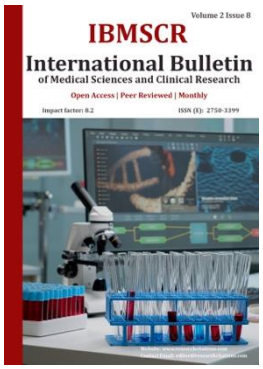

IMAGING OF SPONDYLODISCITIS: AN UPDATED COMPREHENSIVE REVIEW—MULTIMODAL IMAGING FEATURES, DIFFERENTIAL DIAGNOSIS, AND DETECTION OF SPECIFIC MICROORGANISMS

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Abstract

Spondylodiscitis refers to infectious conditions affecting the vertebral column, and its incidence has steadily increased in recent decades. Imaging plays a crucial role at every stage of the disease. Radiological techniques are essential for (i) the initial diagnosis of spondylodiscitis, (ii) distinguishing it from other causes such as inflammatory, degenerative, or calcific disorders, (iii) assessing disease progression, and (iv) providing indications of the microorganisms involved. The latter can be achieved either through minimally invasive procedures (e.g., CT-guided biopsy) or inferred non-invasively by analyzing the features presented in CT, positron emission tomography (PET) CT, or MRI scans. This comprehensive review aims to outline the multimodal imaging characteristics of spondylodiscitis, serving as a reference for physicians, including infectious disease specialists, spine surgeons, and radiologists. Additionally, this review may offer insights for future research articles.

Keywords: magnetic resonance imaging, multidetector computed tomography, image-guided biopsy, positron emission tomography computed tomography, spondylodiscitis

1. Introduction

1.1. Epidemiology

Spondylodiscitis is an infection that affects the intervertebral discs and/or adjacent vertebral bodies. While most cases are caused by bacterial (pyogenic) infections, tuberculosis and fungal infections can also occur, particularly in immunocompromised individuals. Spondylodiscitis accounts for 2–5% of all osteomyelitis cases. In Europe, the incidence ranges between 4 to 24 cases per million people annually. Although more common in older adults, the condition exhibits a bimodal distribution, with incidence peaks in individuals under 20 years and between 50–70 years of age. In pediatric populations, spondylodiscitis constitutes 1–2% of bone infections, with a male-to-female ratio of 1.5–2:1, especially in older age groups. This male predominance is likely due to the higher occurrence of comorbidities in men over 60.

Recent years have seen a rise in spondylodiscitis cases, driven by aging populations and an increase in chronic diseases such as diabetes, renal failure, and immunosuppressive therapies, as well as conditions like sickle cell disease, HIV infection, and intravenous drug use. Direct infection can occur after spinal surgery, with a prevalence as high as 18.8%. In Uzbekistan, the incidence of pyogenic spondylodiscitis rose from 15.35 per 100,000 in 2010 to 33.75 in 2019, while tuberculous spondylodiscitis decreased from 7.55 to 2.04 during the same period. In Russia, cases increased by 41.6% between 2010 and 2020, reaching 14.4 per 100,000 inhabitants. Nearly 60% of cases involved patients aged 70 or older, with 56.2% affecting the

lumbar spine. Inpatient mortality due to pyogenic spondylodiscitis in Russia rose by 347% from 2005 to 2021.

The majority of spondylodiscitis cases result from hematogenous spread, typically associated with bacteremia. One-third of patients with pyogenic spondylitis also have endocarditis, and 2–20% of those with endocarditis develop spondylodiscitis. The two conditions are closely linked, and patients with infectious endocarditis, especially those with risk factors, should be evaluated for metastatic infections of the spine. However, the presence of spondylodiscitis does not appear to worsen the prognosis of endocarditis, either short-term or long-term.

In adults, the intervertebral discs are avascular, making septic emboli likely to cause ischemia and infarction in the vertebral endplates, particularly on their anterior side. This leads to bone destruction and disc involvement [4]. In children, intra-discal anastomoses remain open, limiting infection to the disc. While arterial spread is more common, retrograde venous spread can occur with infections of the pelvic organs or retroperitoneal space. Direct inoculation, typically following spinal surgery or procedures, accounts for about 20% of cases.

Staphylococcus species, especially Staphylococcus aureus, are the most common pathogens, responsible for 40–67% of cases. Methicillin-susceptible strains are common, but methicillin-resistant Staphylococcus aureus (MRSA) is increasingly observed. Gram-negative organisms, such as Escherichia coli, Pseudomonas, and Proteus, are also frequent causes. Streptococcus species are overrepresented in cases linked to endocarditis, while sickle cell disease predisposes individuals to Salmonella infections. Mycobacterium tuberculosis causes approximately 30% of cases, while other bacteria are responsible for the rest. Fungal infections are rare, accounting for just 0.5% of cases, with Aspergillus and Candida being the most common fungal pathogens affecting the spine. In 21–34% of cases, no causative organism is identified.

The lumbosacral region is the most commonly affected, involved in 52–58% of cases, followed by the thoracic spine (26–35%), and the cervical spine (10–22%).

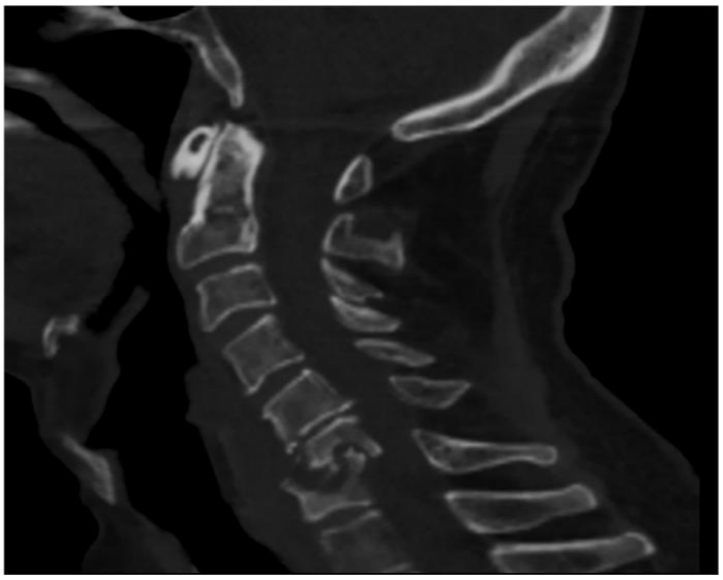

Figure 1

CT of the cervical spine (sagittal reconstruction) of a middle-aged man (HIV+) affected by spondylodiscitis in the C6–C7 tract of the cervical spine complicated by myelopathy.

