Differentiation of Native Vertebral Osteomyelitis: A Comprehensive Review of Imaging Techniques and Future Applications

Weijian Zhu
Sirui Zhou
Jinming Zhang
Li Li
Pin Liu
Wei Xiong

Native vertebral osteomyelitis, also termed spondylodiscitis, is an antibiotic-resistant disease that requires long-term treatment. Without proper treatment, NVO can lead to severe nerve damage or even death. Therefore, it is important to accurately diagnose the cause of NVO, especially in spontaneous cases. Infectious NVO is characterized by the involvement of 2 adjacent vertebrae and intervertebral discs, and common infectious agents include Staphylococcus aureus, Mycobacterium tuberculosis, Brucella abortus, and fungi. Clinical symptoms are generally nonspecific, and early diagnosis and appropriate treatment can prevent irreversible sequelae. Advances in pathologic histologic imaging have led physicians to look more forward to being able to differentiate between tuberculous and septic spinal discitis. Therefore, research in identifying and differentiating the imaging features of these 4 common NVOs is essential. Due to the diagnostic difficulties, clinical and radiologic diagnosis is the mainstay of provisional diagnosis. With the advent of the big data era and the emergence of convolutional neural network algorithms for deep learning, the application of artificial intelligence (AI) technology in orthopedic imaging diagnosis has gradually increased. AI can assist physicians in imaging review, effectively reduce the workload of physicians, and improve diagnostic accuracy. Therefore, it is necessary to present the latest clinical research on NVO and the outlook for future AI applications.

Keywords: Artificial Intelligence • Diagnostic Imaging

Full-text PDF: https://www.medscimonit.com/abstract/index/idArt/943168

Publisher’s note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.
Background

Native vertebral osteomyelitis (NVO), also known as spondylodiscitis, with varying lengths of incubation period, is an easily misdiagnosed and overlooked disease [1]. NVO is usually caused by hematogenous dissemination of a distant lesion, and *Staphylococcus aureus* is the most common causative agent, followed by *Escherichia coli*. The clinical symptoms of patients vary, with neurologic deficits being the most common. However, clinical symptoms are not the only diagnostic basis for NVO, which is one of the reasons for the high rate of misdiagnosis of NVO [1]. In a study by Colmenero et al, data on patients with vertebral osteomyelitis from 1983 to 1989 showed that the mean duration of delayed diagnosis was 14 weeks. Waheed et al found that delayed diagnosis was more than 4 months in a retrospective study of patients with NVO in 2012 to 2017, and that delayed diagnosis in NVO affects the neurological prognosis of the patient, the risk of complications, and even the mortality, thus an early diagnosis of NVO is crucial [2-4]. Relatively inexpensive plain radiographs are insensitive to NVO in the early stages, often leading to misdiagnosis of NVO, and expensive magnetic resonance imaging (MRI) is also needed to aid in the diagnosis. However, early plain radiographs are still helpful for clinicians to rule out other causes of the patient’s condition [5,6]. Currently, a large number of clinical cases of NVO have been studied and imaging techniques are rapidly changing, but no review in recent years has been able to summarize the imaging manifestations and further explore the differential points.

This paper summarizes all imaging studies related to pyogenic spondylitis (PS), tuberculous spondylitis (TS), brucellar spondylitis (BS), and fungal spondylitis (FS) in the last decade. This review aims to summarize the imaging manifestations of the major common spondylitides, explore the points of differentiation and mechanisms of difference based on the available studies, and provide an outlook on future diagnostic approaches to NVO.

Segmental Structure of the Spine

The process of ossification of the spine unfolds from the center to the peripheral endplates, and in late adolescence, the peripheral ossified fragments eventually fuse with the vertebral body and form the well-defined anterior corners of the vertebral body. However, deep within the margins, the remaining unossified cartilage then forms the cartilaginous endplate and attaches to the inner disc annulus, while the thinner portion lies centrally overlying the nucleus pulposus [7,8]. The blood supply to the vertebral body emanates mainly from the abdominal aorta ([Figure 1]) and passes through the lumbar segmental arteries into the vertebral body, where it eventually branches out and terminates near the cartilaginous endplates [8,9]. In addition, the blood supply to the intervertebral disc is mainly from the peripheral periosteal arteries and the internal intrasosseous arteries. The peripheral periosteal arteries originate from the upper and lower margins of the vertebral body, run along the margins of the disc, and interconnect with the periosteal arteries of neighboring vertebrae. The internal intrasosseous arteries, on the other hand, originate from downstream branches of the spinal arteries within the spinal canal. These arteries connect to the surrounding periosteal arteries through the intervertebral foramina [10]. The overall anterolateral blood supply of the vertebral body is rich, and this particular structure determines that the anterior margin of the vertebral body will be involved by bacteria in the early stages of NVO. When the infection develops further, bacteria will infiltrate deeper into the cartilaginous endplates, enter the annulus of the disc, and then spread to the nucleus pulposus [11].

