulted in significant loss ($p < 0.001$) of sagittal balance (preoperative, 1.75) over 6 weeks (-3.73) and 12 months (-0.79), but has no effect on the 1-year outcome (2014) (27)	II
Conservative treatment	30	24 months	SF-36, ODI	Patients without complications and with good outcome (ODI: 26; SF-36: 40.6); MRSA and longer symptom duration worsened outcome (ODI: 58; SF-36: 27.3) (2017) (28)	III
Surgical treatment (epidural vs. no abscess)	135 (46 vs. 89)	No data	Frankel grade	The presence of an epidural abscess is a negative predictor of outcome after surgical treatment (2014) (29)	III
Classification concept for appropriate treatment selection	250	24 months	Radiological and clinical findings	A classification system with treatment recommendations is important to avoid incorrect treatment (2017) (30)	III
Surgical treatment (XLIF and percutaneous dorsal stabilization)	11	9 months	Fusion rate, VAS, inflammatory parameters	Compared to ALIF, the XLIF technique with percutaneous posterior stabilization resulted in good restoration of the lumbar lordosis in 11 of 11 patients (from preoperative 23.1° to postoperative 34.0°) without complication in the form of reoperation (2015) (31)	III
Rigid bracing vs. percutaneous stabilization	27 (15 conservative, 12 surgical)	9 months	(EQ-5D, SF-12, VAS)	Surgery confers no benefit in terms of healing, but confers benefits in outcome in the first 3 months (EQ-5D; 1 and 3 months: 0.8 vs. 0.5/0.9 vs. 0.7) (2014) (32)	III

ALIF, anterior lumbar interbody fusion; HR, hazard ratio; JOA, Japanese Orthopaedic Association; MRSA, methicillin-resistant *Staphylococcus aureus*; ODI, Oswestry Disability Index; SF-36/SF-12/EQ-5D, quality-of-life questionnaires; VAS, visual analog scale; XLIF, extreme lateral interbody fusion; 95% CI, 95% confidence interval; vs., versus

* According to the evidence ranking scheme of the Oxford Centre for Evidence-based Medicine

TABLE 2

Important aspects of patient history and clinical examination

Patient history	Clinical symptoms
General disease symptoms (fatigue, drowsiness, lack of appetite, fever, night sweats)	
<ul style="list-style-type: none"> – Spinal segment pain (pain at night and/or rest pain) – Pain increases upon exertion – Pre-existing diseases (diabetes, rheumatoid arthritis) – Spinal surgery – General invasive procedures (catheterization, surgery, fine-needle aspiration) 	<ul style="list-style-type: none"> – Patients report pain on percussion over the spinal segment but no or little pain on pressure – Inclining and straightening up again cause pain – Pain on knee flexion and compression in the heel drop test

TABLE 3

Radiological changes on MRI (e26)

MRI weighting	Radiological changes
T2/STIR	Hyperintense intervertebral disc
	Hyperintense adjacent vertebral bodies
T1	Hypointense intervertebral disc
	Hypointense adjacent vertebral bodies
Regardless of weighting	Loss of disc height
	End plate erosion
	Signs of paravertebral/epidural inflammation

STIR, short-tau inversion recovery

diagnoses (62.9%) could only be made using species-specific rather than conventional PCR (e18). In contrast to culture results with additional antimicrobial resistance testing, however, PCR does not provide any information on pathogen sensitivity to antibiotics.

Diagnostic imaging

Conventional radiological imaging of the relevant spinal segment is the first-line imaging investigation in patients with unclear spinal symptoms; sensitivity and specificity are low at 82% and 57%, respectively (e19). Erosion of the base and upper plates or increasingly destructive kyphosis can manifest after days or weeks depending on the virulence of the pathogen, the patient's immune status, or the clinical course of the disease (33, e7). Therefore, a negative native X-ray does not exclude spondylodiscitis, but is nevertheless important to evaluate disease progression.

CT is often used as an alternative in the case of contraindications to MRI (non-MRI-compatible pacemakers, other patient-specific factors). Paravertebral abscesses can be better diagnosed with contrast-enhanced CT; moreover, CT simplifies fine-needle biopsy or abscess drain placement (e20–e22). CT is

also useful in the preoperative planning of spinal procedures and, depending on the system used, is a prerequisite to computer-assisted spine surgery (e23).

MRI is the gold standard in imaging studies to detect spondylodiscitis, whereby adding a contrast agent also enables a distinction to be made between findings suspicious for spondylodiscitis, degeneration (Modic type I), or neoplasia (e8, e24). Specificity and sensitivity are extremely high at 96% and 92%, respectively (33, e8, e25). Gadolinium-enhanced MRI can increase sensitivity to as much as 95.4% (e26). *Table 3* summarizes radiological signs.