Single-level involvement is observed in 65% of spondylodiscitis cases, while 35% of patients experience multiple-level involvement, including 10% where non-contiguous levels are affected. The median time to diagnosis for pyogenic infections is around 30 days, with a microbiological diagnosis confirmed in roughly 75% of cases. The median duration of antibiotic therapy is 148 days. While conservative treatment is effective in about 70% of pyogenic infection cases, more than 50% of patients across all causes may require surgery. For pyogenic infections, complete healing without disability occurs in over three-quarters of patients, with an overall healing rate of 91%. However, 24% of patients experience residual disabilities, and the mortality rate is 8%. Poor prognostic factors include negative microbiological culture results, neurological deficits at the time of diagnosis, and the presence of endocarditis.

1.2. Complications

Complications of spondylodiscitis include neurological impairment, abscess formation, and spinal instability, occurring in 27.8%, 30.4%, and 6.6% of cases, respectively. The majority of abscesses (60%) are found in the lumbosacral region, while 33% are located in the thoracic region and 7% in the cervical region. Epidural abscesses are most common in the cervical region, where they can lead to spinal cord compression and neurological deficits in up to 56% and 65% of cases, respectively. Surgery is required in 86% of patients with epidural abscesses and in 84% of those with neurological deficits. Most paravertebral abscesses (95%) can be treated through percutaneous drainage. Spinal instability is most frequently observed in the lumbosacral region, affecting 53% of cases, with surgery needed in 87% of these instances. Despite advances in antibiotic and surgical treatments, hospitalization may last between 30 and 57 days, and mortality rates can range from 2% to 17%.

1.3. Clinical Features

Diagnosing spondylodiscitis can be challenging due to its often non-specific symptoms, which may overlap with or be obscured by coexisting conditions such as spondylosis, previous spinal surgeries, cardiovascular diseases, or diabetes mellitus. The vast majority of patients (93%) present with sharp, severe back pain that may radiate to the limbs and intensifies at night or with weight-bearing activities. However, 7% of patients with pyogenic spondylitis may experience no pain, a group more likely to include intravenous drug users or individuals with liver disease or cirrhosis. These patients are also more likely to require surgery (38% versus 16%), have infections caused by E. coli or Pseudomonas species, and experience double the mortality rate.

Many patients report experiencing a febrile illness in the weeks leading up to the onset of back pain, followed by a period of defervescence. Only 50% of patients present with fever, but 75–95% show paraspinal muscle tenderness. Neurological deficits are seen in up to one-third of cases, ranging from sensory abnormalities and radiculopathy to weakness, severe paralysis, and loss of bowel or bladder control. Additionally, 5–50% of patients may display systemic infectious symptoms such as anorexia, nausea, and vomiting. In cases where diagnosis is delayed, patients may also experience weight loss.

Tuberculous spondylitis, when compared to pyogenic spondylitis, is more frequently associated with younger age, a longer duration of symptoms, lack of fever, thoracic spine involvement, involvement of more than three vertebral levels, and the presence of a paraspinal abscess.

Predictors of fungal discitis or osteomyelitis include back pain lasting 10 or more weeks, prior antibiotic use for a week or more, and intravenous drug use.

1.4. General Biological Features

Erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) levels are almost always elevated in cases of spondylodiscitis. CRP is more sensitive as a marker for monitoring treatment response, with levels decreasing by about 50% per week, making it a reliable predictor of treatment success. White blood cell (WBC) count, however, may be either elevated or within normal limits, and thus is not particularly useful for diagnosis. Blood cultures are positive in 30–78% of cases involving pyogenic spondylodiscitis. In cases where blood cultures are negative, a percutaneous CT-guided needle biopsy or surgical biopsy of the disc or vertebra may be recommended, with diagnostic success rates ranging from 47% to 100%. It's important to note that these biological markers may be absent in cases of tubercular spondylodiscitis or infections caused by intracellular microorganisms, such as Brucella spp., Legionella spp., and Listeria spp.

2. Imaging in the Initial Assessment of Suspected Spondylodiscitis

Imaging plays a critical role in the early assessment of suspected spondylodiscitis. Early imaging diagnosis refers to detecting the disease when vertebral and disc damage is minimal or soon after the onset of symptoms. The following tools are used for both early (within 2–3 weeks of symptom onset) and later diagnosis.

2.1. Conventional Radiographs

Conventional radiographs have low sensitivity and specificity, making them less effective for identifying early bone loss. In cases of pyogenic spondylitis, radiographic changes typically do not appear until 2–8 weeks after the onset of symptoms and may remain normal for weeks after the infection begins. Detecting bone loss on radiographs requires a 30–40% reduction in bone density, a process that often takes more than 2 weeks to become apparent, especially in acute infections.

In the early stages of infection, radiographic signs are rarely evident, making it difficult to differentiate spondylodiscitis from degenerative conditions. After 8–12 weeks, more pronounced bone destruction may be visible (Figure 2).

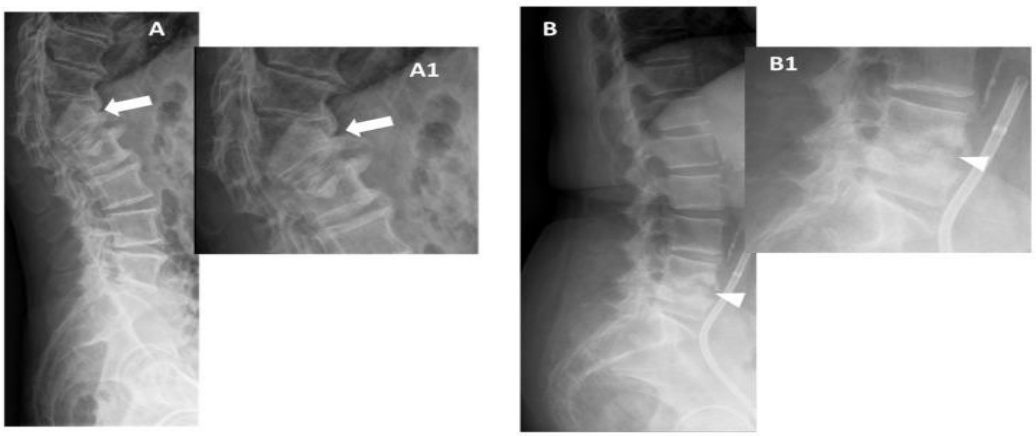

Figure 2

Conventional radiographs, lateral views (Panel A, and Magnification A1), of a 77-year-old male with previous pyogenic spondylodiscitis of T12-L1 vertebral bodies (partially collapsed and fused—arrows). Conventional radiographs, and lateral views (Panel B and

Magnification B1) of a 64-year-old female with spondylodiscitis of L4–L5 vertebral bodies (thick endplate erosions are detected—arrowheads).

As the disease progresses, radiographic changes may include nonspecific osteopenic changes (demineralization) in the subchondral layer, erosive and indistinct endplate margins, reduced intervertebral disc space, paravertebral soft tissue masses, deformities, and visible soft tissue swelling.