Spinal plain radiographs are not sensitive to the early diagnosis of NVO; therefore, most plain radiographs appear normal in the early stages of NVO onset. After 2 to 3 weeks of disease onset, there is a discontinuity in the contour of the vertebral endplates, or even porosity, which often occurs on the anterior or side of the vertebral endplates. After 3 weeks of disease onset, with the spread of the disease toward the vertebrae and discs and the loss of bone mass, dissolution of the vertebral endplates and narrowing or even collapse of the intervertebral space occur. Loss of intervertebral space height is greater in PS than in TS, intervertebral space destruction is greater in TS than in PS, and confined gas can be present around the lamina in BS. Complications such as scoliosis, kyphosis, and spondylolisthesis can be diagnosed radiographically after

**Figure 1.** Bacteria colonize the anterior edge of the upper vertebral plate, which has a rich blood supply, in the direction of blood flow (*Adobe Illustrator 2022. 26.5. Adobe Inc.*).
Computed tomography (CT) can provide a complete anatomical view of the vertebrae and can show the morphology of the vertebral body and bone sclerosis, which is of great significance in the late stages of NVO when the bone marrow edema has subsided; however, the sensitivity and specificity of CT for NVO is much lower than that of MRI (Table 1). CT can be negative in the early stages of NVO, which is not very useful for the diagnosis. When the disease progresses, CT typically shows partial loss of the endplates, hypodense discs with inflammatory changes, and significant bone destruction and defects in the vertebral body [12]. Although CT is not listed as the first choice for the diagnosis of NVO, CT examination is still usually performed before MRI examination due to its ability to visualize the original lesion. In the study by Liu et al,
respective CT comparisons of PS and BS were done, as well as CT comparisons of PS and TS. In the CT images of PS vs BS, it was found that PS was more likely to involve the anterior, middle, and even posterior parts of the vertebral body than was BS, while BS was more likely to involve the periphery of the vertebral body as well as the anterior and posterior parts of the vertebral body; perivertebral sclerosis was less frequent in BS than in PS, and that PS was more likely to cause extensive vertebral body lesions than BS; and isolated anterior or posterior vertebral body wall disruption was more favorable for the diagnosis of BS. Comparison of CT images between PS and TS revealed that PS often involved lumbar vertebral segments, whereas TS often involved thoracolumbar vertebral segments, the degree of destruction of the vertebral body was often deeper and more extensive in TS than in PS, and the extent of regenerative sclerotic bone around the TS lesion was often more extensive than in PS [15,16].

**Diagnostic Value of MRI in NVO**

MRI is the diagnostic choice for NVO, with a sensitivity of up to 100% and a specificity of up to 91.7% [17-19]. In the early stages of NVO, MRI can show inflammation-induced vertebral disc edema, which is usually characterized by a low signal on T1-weighted (T1WI) and a high signal on T2-weighted imaging (T2WI) (the upper part of the inferior horn can also be affected by inflammation), as well as a short Tau inversion recovery (STIR) of the infected vertebral discs and discs that is slightly higher than the surrounding vertebral body’s signal. The next stage of NVO is the progression of vertebral destruction with the extension of the infection into the intravertebral canal and paravertebral soft tissues, with the possible formation of epidural and paravertebral abscesses. Lesions appear as homogeneous or nonhomogeneous hyperintense on T2WI, and T1 fat suppression removes the fat signal and avoids its interference. In addition, appropriate use of intravenous contrast can show the extent of infection spread in the paraspinous as well as epidural areas. Finally, the vertebral lesions appear ossified and show low signal on T1 and T2, with localized residual high signal.