Fluorine-18 fluorodeoxyglucose positron emission tomography/CT (^{18}F -FDG-PET-CT) is a procedure well known in oncology and infectious diseases and appears to be playing an increasingly important role in the diagnosis of spondylodiscitis (18, 19, 34). PET-CT represents a good alternative particularly in the case of contraindications to contrast-enhanced MRI/CT (e.g., kidney failure). However, on the whole, it remains an expensive procedure that is only available in specialized centers. Physiologically, the correspondingly labeled glucose does not accumulate in the bone marrow and spine, such that inflammatory processes with increased glucose activity appear as “hot spots” on PET-CT. Ioannou et al. and Skanjeti et al. consider MRI to be equivalent to PET-CT with minor advantages for PET-CT in the first 2 weeks following disease onset (35, 36). Recent studies have shown that PET-CT has clear advantages in the differentiation between degenerative (Modic type I) and inflammatory changes (19, 20, 37, e27) compared with MRI. However, PET-CT's lack of specificity to differentiate between neoplasia, spondylodiscitis, and post-traumatic bone marrow edema represents a drawback (e28, e29). Thus, its combination with MRI is recommended. On the other hand, PET-CT offers the advantage that it can be performed in all patients irrespective of metal implants and non-MRI-compatible pacemakers.

Multiphase bone scintigraphy can be performed with ^{99}Tc (TM)-labeled leukocytes in combination with ^{67}Ga citrate, thereby increasing sensitivity to 86%. To this end, radioactively labeled antigranulocyte antibodies, which accumulate in the case of an inflammatory reaction, are used. However, specificity is low, since remodeling processes such as osteochondrosis (e30) are also visualized. The advantage of this technique is its potential to detect further sources of infection. *Figure 2* shows the three-step diagnostic algorithm for the detection of spondylodiscitis.

Treatment

Spondylodiscitis is highly heterogeneous in terms of severity, which depends, e.g., on patients' health condition and pathogen spectrum. The formulation of a standard treatment consensus is hampered by the varying study results (level I–IV) and expert opinions (level V). Therefore, Pola et al. proposed a treatment algorithm on the basis of a retrospective analysis in which clinical radiological findings were taken into account (30).

FIGURE 2

Three-step diagnostic algorithm to detect spondylodiscitis
PCR, polymerase chain reaction; PET, positron emission tomography

In this context, it is important to mention the risk of bias. With the exception of the recommendations on antibiotic therapy, the studies presented in the present review differ greatly in terms of evidence level and should primarily be considered level III/IV studies. Given that it is impossible to establish uniformity in terms of the statistics used, the follow-up period, or the number of patients investigated, there is also a publication bias.

The aim of spondylodiscitis treatment is to eliminate the focus of infection, restore spinal functionality, and reduce pain. Microbiological pathogen detection forms the basis for the initiation of specific antibiotic therapy. There is consensus that empirical antibiotic therapy should only be initiated once the pathogen has been identified (38, e31). No consensus has been reached as yet on the period of targeted antibiotic therapy; there are a number of retrospective studies and the recommendations equate to an expert opinion; the study by Bernard et al. was the first randomized study to be published on the duration of treatment. Based on an

analysis of 359 patients, it was shown that a 6-week course is not inferior to a 12-week course of treatment in terms of cure rate at 1 year (90.9% of the patients in each group; group difference: 0.05%; 95% confidence interval (CI): [−6.2; 6.3]) (21). It was not possible to establish which subgroups might have required longer therapy. However, there was evidence that advanced age (≥ 75 years) and *S. aureus* are risk factors for the failure of antibiotic therapy. Another retrospective study (n = 314) identified risk factors for recurrence, classified patients into high-risk and low-risk groups, and correlated treatment success with treatment duration (39). The mean time to relapse was given as 5 weeks (1.5 weeks–30 months), and infections with methicillin-resistant *S. aureus* (MRSA), undrained paravertebral and psoas abscesses, as well as severe kidney failure were identified as independent risk factors.