Endplate erosion, though often subtle, is considered the most reliable sign detectable on plain radiographs and is the single most important observation when evaluating lumbar spine radiographs. In chronic infections, spinal deformities such as kyphosis, scoliosis, or a combination of both can become evident after approximately four months.

In cases of spinal tuberculosis, particularly in the upper lumbar and lower thoracic spine, radiographs are the primary diagnostic tool, with a sensitivity of 82%, specificity of 57%, and accuracy of 73%. Typical findings include rarefaction of vertebral endplates, disc height loss, bone destruction, new bone formation, and soft tissue abscesses, often leading to gibbus deformity and vertebral collapse. Additionally, up to 67% of patients with spinal tuberculosis have concomitant pulmonary tuberculosis or a history of primary lung involvement.

2.2. Computed Tomography (CT)

CT is particularly effective in detecting bone changes earlier than radiographs. Although CT scans may appear normal within the first three weeks of infection, they can later reveal the following:

- Fragmentation or erosive changes in the vertebral endplates
- Poorly defined reactive sclerosis or osteopenia
- Hypodensity within the intervertebral disc
- Soft tissue swelling that obscures the surrounding fat planes near the vertebral body

The use of intravenous contrast can further enhance visualization of the epidural venous plexus, helping assess the extent of mass effect on the thecal sac. CT also aids in identifying paravertebral soft tissue swellings and thickenings, increased enhancement, abscess formation (commonly in the psoas muscle or epidural space), and the presence of gas inclusions, which can indicate an inflammatory soft tissue infection—although gas can also be seen in degenerative discitis.

As the infection progresses, CT may show the replacement of soft tissue by bone, with erosive changes to the endplates becoming evident (Figure 3).

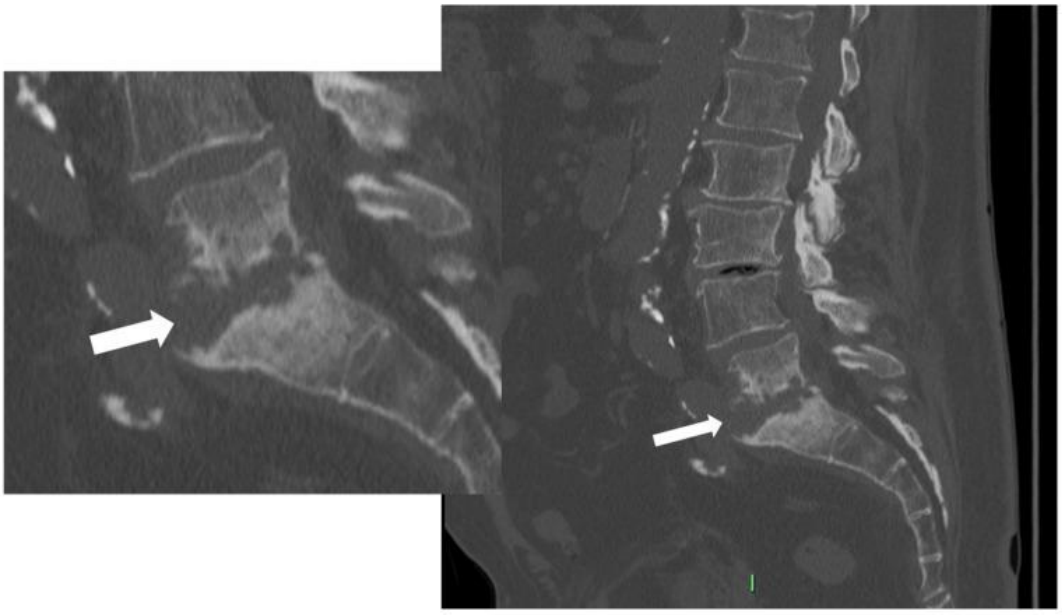

Figure 3

CT, sagittal reconstruction (magnification on the left), of a 77-year-old female with L5-S1 pyogenic spondylodiscitis characterized by thick endplates erosions (arrows).

Additionally, direct inoculation of the disc space may occur, affecting the adjacent endplate and potentially resulting in the collapse of the disc space.

If an abscess is present, CT-guided punctures can be performed to obtain tissue samples for microbiological analysis. CT is also often recommended as the primary method for tissue biopsy (such as from the intervertebral disc or vertebral body) to identify causative organisms (refer to Section 3.2 on image-guided biopsy). CT can be especially valuable for patients in whom MRI is contraindicated due to implanted devices or if MRI is not available.

2.3. MRI

Contrast-enhanced MRI is the preferred imaging technique for diagnosing spinal infections, with a sensitivity of 97%, specificity of 93%, and an accuracy of 94% for spondylodiscitis diagnosis. MRI is highly effective at determining the extent of infection and provides superior visualization of paraspinal soft tissues and the epidural space. However, MRI may appear normal within the first 2–4 days of infection onset.

MRI protocols for spondylodiscitis suggest using fat-suppressed T2-weighted imaging (WI) sequences and post-gadolinium T1-WI with fat suppression. Alternatively, DIXON T2-WI and contrast-enhanced (CE) T1-WI sequences can be employed (providing Fat, Water, and In-phase images).

Diffusion-weighted imaging (DWI), while not used routinely, can be useful in patients who cannot undergo contrast-enhanced MRI due to contraindications such as allergies or renal impairment. DWI can help detect abscesses and provide additional diagnostic insights. It is also helpful for distinguishing infections from degenerative changes and differentiating between normal postoperative fluid collections and infected ones. However, DWI's moderate-to-low sensitivity for distinguishing spondylodiscitis from other conditions is still debated.

Spondylodiscitis causes inflammatory exudate, replacing normal bone marrow with white blood cells and inducing hyperemia. This results in MRI signal changes, appearing as hypo- or isointense signals on T1-weighted images and hyperintense signals on T2-weighted images in

the subchondral endplates and intervening disc. Typically, these signal changes begin in the anterior part of the vertebral body and may involve single or multiple spinal segments. Early in the disease, the changes can be unilateral. Endplate erosion is also observed. Contrast enhancement of the vertebral endplate may exhibit different patterns, such as diffuse, patchy, clumped, or linear enhancement parallel to the endplate (Figure 4).