**Pyogenic Spondylitis**

PS is an inflammatory disease of the vertebral body, the intervertebral disc, and even the peripheral tissues of the vertebral body caused by bacterial infection. Due to the nonspecific radiological findings in the early stage of PS, it is more difficult to distinguish PS from Modic type I [14]. Modic type I shows a low signal in T1WI and a high signal in T2WI, which is almost the same as the signal intensity in the early stage of NVO. Modic type I is composed of vascularized granulation tissues, which have high water content, so it is difficult to distinguish it from early NVO in images. In NVO, the large infiltration of inflammatory cells in the bone marrow inflammatory tissue results in a small extracellular volume, and the diffusion of water molecules is not very strong. Whereas in Modic I, on the contrary, the vascular fibrous tissues replace the bone marrow tissues completely, resulting in the diffusion of water molecules with high strength. As a result, Modic I have a higher gray scale rating in diffusion-weighted imaging (DWI) than NVO [20,21]. In the study of Patel et al, 73 patients with MR imaging features similar to Modic type I degeneration were studied and examined by DWI, and the presence of a well-defined linear high-signal region at the junction of normal and abnormal bone marrow was an identification of degenerative lesions, whereas the absence of this sign was strongly suggestive of NVO [22]. It is well known that the differences between PS and TS depend on the virulence of the pathogen, invasive protein hydrolysis, and the host immune response. Variable host interactions with low-virulence bacteria or weaker protein hydrolysis will result in atypical forms of spondylitis that can mimic tuberculosis or even metastatic masses. The common pathogen of PS is *S. aureus* [1], which produces a variety of proteolytic enzymes, including α-hemolysin and phenol-soluble modulins. α-Hemolysin is a toxin that disrupts the membranes of erythrocytes and other cells, leading to cell lysis. Phenol-soluble modulins is a class of small molecule peptides with hemolytic and cytotoxic activity. These proteases play an important role in the pathogenicity of *S. aureus* and can lead to rapid spread of infection and tissue damage [23]. It has been shown [24,25] that PS is associated with a long delayed diagnosis in fungal spondylitis, compared with BS and TS, which can be related to the high content of pathogenic bacterial proteases in PS.