The guidelines of the Infectious Diseases Society of America (IDSA) deem 6-week therapy to be adequate in most patients with non-specific spondylodiscitis

TABLE 4

Recommendations on antibiotic treatment (according to IDSA guidelines [38])

Pathogen	First line treatment	Alternative treatment
Staphylococci, oxacillin-susceptible	<ul style="list-style-type: none"> – Flucloxacillin 1.5–2 g i. v. (3–4 × d) – Cefazolin 1–2 g i. v. (3 × d) – Ceftriaxone 2 g i. v. (1 × d) 	<ul style="list-style-type: none"> – Vancomycin i. v. 15–20 mg/kg (2 × d) (monitor serum levels) – Daptomycin 6–8 mg/kg i. v. (1 × d) – Linezolid 600 mg p. o./i. v. (2 × d) – Levofloxacin p. o. 500–750 mg (1 × d) and rifampin p. o. 600 mg/d or clindamycin i. v. 600–900 mg (3 × d)
Staphylococci, oxacillin-resistant	<ul style="list-style-type: none"> – Vancomycin i. v. 15–20 mg/kg (2 × d) (monitor serum levels) 	<ul style="list-style-type: none"> – Daptomycin 6–8 mg/kg i. v. (1 × d) – Linezolid 600 mg p. o./i. v. (2 × d) – Levofloxacin p. o. 500–750 mg (1 × d) and rifampin p. o. 600 mg/d
<i>Enterococcus</i> spp., penicillin-susceptible	<ul style="list-style-type: none"> – Penicillin G 20–24 million IU i. v. continuously over 24 h or in 6 partial doses – Ampicillin 12 g i. v. continuously over 24 h or in 6 partial doses 	<ul style="list-style-type: none"> – Vancomycin 15–20 mg/kg i. v. (2 × d) (monitor serum levels) – Daptomycin 6 mg/kg i. v. (1 × d) – Linezolid 600 mg p. o. or i. v. (2 × d)
<i>Enterococcus</i> spp., penicillin-resistant	<ul style="list-style-type: none"> – Vancomycin i. v. 15–20 mg/kg (2 × d) (monitor serum levels) 	<ul style="list-style-type: none"> – Daptomycin 6 mg/kg i. v. (1 × d) – Linezolid 600 mg p. o. or i. v. (2 × d)
β-Hemolytic streptococci	<ul style="list-style-type: none"> – Penicillin G 20–24 million IU i. v. continuously over 24 h or in 6 partial doses – Ceftriaxone 2 g i. v. (1 × d) 	<ul style="list-style-type: none"> – Vancomycin 15–20 mg/kg i. v. (2 × d) (monitor serum levels)
Enterobacteriaceae	<ul style="list-style-type: none"> – Cefepime 2 g i. v. (2 × d) – Ertapenem 1 g i. v. (1 × d) 	<ul style="list-style-type: none"> – Ciprofloxacin 500–750 mg p. o. (2 × d) – Ciprofloxacin 400 mg i. v. (2 × d)

d, Day; h, hour; IU, internationale unit; i. v., intravenous; p. o., per os;

BOX

Criteria for surgical treatment*

- **Surgical indications**
 - Neurological deficits
 - Sepsis
 - Presence of intraspinal empyema
 - Presence of a ventral, paravertebral abscess >2.5 cm
 - Failure of conservative therapy
- **Instability criteria**
 - Segmental kyphosis (>15°)
 - Vertebral body collapse >50%
 - Translation >5 mm

* Modified from (e9, e33)

(38). It remains unclear at what point oral administration is possible. In the above-mentioned study by Bernard et al., treatment was administered intravenously for a short period of time [median 14 days (interquartile range 7–27)]. The IDSA guidelines propose oral therapy in the case of good oral bioavailability as a possible alternative to i.v. therapy. Quinolones, clindamycin, and cotrimoxazole are suitable for this purpose, whereby β-lactams have poor bioavailability. The OVIVA (oral versus intravenous antibiotics for bone and joint infections) study is currently investigating the possibility of oral administration in bone infections, including spondylodiscitis; the results of this study are still pending. In the case of culture-negative spondylodiscitis, antibiotics that cover the most common pathogens (especially *S. aureus*, streptococci, and *E. coli*) should be administered (6). When deciding on antibiotics and oral administration, one also needs to take bioavailability and bone penetration into consideration in the course of treatment. *Table 4* summarizes further recommendations for targeted therapy.

In addition to antibiotic therapy, conservative treatment comprises an analgesic component as well as relief of the affected spinal segment by means of, e.g., reclining orthosis. The former practice of long-term bed rest is now obsolete (e32). A conservative approach is justified if symptoms and spread of infection are mild. In their retrospective analysis of 45 geriatric

patients with neurological symptoms, Yashimoto et al. showed that neurological symptoms decreased within a minimum follow-up period of 10 months in 72,7% (8 of 11 patients) under antibiotic therapy alone (22). De Graeff et al. pointed out that the risk of treatment failure is increased in the presence of concomitant epidural abscess, further osteomyelitis, or diabetes (23). Therefore, inflammatory parameters and clinical findings should be checked at least once a week in order to promptly identify treatment response or failure (38). One can assume treatment failure if symptoms remain unchanged or worsened after a period of 4 weeks. Repeat MRI is only useful if there is no clinical improvement or if conventional radiological imaging shows signs of deterioration (e25).