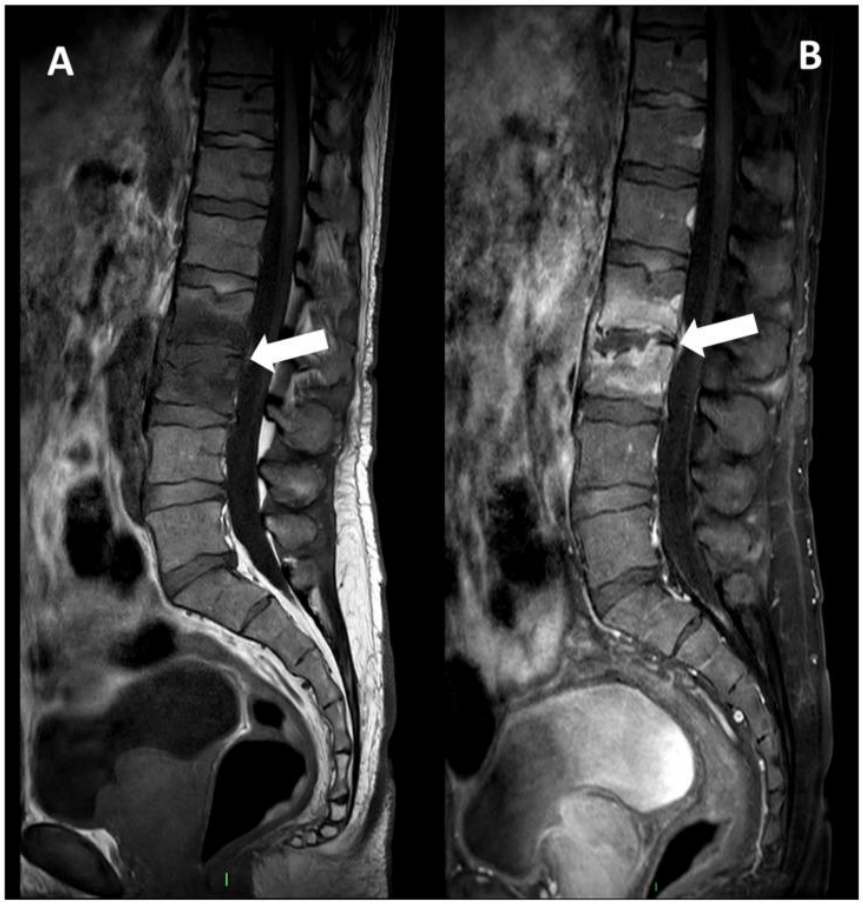

Figure 4

MRI, Sagittal T1w (Panel A), and T1w after contrast media injection (Panel B) of a 54-year-old male with pyogenic spondylodiscitis of L2-L3 vertebrae: complete alteration of disc signal intensity, endplates erosions, and diffuse pattern of vertebral body enhancement are detectable (arrows).

This infection process leads to the loss of endplate definition, reduced disc height, the potential appearance of a positive nuclear cleft sign, and, in more advanced stages, destruction of the vertebral body.

The nuclear cleft, typically seen as a low signal intensity band on T2-weighted imaging (T2-WI) in a healthy disc, becomes distorted and eventually disappears with infection. However, this sign is not specific to spondylodiscitis and can also occur in degenerative disc disease. In the later stages of infection, a high signal intensity on T2-WI may appear, which can show enhancement following the injection of gadolinium-based contrast agents. As the infection progresses, disc height diminishes.

After administering gadolinium contrast, enhancement of the subchondral bone or vertebral body can be observed, with the affected disc typically showing diffuse enhancement.

Additionally, abscesses may be detected, presenting as areas of T1 hypointensity, T2 hyperintensity, and contrast enhancement within the disc or vertebral bone.

As the infection spreads, it can extend to the epidural space and paravertebral soft tissues, manifesting on imaging as a phlegmonous, ill-defined infiltrate (with high signal intensity on fat-suppressed contrast-enhanced T1-WI and T2-WI). Paraspinal abscesses often show a low signal on T1-WI, high fluid-like signal on T2-WI without contrast uptake, and a peripheral rim of contrast enhancement on fat-suppressed CE-T1-WI.

Notably, pyogenic spondylodiscitis typically spares the posterior elements of the spine. Key MRI findings that are highly sensitive for diagnosing pyogenic spondylodiscitis include paraspinal or epidural inflammation, T1 hypointensity of the vertebral body, T2 hyperintensity of the disc space, and disc space enhancement.

Moreover, MRI can help differentiate spinal tuberculosis from pyogenic spondylodiscitis (see Section 3.1 for details on MRI-based differential diagnosis between infectious agents) [44]. Some distinguishing features include the presence of a large, well-defined paraspinal abscess with thin rim enhancement and smooth margins, thoracic spine involvement, subligamentous spread to adjacent vertebrae with preserved disc height, and multilevel involvement with skip lesions. In cases of neurological deficit, MRI is crucial for surgical planning and determining the levels of decompression and stabilization. If possible, a full spinal MRI is recommended to assess for skip abscesses and other areas of neurological compression.

3. Specific Microorganism Diagnosis

Imaging can be a valuable tool for identifying potential microorganisms involved in the infection process. The microorganism can sometimes be inferred by analyzing imaging features, particularly with MRI, or confirmed through minimally invasive procedures, such as CT-guided biopsies.

3.1. MRI and Other Imaging Tools for Differentiating Between Tubercular and Pyogenic Spondylodiscitis

MRI is considered the gold standard for diagnosing spinal infections, with a sensitivity of about 96%, specificity of 93%, and accuracy of 94%. Its diagnostic precision improves significantly with the use of gadolinium contrast enhancement [52]. MRI is especially critical when isolating the microorganism is not possible, as it helps guide targeted antibiotic therapy and prevents complications such as abscess formation, spinal deformities, and neurological deficits.

Many studies since the early 2000s have explored the differences between pyogenic spondylodiscitis (PyS) and tubercular spondylodiscitis (TbS), identifying specific MRI features that aid in differentiating between the two.

Two key features commonly associated with TbS in nearly all studies are thoracic spine involvement and the presence of more than two affected vertebral elements, often with non-adjacent vertebral bodies (skip lesions). The infection typically begins in the anterior subchondral region of the vertebral body and often spreads to the anterior longitudinal ligament and other subligamentous areas. In TbS, the posterior elements of the spine are also more likely to be involved, although the vertebral bodies are more commonly affected than the posterior arches. When disc preservation is observed, posterior lesions should be carefully distinguished from neoplastic ones. In these cases, it is helpful to note that

tubercular infections tend to spread to soft tissue and adjacent ligaments in an anterolateral direction.

Virtually all studies have reported well-defined paraspinal signal abnormalities, with intraosseous, epidural, and paraspinal abscesses more frequently seen in TbS. One of the most reliable MRI findings in TbS is the thin, smooth enhancement of the abscess wall, sometimes with calcifications, whereas ill-defined paraspinal signal abnormalities and thick, irregular abscess wall enhancement are more indicative of PyS. The chronic nature of TbS, the relatively late onset of symptoms, and the minimal inflammation associated with "cold abscesses" likely contribute to these characteristic abscess appearances. Gadolinium-enhanced imaging is essential for differentiating between these two forms of spondylodiscitis.