In the further course of the disease, there is a loss of disc height, progressive osteolysis, and further destruction of the subchondral endplates [26]. In the study by Frel et al, the vast majority of vertebrae involved in PS showed diffuse enhancement on T2WI imaging, compared with TS, an observation that has been confirmed in other studies [27,28]. However, comparative studies of intervertebral disc destruction and the extent of its destruction have not reached uniform conclusions. In the study by Frel et al, the extent of destruction of the involved discs did not differ between the PS and TS groups, while Gupta et al [29] concluded that the extent of intervertebral disc destruction was significantly higher in TS than in PS, and Galhotra et al [27] concluded that the PS was more severe than TS in terms of intervertebral disc destruction, which was more severe. From the statistical data (Table 2), Gupta et al [29] and Galhotra et al [27] reached opposite conclusions despite the small difference in the delayed diagnosis values of their study populations. The study group of Frel et al [24] had a long delayed diagnosis, and a long delayed diagnosis...
### Table 2. Application of magnetic resonance imaging in native vertebral osteomyelitis.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Sample size</th>
<th>Disease conditions</th>
<th>Research purposes</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frel et al [24]</td>
<td>2017</td>
<td>34</td>
<td>The median age was 61.5 years in the PS group and 52 years in the TS group/3 months – 1 year for PS group, 5 months – 1 year for BS group</td>
<td>Identify and differentiate MRI image features of TS and PS</td>
<td>PS showed homogeneous diffuse enhancement of the vertebral body, and TS showed focal inhomogeneous enhancement of the vertebral body. TS had a higher incidence of paravertebral soft tissue swelling, epidural swelling, and meningeal enhancement</td>
</tr>
<tr>
<td>Lee et al [31]</td>
<td>2018</td>
<td>69</td>
<td>Median age 60 years in the PS group and 57 years in the TS group</td>
<td>Differentiation of PS from TS</td>
<td>MRI images of TS show a heterogeneous pattern of enhancement of the vertebral body and are often accompanied by a marginally enhanced abscess, with the disc usually relatively preserved. MRI images of PS usually show the following features: the vertebral body shows a homogeneous pattern of enhancement, and the disc may be affected</td>
</tr>
<tr>
<td>Galhotra et al [27]</td>
<td>2015</td>
<td>50</td>
<td>10 weeks</td>
<td>To explore the potential of MRI in the diagnosis of NVO, especially its accuracy in identifying TS and PS</td>
<td>Vertebral destruction is usually at grade 3 (25%-50% vertebral destruction) or higher in TS and usually no more than 25% in PS. Loss of cortical contour is more common in TS than PS. Vertebral enhancement patterns are usually localized and inhomogeneous, and diffuse and homogeneous in TS vs PS, respectively</td>
</tr>
<tr>
<td>Gupta et al [29]</td>
<td>2023</td>
<td>90</td>
<td>The delayed diagnosis for the TS group was 105 days</td>
<td>Identify image features that help differentiate PS from TS</td>
<td>TS is more common in the thoracic spine and is often accompanied by a paraspinous abscess with a well-defined wall and central liquefaction. TS can lead to destruction of the intervertebral discs to a degree greater than 50%. TS can lead to a reduction in the height of the vertebral body, with a reduction in the height of the L2 vertebrae of more than 25% of the L3 vertebral body. TS can lead to vertebral body deformities. PS can occur in any part of the spine, including the cervical, thoracic, and lumbar spine, and is often accompanied by involvement of posterior structures, such as the arch and the lamina, etc. PS can lead to deformities of the spine</td>
</tr>
</tbody>
</table>
Table 2 continued. Application of magnetic resonance imaging in native vertebral osteomyelitis.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Sample size</th>
<th>Disease conditions</th>
<th>Research purposes</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naselli et al</td>
<td>2021</td>
<td>114</td>
<td>Average age 60 years</td>
<td>Exploring the value of MRI examination combined with epidemiologic data for the differential diagnosis of TS and PS</td>
<td>In TS compared with PS, involvement of posterior structures was more common (93.3% versus 52.4%), discontinuity of spinal involvement was more common (26.6% versus 3.6%), the thoracic spine region was significantly more prevalent than in pyogenic spondylitis (60% versus 38.1%), having more than 2 vertebrae involved was more common (60% versus 16.7%), and the intra-vertebral bone abscess versus the paravertebral abscess had a ratio TS is high, and extra vertebral abscesses are more common in PS. Contrast enhancement of TS vertebrae usually shows heterogeneity</td>
</tr>
<tr>
<td>Batirel et al</td>
<td>2015</td>
<td>314</td>
<td>Average age 51±18 years/median of 78 days</td>
<td>Describe the clinical, laboratory, diagnostic and therapeutic features of TS</td>
<td>TS leads to a decrease in disc height and the patient experiences lysogenic changes in the bony ends of the vertebrae, which may lead to infection and abscess formation in the paravertebral tissues, usually involving multiple vertebrae, with the most common sites of involvement being the thoracic and lumbar spine</td>
</tr>
<tr>
<td>Kanna et al</td>
<td>2019</td>
<td>150</td>
<td>Average age 51 years</td>
<td>Describe the diagnostic features of TS at the pro-histologic level with imaging</td>