In the case of spondylodiscitis with psoas abscesses, percutaneous abscess drainage is an adjunct to conservative treatment, since drainage placement relieves the focus of infection. Success rates of up to 87.5% are described for ultrasound-guided percutaneous drainage placement or CT-guided drainage placement (25, 26).

In addition to the elimination of infection, the primary aim of surgical therapy is segmental stabilization (*Box*).

There are recommendations on anterior, posterior, or combination procedures (24, 33, e7). Si et al. showed that a single anterior procedure results in a better outcome at 2 years (Oswestry Disability Index [ODI]: 25 versus 29), whereas, according Nasto et al., minimally invasive transpedicular stabilization combined with debridement leads to faster recovery (32, 40). Vcelak et al. showed that a single posterior procedure causes a significant loss of sagittal balance (preoperative 1.75° over 6 weeks (−3.73) and 12 months (−0.79), but that this has no effect on outcome compared with an antero-posterior procedure (27). Minimally invasive procedures, such as the retroperitoneal transpsoas approach (XLIF), permit removal of the site of infection, good restoration of the lumbar lordosis (from 23.1° preoperatively to 34.0° postoperatively), and additional percutaneous posterior instrumentation (31). There is also no common consensus on the timing of the treatment plan (single-/two-stage).

Conclusion

Ascione et al. showed that conservative treatment leads to good results after 2.5 years in terms of quality of life parameters (ODI: 26, SF-36 Health Questionnaire: 40.6) (28). MRSA-positive spondylodiscitis and delayed diagnosis can worsen the outcome. Gupta et al. showed that surgical treatment often fails within the first 6 months, whereas the failure rate at 2 years is similarly high to that at 5 and 10 years (5). Rossbach et al. demonstrated that the prognosis of neurological deficits, independent of the surgical approach used, is improved by 1 or 2 Frankel scores (measurement of spinal cord function) if decompression of the causal epidural abscess is achieved (29). On the whole, back pain often persists irrespective of the selected treatment approach.

KEY MESSAGES

- Spondylodiscitis is a highly heterogeneous disease, which hampers its scientific evaluation and the formulation of treatment recommendations.
- Empirical antibiotic therapy should only be initiated once the pathogen has been determined.
- Antibiotic treatment for 6 weeks appears to be sufficient.
- Age >75 years and *Staphylococcus aureus* infection are risk factors for antibiotic failure.
- The risk of surgical failure is highest in the first 6 months following surgery.

Conflict of interest statement

Dr. Jung received lecture fees and travel expenses from Novartis and Gilead, as well as lecture fees from Labor Stein GmbH and travel expenses from Basilea. She received fees for carrying out a clinical study commissioned by InfectoPharm Arzneimittel.

The remaining authors state that they have no conflict of interests.

Manuscript received on 19 May 2017, revised version accepted on 16 October 2017

Translated from the original German by Christine Schaefer-Tsorpätzidis

REFERENCES

1. Douchi M, Seng P, Menard A, et al.: Changing trends in the epidemiology of vertebral osteomyelitis in Marseille, France. *New Microbes New Infect* 2015; 7: 1–7.
2. Statistisches Bundesamt: Diagnosedaten der Krankenhäuser ab 2000 (Eckdaten der vollstationären Patienten und Patientinnen). Gliederungsmerkmale: Jahre, Behandlungs-/Wohnort, ICD10. Statistisches Bundesamt 2017.
3. Sobottke R, Seifert H, Fätkenheuer G, Schmidt M, Goßmann A, Eysel P: Current diagnosis and treatment of spondylodiscitis. *Dtsch Arztebl Int* 2008; 105: 181–7.
4. Cheung WY, Luk KDK: Pyogenic spondylitis. *Int Orthop* 2012; 36: 397–404.
5. Gupta A, Kowalski TJ, Osmon DR, et al.: Long-term outcome of pyogenic vertebral osteomyelitis: a cohort study of 260 patients. *Open Forum Infect Dis* 2014; 1: ofu107.
6. Kehrer M, Pedersen C, Jensen TG, Hallas J, Lassen AT: Increased short- and long-term mortality among patients with infectious spondylodiscitis compared with a reference population. *Spine J* 2015; 15: 1233–40.
7. Sobottke R, Rollinghoff M, Zarghooni K, et al.: Spondylodiscitis in the elderly patient: clinical mid-term results and quality of life. *Arch Orthop Trauma Surg* 2010; 130: 1083–91.
8. Kim CJ, Song KH, Jeon JH, et al.: A comparative study of pyogenic and tuberculous spondylodiscitis. *Spine* 2010; 35: E1096–100.
9. Jean M, Irison JO, Gras G, et al.: Diagnostic delay of pyogenic vertebral osteomyelitis and its associated factors. *Scand J Rheumatol* 2017; 46: 64–8.
10. Kapsalaki E, Gatselis N, Stefanos A, et al.: Spontaneous spondylodiscitis: presentation, risk factors, diagnosis, management, and outcome. *Int J Infect Dis* 2009; 13: 564–9.
11. Maus U, Andereya S, Gravius S, Ohnsorge JA, Miltner O, Niedhart C: Procalcitonin (PCT) as diagnostic tool for the monitoring of spondylodiscitis. *Z Orthop Unfall* 2009; 147: 59–64.