Paravertebral abscesses in TbS are generally larger than those in PyS and are often symmetrical. Psoas abscesses are a common feature in TbS. Epidural abscesses are also more frequent in TbS and are associated with a higher likelihood of nerve and spinal cord compression. Some studies have shown that meningeal enhancement at the level of the infected spinal segment is strongly associated with TbS.

In PyS, vertebral damage tends to be more limited, with most changes confined to the endplate. In contrast, TbS often involves more than half of the vertebral bodies, which are frequently severely damaged. Vertebral height loss, collapse, and kyphosis (potentially accompanied by spinal "cold injury") are most common in TbS, particularly in the thoracic spine and in the later stages of infection. Additional findings such as large geodes, bone scalloping, sequestrum, vertebral fragmentation, and ivory vertebra (from sclerotic responses to osteonecrosis) are more characteristic of TbS than PyS.

In TbS, disc space narrowing tends to occur later and is less pronounced compared to PyS. This relative preservation of the intervertebral disc is likely due to the absence of proteolytic enzymes in Mycobacterium, whereas organisms causing PyS (such as Staphylococcus aureus, Enterobacter, and Salmonella) produce hyaluronidase, which leads to disc destruction. Some studies have reported similar levels of disc space narrowing in both types of spondylodiscitis, potentially due to longer intervals between symptom onset and MRI in the TbS cases studied.

Another typical characteristic of tubercular spondylodiscitis (TbS) is a heterogeneous signal in the vertebral body on T1-weighted, fluid-sensitive, and contrast-enhanced (CE) sequences.

In summary, the key features of pyogenic spondylodiscitis (PyS) include lumbar spine involvement, poorly defined enhancement of paravertebral tissues, diffuse or homogeneous contrast enhancement of the vertebral bodies, limited vertebral body destruction, high and homogeneous signal intensity on T2-weighted images, disc signal changes, and disc height loss. Additionally, anterior subligamentous spread and involvement of the posterior spinal structures are generally absent in PyS.

Interestingly, the standardized uptake value (SUV) in TbS tends to be significantly higher than that in PyS (with a mean SUV of 12.4, ranging from 6 to 22, in TbS patients, compared to 7.3, ranging from 4.1 to 13.4, in PyS patients).

A notable limitation in distinguishing between TbS and PyS based on the aforementioned imaging features is that most of these criteria are qualitative (with the exception of SUV max and the number of vertebrae involved). This qualitative nature can lead to diagnostic errors, particularly for less experienced readers. The current literature review seeks to expand awareness of these differentiating features.

Table 1 provides a summary of the main MRI features that differentiate TbS from PyS spondylodiscitis.

Table 1

Imaging features in the differential diagnosis between TbS and PyS.

Imaging Features	Tuberculous Spondylitis (TbS)	Pyogenic Spondylitis (PyS)
Thoracic spine involvement	Present	Usually absent
Subligamentous spread to 3 or more vertebral bodies	Multiple body involvement	Usual involvement ≤ 2 vertebral bodies
Involvement of posterior elements	Present	Usually absent
(MRI) Paraspinal signal	Well-defined	Ill-defined
Paraspinal abscess	75% of cases	39–40% of cases
Epidural abscess	56–60% of cases	11–15% of cases
Intraosseous abscess	Present	Absent
Abscess wall	Thin and smooth	Thick and irregular
(MRI) Vertebral enhancement	Focal/heterogeneous	Diffuse/homogeneous
(MRI) Vertebral signal in T2 images	Heterogeneous	Hyperintense/homogeneous
(MRI) Vertebral signal in T1 images	Heterogeneous	Hypointense/homogeneous
Destruction of vertebral bodies	Frequent and more severe	Infrequent and mild to moderate
Disc destruction	Mild to moderate	Severe to complete
(PET) FDG SUV	Higher (mean = 12)	Lower (mean = 7)

In Figure 6 an exemplificative case of TbS is presented.

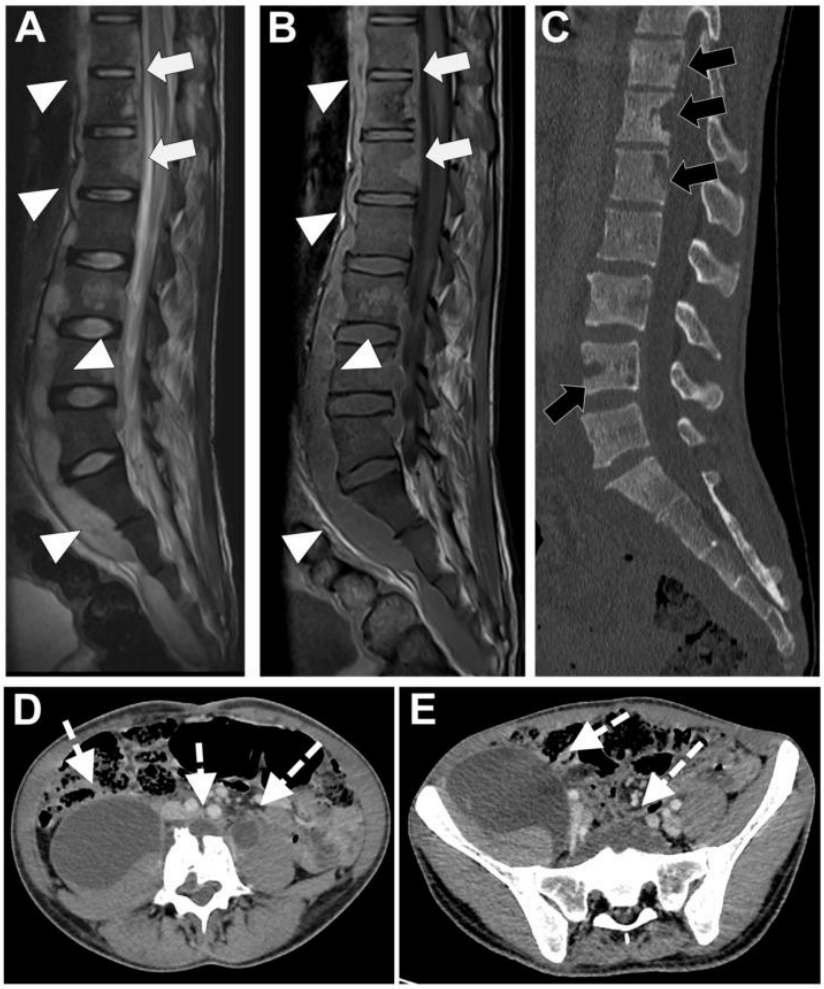

Figure 6

Tubercular spondylodiscitis. A 24-year-old man of Sudanese origin presented with thoracic and lumbar pain evolving for several months. An MRI was performed with (A) T2-weighted imaging (WI) and (B) contrast-enhanced (CE) T1-WI, as well as a CT-scan in bone kernel (C) and abdominal kernel after contrast medium injection (D,E). It demonstrates preserved disk but extensive sub ligamentous collections spreading along the anterior side of the thoracic and lumbar vertebral bodies (white arrowhead), but also along the posterior vertebral collateral ligament (white arrows) with large anterior and posterior erosions (black arrows). Please note the extensive collections spreading in the presacral space and along bilateral iliopsoas muscles without surrounding inflammation (white dashed arrows).