12. Choi SH, Sung H, Kim SH, et al.: Usefulness of a direct 16S rRNA gene PCR assay of percutaneous biopsies or aspirates for etiological diagnosis of vertebral osteomyelitis. *Diagn Microbiol Infect Dis* 2014; 78: 75–8.
13. Sehn JK, Gilula LA: Percutaneous needle biopsy in diagnosis and identification of causative organisms in cases of suspected vertebral osteomyelitis. *Eur J Radiol* 2012; 81: 940–6.
14. Foreman SC, Schwaiger BJ, Gempt J, et al.: MR and CT Imaging to optimize CT-guided biopsies in suspected spondylodiscitis. *World Neurosurg* 2017; 99: 726–34.
15. Spira D, Germann T, Lehner B, et al.: CT-guided biopsy in suspected spondylodiscitis—the association of paravertebral inflammation with microbial pathogen detection. *PLoS one* 2016; 11: e0146399.
16. Kim CJ, Kang SJ, Choe PG, et al.: Which tissues are best for microbiological diagnosis in patients with pyogenic vertebral osteomyelitis undergoing needle biopsy? *Clin Microbiol Infect* 2015; 21: 931–5.
17. Chang CY, Simeone FJ, Nelson SB, Taneja AK, Huang AJ: Is biopsying the paravertebral soft tissue as effective as biopsying the disk or vertebral end-plate? 10-year retrospective review of CT-guided biopsy of diskitis-osteomyelitis. *Am J Roentgenol* 2015; 205: 123–9.
18. Prodromou ML, Ziakas PD, Poulou LS, Karsaliakos P, Thanos L, Mylonakis E: FDG PET is a robust tool for the diagnosis of spondylodiscitis: a meta-analysis of diagnostic data. *Clin Nucl Med* 2014; 39: 330–5.
19. Rensi M, Giacomuzzi F, Geatti O: FDG PET-CT (PET), in the diagnosis of spondylodiscitis (SPD): experience in 146 patients (pts). *J Nucl Med* 2014; 55: 93.
20. Ohtori S, Suzuki M, Koshi T, et al.: 18F-fluorodeoxyglucose-PET for patients with suspected spondylitis showing Modic change. *Spine (Phila Pa 1976)* 2010; 35: E1599–603.
21. Bernard L, Dinh A, Ghout I, et al.: Antibiotic treatment for 6 weeks versus 12 weeks in patients with pyogenic vertebral osteomyelitis: an open-label, non-inferiority, randomised, controlled trial. *Lancet* 2015; 385: 875–82.
22. Yoshimoto M, Takebayashi T, Kawaguchi S, et al.: Pyogenic spondylitis in the elderly: a report from Japan with the most aging society. *Eur Spine J* 2011; 20: 649–54.
23. de Graeff JJ, Pereira NR, van Wulfften Palthe OD, Nelson SB, Schwab JH: Prognostic factors for failure of antibiotic treatment in patients with osteomyelitis of the spine. *Spine (Phila Pa 1976)* 2017; 42: 1339–46.
24. Menon VK, Kumar KM, Al Ghafri K: One-stage biopsy, debridement, reconstruction, and stabilization of pyogenic vertebral osteomyelitis. *Global Spine J* 2014; 4: 93–100.
25. Aboobakar R, Cheddie S, Singh B: Surgical management of psoas abscess in the Human Immunodeficiency Virus era. *Asian J Surg* 2016; DOI: 10.1016/j.asjsur.2016.10.003 [Epub ahead of print].
26. Matsumoto T, Yamagami T, Morishita H, et al.: CT-guided percutaneous drainage within intervertebral space for pyogenic spondylodiscitis with psoas abscess. *Acta radiologica* 2012; 53: 76–80.
27. Vcelak J, Chomiak J, Toth L: Surgical treatment of lumbar spondylodiscitis: a comparison of two methods. *Int Orthop* 2014; 38: 1425–34.
28. Ascione T, Balato G, Di Donato SL, et al.: Clinical and microbiological outcomes in haematogenous spondylodiscitis treated conservatively. *Eur Spine J* 2017; 26 (Suppl 4): 489–95.
29. Rossbach BP, Niethammer TR, Paulus AC, et al.: Surgical treatment of patients with spondylodiscitis and neurological deficits caused by spinal epidural abscess (SEA) is a predictor of clinical outcome. *J Spinal Disord Tech* 2014; 27: 395–400.
30. Pola E, Autore G, Formica VM, et al.: New classification for the treatment of pyogenic spondylodiscitis: validation study on a population of 250 patients with a follow-up of 2 years. *Eur Spine J* 2017; 26 (Suppl 4): 479–88.
31. Blizzard DJ, Hills CP, Isaacs RE, Brown CR: Extreme lateral interbody fusion with posterior instrumentation for spondylodiscitis. *J Clin Neurosci* 2015; 22: 1758–61.
32. Nasto LA, Colangelo D, Mazzotta V, et al.: Is posterior percutaneous screw-rod instrumentation a safe and effective alternative approach to TLSO rigid bracing for single-level pyogenic spondylodiscitis? Results of a retrospective cohort analysis. *Spine J* 2014; 14: 1139–46.
33. Cornett CA, Vincent SA, Crow J, Hewlett A: Bacterial spine infections in adults: evaluation and management. *J Am Acad Orthop Surg* 2016; 24: 11–8.
34. Smids C, Kouijzer IJ, Vos FJ, et al.: A comparison of the diagnostic value of MRI and 18F-FDG-PET/CT in suspected spondylodiscitis. *Infection* 2017; 45: 41–9.
35. Ioannou S, Chatziioannou S, Pneumaticsos SG, Zormpala A, Sipsas NV: Fluorine-18 fluoro-2-deoxy-D-glucose positron emission tomography/computed tomography scan contributes to the diagnosis and management of brucellar spondylodiscitis. *BMC Infect Dis* 2013; 7: 73.
36. Skanjeti A, Penna D, Douroukas A, et al.: PET in the clinical work-up of patients with spondylodiscitis: a new tool for the clinician? *J Nucl Med Mol Imaging* 2012; 56: 569–76.
37. Fuster D, Tomas X, Mayoral M, et al.: Prospective comparison of whole-body (18)F-FDG PET/CT and MRI of the spine in the diagnosis of haematogenous spondylodiscitis. *Eur J Nucl Med Mol Imaging* 2015; 42: 264–71.
38. Berbari EF, Kanj SS, Kowalski TJ, et al.: Infectious Diseases Society of America (IDSA): clinical practice for the diagnosis and therapy of native vertebral osteomyelitis in adults. *Clin Infect Dis* 2015; 61: 26–46.
39. Park KH, Cho OH, Lee JH, et al.: Optimal duration of antibiotic therapy in patients with hematogenous vertebral osteomyelitis at low risk and high risk of recurrence. *Clin Infect Dis* 2016; 62: 1262–9.
40. Si M, Yang ZP, Li ZF, Yang Q, Li JM: Anterior versus posterior fixation for the treatment of lumbar pyogenic vertebral osteomyelitis. *Orthopedics* 2013; 36: 831–6.