In Figure 7 an exemplificative case of PyS is presented.

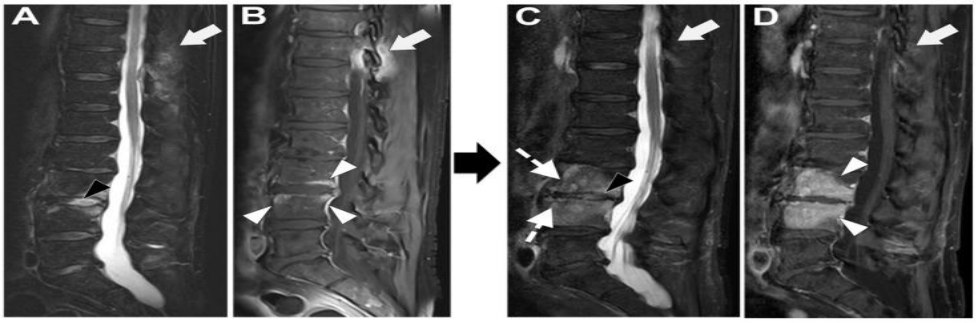

Figure 7

A 73-year-old male presented with a rapidly evolving lumbar pain and fever, with an inflammatory syndrome on blood samples. A first MRI was performed as infectious spondylodiscitis was suspected, which included (A) STIR T2-weighted imaging (WI) and (B) fat sat T1-WI after gadolinium chelates injection. It shows a high signal intensity (SI) of the L3-L4 disc while other disks are in lower signal (black arrowhead), as well as linear subchondral contrast enhancement (CE) of the L3-L4 endplates both linear and more pronounced at the upper anterior corner of the L4 vertebral body (white arrowheads). Moreover, the left T11-T12 facet joints displayed marked edema of the subchondral bone and surrounding tissues (white arrows). A control MRI with SITR T2-WI (C) and fat-suppressed CE-T1-WI (D) was performed one month later, demonstrating a marked narrowing of the L3-L4 disk (black arrowhead), erosions of the vertebral body (dashed white arrows), extensive edema in the L3 and L4 vertebral body (white arrowhead), a persisting arthritis involving the left T1-T12 facet joint. Bacillus cereus was found on the Bacterial analysis of the L3-L4 disk biopsy.

3.2. Other Microorganisms

Other, less common microorganisms may present with distinct MRI features that can help determine the cause of infectious spondylodiscitis:

Brucellosis: Brucella, a zoonotic gram-negative coccobacillus, primarily affects adults from regions like South America, the Mediterranean, and the Middle East, where exposure to unpasteurized dairy products or infected animals is common. Spondylodiscitis accounts for nearly half of the musculoskeletal complications of brucellosis (BrS). Recognizing the MRI characteristics of BrS is important, as biopsies and blood cultures are often negative, and clinical or biological signs of inflammation can be minimal. BrS progresses slowly, with radiological abnormalities typically appearing weeks after disease onset. It often involves the lumbar spine, particularly the anterosuperior corner, at a single level. Early disc involvement without affecting the posterior elements, and a preserved vertebral body despite significant signal changes, should raise suspicion for BrS. Additionally, peri-vertebral bone formations resembling anterior osteophytes may be observed.

Fungal spondylodiscitis: Rare and usually occurring due to hematogenous spread following a systemic infection in severely immunocompromised patients or intravenous drug users. The most common organisms involved are *Candida albicans* and *Aspergillus fumigatus* or *flavus*. Radiological features lack specificity, but according to Simeone et al., partial disc involvement and focal soft tissue abnormalities (in contrast to diffuse involvement) are more frequently seen in fungal spondylodiscitis compared to pyogenic spondylodiscitis.

3.3. Image-Guided Percutaneous Biopsy

Image-guided percutaneous biopsy is a reliable and safe method for confirming a suspected diagnosis of spondylodiscitis and identifying the specific microorganism involved.

Among the available imaging techniques for guiding biopsies, CT is the most commonly used and effective, particularly for safely accessing the spine. CT guidance is superior to fluoroscopy, especially when targeting small spinal lesions. Moreover, it can be used to guide procedures in all skeletal regions, including spinal segments (Figure 8).

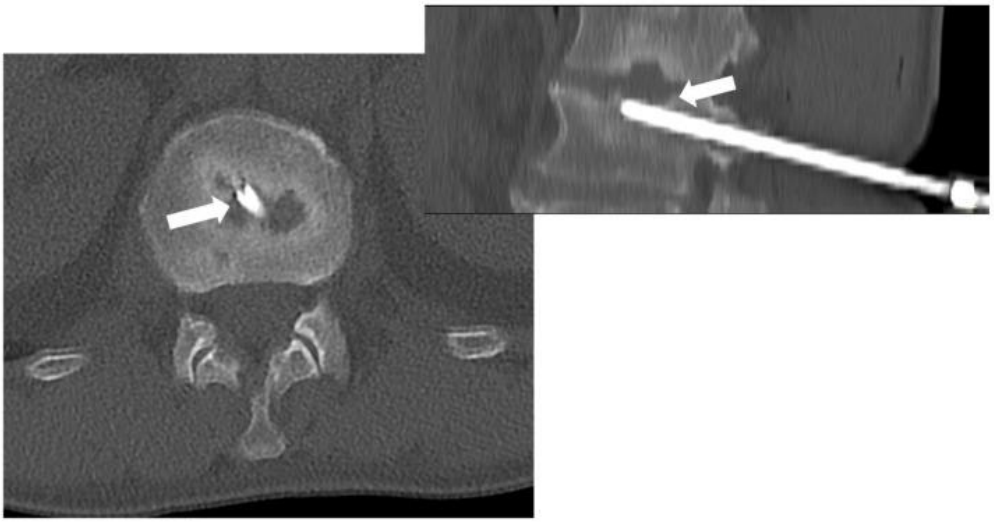

Figure 8
CT-guided biopsy in a 55-year-old male with suspected spondylodiscitis; CT (axial view on the left—sagittal reconstruction on the right) permits to guide the tip of the needle (8 gauge) into the end plate erosion (arrows) adjacent to the disc

Ultrasound guidance is only used for spinal biopsies in select cases, particularly when a large paravertebral abscess is present.