Corresponding author

Dr. med. Christian Herren
Klinik für Unfall- und Wiederherstellungschirurgie
Uniklinik RWTH Aachen
Pauwelsstr. 30
52074 Aachen, Germany
cherren@ukaachen.de

Supplementary material

For eReferences please refer to:
www.aerzteblatt-international.de/ref5117

eTable:

www.aerzteblatt-international.de/17m0875

Supplementary material to:

Spondylodiscitis: Diagnosis and Treatment Options

A Systematic Review

by Christian Herren, Norma Jung, Miguel Pishnamaz, Marianne Breuninger, Jan Siewe, and Rolf Sobottke

Dtsch Arztebl Int 2017; 114: 875–82. DOI: 10.3238/arztebl.2017.0875

eREFERENCES

- e1. Gouliouris T, Aliyu SH, Brown NM: Spondylodiscitis: update on diagnosis and management. *J Antimicrob Chemother* 2010; 65 (Suppl 3): iii11–24.
- e2. Kehrer M, Pedersen C, Jensen TG, Lassen AT: Increasing incidence of pyogenic spondylodiscitis: a 14-year population-based study. *J Infect* 2014; 68: 313–20.
- e3. Fantoni M, Trecarichi EM, Rossi B, et al.: Epidemiological and clinical features of pyogenic spondylodiscitis. *Eur Rev Med Pharmacol Sci* 2012; 16 (Suppl 2): 2–7.
- e4. Eren Gok S, Kaptanoglu E, Celikbas A, et al.: Vertebral osteomyelitis: clinical features and diagnosis. *Clinical microbiology and infection: the official publication of the European Society of Clinical Microbiology and Infectious Diseases* 2014; 20: 1055–60.
- e5. Cottle L, Riordan T: Infectious spondylodiscitis. *J Infect* 2008; 56: 401–12.
- e6. Oxford: Centre for Evidence-based Medicine: Levels of evidence. www.cebm.net/oxford-centre-evidence-based-medicine-levels-evidence-march-2009/ (last accessed on 30 November 2017).
- e7. Boody BS, Jenkins TJ, Maslak J, Hsu WK, Patel AA: Vertebral osteomyelitis and spinal epidural abscess: an evidence-based review. *J Spinal Disord Tech* 2015; 28: E316–27.
- e8. Diehn FE: Imaging of spine infection. *Radiol Clin North Am* 2012; 50: 777–98.
- e9. Guerado E, Cervan AM: Surgical treatment of spondylodiscitis. An update. *Int Orthop* 2012; 36: 413–20.
- e10. Legrand E, Flipo RM, Guggenbuhl P: Management of nontuberculous infectious discitis. Treatments used in 110 patients admitted to 12 teaching hospitals in France. *Joint Bone Spine* 2001; 68: 504–9.
- e11. McHenry MC, Easley KA, Locker GA: Vertebral osteomyelitis: long-term outcome for 253 patients from 7 Cleveland-area hospitals. *Clin Infect Dis* 2002; 34: 1342–50.
- e12. Nolla JM, Ariza J, Gomez-Vaquero C, Fiter J: Spontaneous pyogenic vertebral osteomyelitis in non-drug-users. *Semin Arthritis Rheum* 2002; 31: 271–8.
- e13. Yoon SH, Chung SK, Kim KJ, Kim HJ, Jin YJ, Kim HB: Pyogenic vertebral osteomyelitis: identification of microorganism and laboratory markers used to predict clinical outcome. *Eur Spine J* 2010; 19: 575–82.
- e14. Carragee EJ, Kim D, van der Vlugt T, Vittum D: The clinical use of erythrocyte sedimentation rate in pyogenic vertebral osteomyelitis. *Spine* 1997; 22: 2089–93.