CT-guided biopsy is effective for detecting active bacterial infections of the spine, but its accuracy decreases significantly in chronic or inactive diseases, as well as in fungal infections.

In a recent systematic review and meta-analysis, Chang et al. evaluated the diagnostic yield of image-guided biopsy for acute discitis-osteomyelitis. The study found no statistically significant difference in diagnostic yield between CT and fluoroscopic guidance. However, the biopsy site had a significant impact on microbiological diagnostic yield: 64.8% when the biopsy was performed on the disc or paravertebral soft tissue, compared to 45.5% when taken from the bone endplates ($p < 0.001$).

Additionally, several factors are known to be associated with higher diagnostic yield in CT-guided biopsies for assessing spondylodiscitis and in general; the key factors are summarized in Table 2.

Table 2
Factors associated with higher or lower diagnostic yield on CT-guided biopsies.

CT-Guided Biopsy for Spondylodiscitis—Factors Associated with Diagnostic Yield	
Lower Diagnostic Rate	**Higher Diagnostic Rate**
Small lesion size	Large lesion size
Single bone sample	Multiple bone samples
Short sample (short needle penetration in the lesion/perpendicular needle trajectory)	Large sample (long needle penetration in the lesion/oblique needle trajectory)
Targeting the vertebral bone or endplates only	Targeting the disc, and/or soft-tissue

CT-Guided Biopsy for Spondylodiscitis—Factors Associated with Diagnostic Yield	
Lower Diagnostic Rate	**Higher Diagnostic Rate**
	involvement, and/or Fluid collection aspiration.
Target lesion not visible on CT	Target lesion visible on CT
Fungal Infection	Mycobacterium Tubercolosis

4. Differential Diagnoses

Several conditions can radiologically resemble spinal infections. Radiologists play a crucial role in preventing misdiagnoses by interpreting CT and MRI features within the appropriate clinical and biological context. This section focuses on the most common differential diagnoses.

4.1. Degenerative Endplate Changes

In the early inflammatory phase (Modic Type 1), degenerative endplate changes can present radiological features that resemble those of infectious spondylodiscitis. These features may include irregular endplate contours, subchondral cysts, and vertebral edema with a horizontal orientation. On imaging, this appears as high signal intensity on T2-weighted images (especially with fat suppression), low signal intensity on T1-weighted images, and, if contrast is used, possible enhancement—see Figure 9.

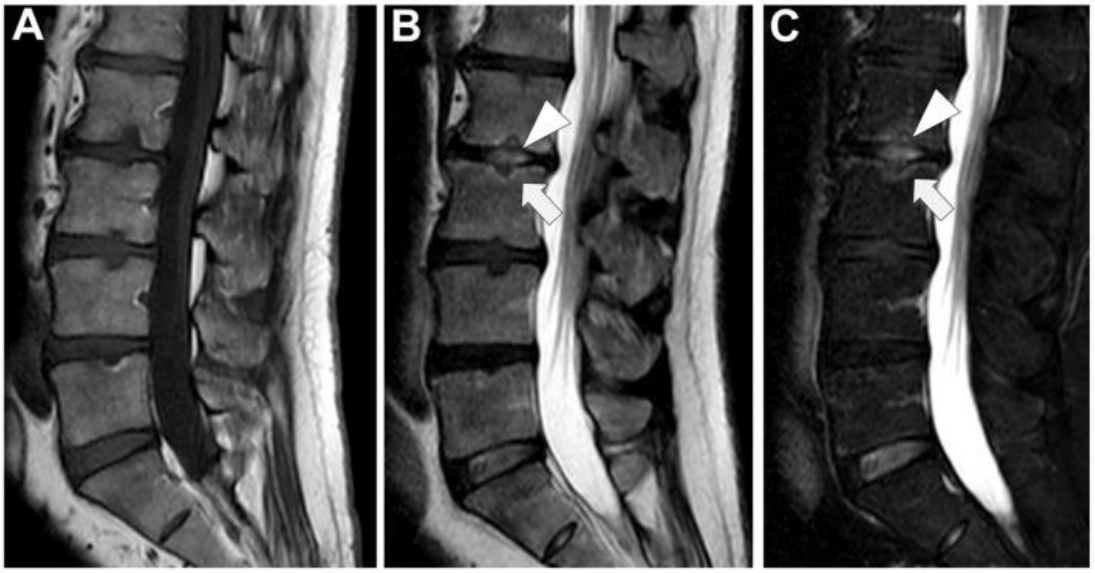

Figure 9

A 56-year-old male presented with a chronic and mechanic lumbar pain. An MRI was performed with (A) T1-weighted imaging (WI), (B) T2-WI, and (C) fat suppressed T2-WI. It demonstrates multiple Schmorl nodes (arrowheads) and a linear high signal intensity (SI) of the subchondral bones on both side of the L2-L3 level (arrows). There was no erosion, small anterior osteophyte, and degenerative disks. Hence, Modic 1 was diagnosed.

However, several additional features can help differentiate degenerative changes from infectious spondylodiscitis. First, disc thinning in degenerative conditions typically extends throughout the entire disc, with low signal intensity on T2-weighted images. Second, T1-

weighted and DIXON fat-saturated sequences often reveal a fatty signal intensity at the endplate. Third, the endplate borders are usually preserved and remain continuous. Fourth, the surrounding soft tissues and epidural spaces should remain unaffected. Additionally, associations with Modic 2 (fatty replacement of the vertebral endplate during the healing process) and Modic 3 (sclerosis or hardening of the vertebral endplate) changes are common.

Although erosions can occur during inflammatory degeneration of the disc, they typically do not result in significant destruction. Lastly, diffusion-weighted imaging (DWI) has been proposed to help distinguish Modic 1 changes from infectious spondylodiscitis, though inconsistent acquisition parameters have hindered the identification of an accurate ADC cut-off. However, certain qualitative DWI features remain useful for diagnosing Modic 1, such as the "claw sign," which appears as paired linear areas of high signal intensity with well-defined margins. In contrast, infectious spondylodiscitis would show ill-defined, diffuse, or unpaired signal abnormalities on DWI.

4.2. Andersson Lesion

An Andersson lesion is a relatively uncommon inflammatory complication affecting the intervertebral discs and vertebrae in patients with ankylosing spondylitis, occurring in 1 to 28% of cases. It is believed to result from a combination of acute inflammatory enthesopathy that extends to the disc and endplates, along with microtrauma (Figure 10).

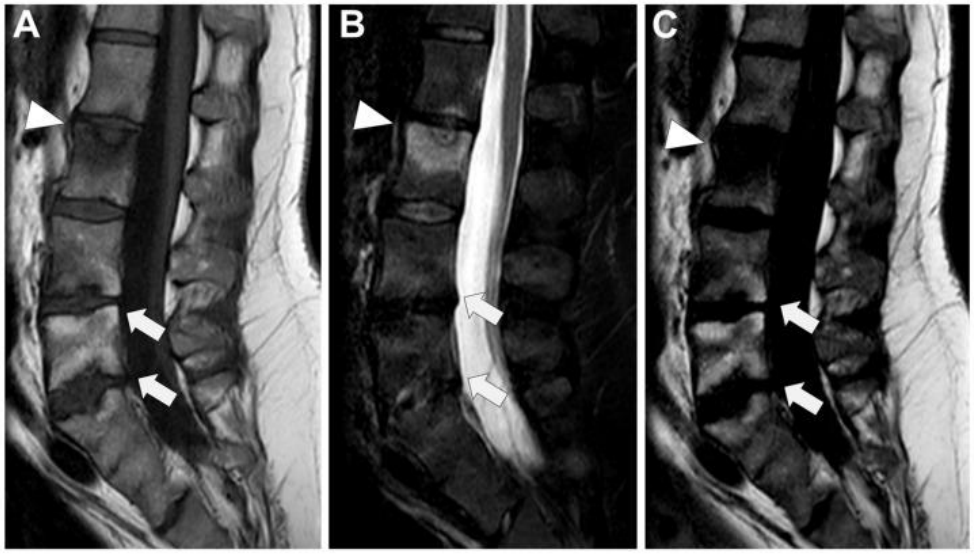

Figure 10

A 47-year-old male with a medical history of ankylosing spondylitis presented with the resurgence of upper lumbar pain with an inflammatory schedule. An MRI was performed, including (A) T1-weighted imaging (WI), (B) Dixon T2-WI with the Water Image (B), and the Fat image (C). This examination exhibits Andersson lesions of various ages. The white arrowhead shows the most recent lesions with a deep erosion in the middle of the upper L2 endplate with marked edema of the upper half of the L2 vertebral body. The white arrows show older lesions at the L4-L5 and L5-S1 levels with fatty replacement of the subchondral bone of the endplates.

The Andersson lesion is commonly found at the thoracolumbar junction or lumbar spine and typically affects more than one spinal level per patient. On CT and MRI, central or peripheral focal erosions of varying depth are often visible, along with sclerosis of the

endplates and significant bone edema on both sides of the disc-vertebral unit (seen as high signal intensity on fat-suppressed T2-weighted images, low signal intensity on T1-weighted images, and possible contrast enhancement if injected).

Several radiological features help distinguish Andersson lesions from infectious spondylodiscitis. First, there is no spread to the paraspinal soft tissue or epidural space. Additionally, other spondyloarthritis-related features are frequently present, such as inflammatory anterior enthesitis, fatty or sclerotic changes at the anterior corners of the vertebral body, syndesmophytes, sacroiliitis, and inflammation of the costovertebral and costotransverse joints.

4.3. Spinal Involvement in SAPHO Syndrome

Axial skeleton involvement in SAPHO syndrome (synovitis, acne, pustulosis, hyperostosis, and osteitis) occurs in 32–52% of patients. In this inflammatory disorder, spinal lesions can affect any level from the mid-cervical spine to the sacrum but are most common on the anterior aspect of the thoracic or lumbar vertebral body. A characteristic feature is erosion at the vertebral corner, almost always on the anterior side. Additionally, contiguous vertebral lesions are seen in 89% of patients, and in about 17% of cases, these lesions appear on both anterior sides of the same disc, which can resemble the early stages of pyogenic spondylodiscitis (PyS). Bone marrow edema within the vertebral body is a typical finding. Moreover, one-third of patients show prevertebral tissue thickening, particularly subligamentous anterior thickening, as well as abnormal high signal intensity within the disc on T2-weighted imaging, further mimicking infectious spondylodiscitis.

However, accurate diagnosis of spinal SAPHO syndrome can be achieved by recognizing the involvement of other common sites, such as the sacroiliac and sternoclavicular joints, as well as the presence of osteosclerosis at one or more levels, hyperostosis, or paravertebral ossification.

5. Future Perspective

Given the sensitivity and negative predictive value of 18F-FDG-PET/CT, combined with the diagnostic accuracy and specificity of high-quality CT scans and contrast-enhanced MRIs (including sequences like T1-WI, T2-WI, DWI, Dixon, and fat-suppressed CE-T1-DWI), there is potential for enhancing the added value of these imaging techniques. However, no studies have yet compared the effectiveness of CE MRI, 18F-FDG-PET/CT, and PET/MRI in cases of suspected infectious spondylitis.

Radiomics is a relatively new field of research that involves (i) extracting numerous quantitative variables that describe the texture and shape of "objects of interest" on imaging (known as radiomic features, often numbering in the hundreds) and (ii) training machine-learning algorithms to make predictions based on these features. For successful implementation, this approach requires standardized imaging acquisition, post-processing protocols, and well-defined statistical learning methods to ensure reproducibility across different centers. Radiomics has been applied successfully in oncology, aiding in the differentiation between benign and malignant tumors, identifying molecular subtypes of cancers, predicting treatment responses, and estimating patient survival. More recently, radiomics, along with deep learning and machine learning, has been applied to spinal degenerative diseases. A few recent studies have also explored its use in specific diagnoses. For example, in 2018, Kim et al. developed a deep convolutional neural network-based MRI algorithm to distinguish between tuberculous and pyogenic spondylodiscitis. In 2024, Yasin et

al. used MRI-based radiomics analysis to differentiate between Brucella and pyogenic spondylodiscitis.

6. Conclusions

In conclusion, this comprehensive review offers an in-depth analysis of the imaging features of infectious spondylodiscitis. It is crucial for general radiologists and those specializing in musculoskeletal imaging to become proficient in recognizing the disease's characteristics on both CT and MRI, as its incidence is expected to continue rising. Early and subtle imaging signs must be identified to prevent diagnostic delays and ensure timely treatment for patients. Additionally, contrast-enhanced MRIs and CTs can aid in identifying the causative microorganisms, especially in distinguishing between common subtypes like *Mycobacterium tuberculosis* and pyogenic bacteria, which is particularly valuable when blood cultures or invasive samples are inconclusive.

Moreover, imaging can help avoid misdiagnosis of infectious spondylitis. Although clinical and biological features may overlap between degenerative, inflammatory, and infectious spondylodiscitis, CT and MRI provide distinguishing characteristics that allow for accurate diagnosis, preventing unnecessary percutaneous biopsies and inappropriate antibiotic treatments. Finally, the combination of 18F-FDG-PET/CT with MRI, as well as the potential application of radiomics, could further enhance the diagnostic capabilities of imaging for infectious spondylodiscitis.

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