- e15. Cramer J, Haase N, Behre I, Ostermann PAW: Spondylitis und Spondylodiscitis. *Trauma und Berufskrankheit* 2003; 5: 336–41.
- e16. Garg V, Kosmas C, Young PC, Togaru UK, Robbin MR: Computed tomography-guided percutaneous biopsy for vertebral osteomyelitis: a department's experience. *Neurosurg Focus* 2014; 37: E10.
- e17. Fleege C, Wichelhaus TA, Rauschmann MA: Systemic and local antibiotic therapy of conservative and operative treatment of spondylodiscitis. *Orthopäde* 2012; 41: 727–35.
- e18. Morel AS, Dubourg G, Prudent E, et al.: Complementarity between targeted real-time specific PCR and conventional broad-range 16S rDNA PCR in the syndrome-driven diagnosis of infectious diseases. *Eur J Clin Microbiol Infect Dis* 2015; 34: 561–70.
- e19. Grados F, Lescure FX, Senneville E, Flipo RM, Schmit JL, Fardel-lone P: Suggestions for managing pyogenic (non-tuberculous) discitis in adults. *Joint Bone Spine* 2007; 74: 133–9.
- e20. Enoch DA, Cargill JS, Laing R: Value of CT-guided biopsy in the diagnosis of septic discitis. *J Clin Pathol* 2008; 61: 750–3.
- e21. Chew FS, Kline MJ: Diagnostic yield of CT-guided percutaneous aspiration procedures in suspected spontaneous infectious discitis. *Radiology* 2001; 218: 211–4.
- e22. Gasbarrini A, Boriani L, Salvadori C, et al.: Biopsy for suspected spondylodiscitis. *Eur Rev Med Pharmacol Sci* 2012; 16: 26–34.
- e23. Lund T, Laine T, Österman H, Yrjönen T, Schlenzka D: Computer-aided spine surgery. In: Bentley G (ed.): *European surgical orthopaedics and traumatology*. Berlin, Heidelberg, New York: Springer 2014; 677–95.
- e24. Sharif HS: Role of MR imaging in the management of spinal infections. *Am J Roentgenol* 1992; 158: 1333–45.
- e25. Zimmerli W: Clinical practice. Vertebral osteomyelitis. *N Engl J Med* 2010; 362: 1022–9.
- e26. Ledermann HP, Schweitzer ME, Morrison WB: MR imaging findings in spinal infections: rules or myths? *Radiology* 2003; 506–14.
- e27. Hungenbach S, Delank KS, Dietlein M, Eysel P, Drzezga A, Schmidt MC: 18F-fluorodeoxyglucose uptake pattern in patients with suspected spondylodiscitis. *Nuc Med Commun* 2013; 34: 1068–74.
- e28. Schmitz A, Risse JH, Grunwald F: Fluorine-18 fluorodeoxyglucose positron emission tomography findings in spondylodiscitis: preliminary results. *Eur Spine J* 2001; 10: 534–9.
- e29. Zhuang H, Sam JW, Chacko TK, et al.: Rapid normalization of osseous FDG uptake following traumatic or surgical fractures. *Eur J Nucl Med Mol Imaging* 2003; 30: 1096–103.
- e30. Treglia G, Focacci C, Caldarella C, et al.: The role of nuclear medicine in the diagnosis of spondylodiscitis. *Eur Rev Med Pharmacol Sci* 2012; 16 (Suppl 2): 20–5.
- e31. Jung N, Seifert H, Siewe J, Fätkenheuer G: [Vertebral osteomyelitis]. *Der Internist* 2013; 54: 945–53.
- e32. Zarghooni K, Rollinghoff M, Sobottke R, Eysel P: Treatment of spondylodiscitis. *Int Orthop* 2012; 36: 405–11.
- e33. Dietze DD, Fessler RG, Jacob RP: Primary reconstruction for spinal infections. *J Neurosurg* 1997; 86: 981–9.

eTABLE

Treatment of spondylodiscitis: overview of the literature on diagnostic methods

Diagnostic method	Number of patients	Key message (year of publication)	Evidence level*
Patient history	79	Direct link between previous spinal surgery and pyogenic spondylodiscitis (32.9% of patients with pyogenic spondylodiscitis) (2010) (8)	IV
Patient history	32	Spondylodiscitis following conservative (22.2 %) and invasive intervention such as catheterization, surgery, or fine-needle aspiration (50.4%) (2010) (7)	IV
Laboratory parameter (CRP)	88	High CRP (56 days shorter) or positive blood culture (60 days shorter) are associated with a shorter diagnostic delay (2017) (9)	III
Patient history	8	Diabetes as a predisposing factor (2009) (10)	III
Laboratory parameter (PCT)	35	PCT is not suitable as a diagnostic parameter or for monitoring spondylodiscitis (2009) (11)	III
Microbiology (PCR)	45	Using species-specific PCR, spondylodiscitis was detected in 46.7% of patients treated with antibiotics; using conventional PCR, pathogen detection was possible in only 26.7% (2014) (12)	II
Imaging (X-ray)	No data	Conventional X-ray as the first imaging technique, but not particularly helpful in the early phase (2015) (e7)	V
Biopsy (CT)	92	Low pathogen detection rate using CT-guided fine needle aspiration in patients with high radiological and clinical likelihood of infection (30.4%) (2012) (13)	III
Biopsy (MRI and CT)	102	Fine needle aspiration using combined MRI/CT data increases the pathogen detection rate (36%) (2016) (14)	III
Biopsy (MRI and CT)	34	Combined MRI/CT data increases the detection rate (100% sensitivity, 50% specificity) (2016) (15)	III
Biopsy (tissue)	128 (136 samples)	In the case of suspected adjacent soft tissue abscess formation, soft tissue is superior to bone tissue for pathogen detection (odds ratio: 2.28; 95% CI: [1.08; 4.78]) (2015) (16)	III
Biopsy (tissue)	102 (122)	There is no statistically significant difference ($p < 0.05$) in specificity and sensitivity according to biopsy tissue (sensitivity/specificity end plate vs. paravertebral soft tissue 38%/86% vs. 68%/92%, $p = 0.09$; disc vs. end plate: 57%/89% vs. 38%/86%; $p = 0.05$) (2015) (17)	IV
Imaging (MRI)	No data	MRI remains the gold standard (2012) (e8)	V
Imaging (PET-CT)	224	High specificity (88%; 95% CI: [0.74; 0.95]) and sensitivity (97%; 95% CI: [0.83; 1.00]) to detect spondylodiscitis (2014) (18)	I
Imaging (PET-CT)	146	MRI (98%) with better sensitivity than PET-CT (95%); but PET-CT has better specificity (86% vs. 67%), particularly in the differentiation between postoperative/severe degenerative changes and spondylodiscitis (2014) (19)	III
Imaging (PET-CT)	312	PET-CT as a helpful diagnostic tool if concomitant degenerative changes are present (Modic I); differentiation between Modic I changes and spondylodiscitis simplified by PET-CT (2010) (20)	II

CRP, C-reactive protein; CT, computed tomography; MRI, magnetic resonance imaging; PCR, polymerase chain reaction; PCT, procalcitonin level; PET, positron emission tomography; 95% CI, 95% confidence interval; vs., versus

* According to the evidence ranking scheme of the Oxford Centre for Evidence-based Medicine