<td>Imaging features of TS include involvement of more than two adjacent vertebrae, presence of fluid or abscesses within the vertebral body or in adjacent paravertebral soft tissues, changes in anterior bone signal and expansion of abscesses to the level of more than two vertebrae, disruption of the vertebral body with a reduction of more than half of its height, expansion of the abscess beyond one vertebral body, abscess wall thickness of less than 2 mm (greater than 2 mm is considered thick walled), involvement of non-adjacent vertebral bodies at different sites at different vertebral levels, alterations in the morphology of the discs, which are isointense with the fluid signal, vertebral endplate margins irregularities, which may be observed on T2WI/STIR images, and erosion or compression of epidural tissues by the abscesses or granulation tissue</td>
</tr>
</tbody>
</table>
Table 2 continued. Application of magnetic resonance imaging in native vertebral osteomyelitis.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Sample size</th>
<th>Disease conditions</th>
<th>Research purposes</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liang et al [51]</td>
<td>2019</td>
<td>67</td>
<td>The mean age of the patients was 50.5±10.2 years old</td>
<td>Describe the epidemiologic features and imaging characteristics of BS</td>
<td>Imaging features of BS include lumbar spine involvement in 81.2%, MRI can show paraspinal and epidural abscesses, paraspinal abscesses in 20.9% of patients and epidural abscesses in 10.4% of patients, and abscesses and areas of lesions in BS show irregular and marked enhancement on MRI</td>
</tr>
<tr>
<td>Li et al [33]</td>
<td>2018</td>
<td>64</td>
<td>Mean age 55 years in the PS group and 57 years in the BS group/Interval between onset and radiographs, mean 6 weeks in the PS group and 9 weeks in the BS group</td>
<td>To investigate the accuracy of MRI in identifying PS and BS</td>
<td>Differences between PS and BS: diffuse, partial, and scalloped high signal on median sagittal fat suppression-weighted images (PS: 51, 11, 3/65 vs BS: 35, 18, 19/72); vertebral plate disruption (PS: 9/43 vs BS: 27/35); extensive vertebral plate disruption (PS: 29/43 vs BS: 8/35); distensibility changes of the intradural intervertebral space (PS: 7/32 vs BS: 0/32); inflammatory response lines starting from the vertebral body plate (PS: 30/65 vs BS: 1/72); signs of disc encroachment (PS: 1/28 vs BS: 12/33); inflammatory response lines within the intervertebral discs (PS: 5/28 vs BS: 25/33); and severe intravertebral space disruption (PS: 17/28 vs BS: 12/33)</td>
</tr>
<tr>
<td>Hammami et al [25]</td>
<td>2021</td>
<td>117</td>
<td>Mean age 49±19 years in the TS group and 50±16 years in the BS group/Duration of symptoms, 17±12 weeks in the BS group and 21±15 weeks in the TS group</td>
<td>Compare the clinical, laboratory, imaging and evolutionary features of TS and BS</td>
<td>TS usually erodes the thoracic spine, while BS usually erodes the lumbar spine. TS usually shows multiple bone destruction and disc destruction, while BS usually shows localized bone destruction and limited paravertebral soft-tissue involvement. TS shows low signal of the vertebral body, especially in the anterior corners on the T1WI images, while BS shows relatively high signal on the T1WI images. TS usually shows low signal in the anterior corners and the posterior-superior corners of the vertebral body, while BS shows low signal in the anterior corners of the vertebral body. The intervertebral discs of TS exhibit high signal on T2WI images, whereas the intervertebral discs of BS have relatively low signal</td>
</tr>
</tbody>
</table>
Table 2 continued. Application of magnetic resonance imaging in native vertebral osteomyelitis.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Sample size</th>
<th>Disease conditions</th>
<th>Research purposes</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liu et al [50]</td>
<td>2018</td>
<td>67</td>
<td>Interval between patient’s visit and onset of illness ≤12 months</td>
<td>Revealing MRI features of BS with TS in acute and subacute phases</td>
<td>The signal intensity of BS vertebrae was more homogeneous than that of TS vertebrae on fat suppression T2WI, and TS showed an increase in signal intensity of vertebrae on fat suppression T2 WI, which was nearly inhomogeneous</td>
</tr>
<tr>
<td>Koubaa et al [49]</td>
<td>2013</td>
<td>32</td>
<td>Mean age of patients 51±15 years/Median 90 days</td>
<td>Evaluate the clinical, laboratory, and imaging manifestations and outcomes of BS.</td>
<td>In acute BS, MRI shows low signal intensity on T1WI images of the intervertebral disc and adjacent vertebrae. The signal in these areas becomes high signal intensity on T2WI MRI sequences, which can have a homogeneous or inhomogeneous pattern. Intravenous injection of gadolinium allows for better definition of inflammatory spinal lesions and more complete assessment of soft tissue involvement and epidural extent. These features are best displayed when fat suppression techniques are applied to the enhanced images</td>
</tr>
<tr>
<td>Yang et al [52]</td>
<td>2014</td>
<td>63</td>
<td>Evaluation of MRI in patients with BS</td>
<td>Assessment of image characteristics of MRI in patients with BS</td>
<td>In the acute stage, MRI shows low signal intensity on T1WI images and high signal intensity on T2WI images over the vertebral body, intervertebral discs and vertebral endplates. In the subacute and chronic stages, MRI showed low signal intensity on T1WI images and heterogeneous high signal intensity on T2WI images. Contrast-enhanced images show contrast enhancement of the intervertebral disc and affected vertebrae in the acute, subacute, and chronic stages. Soft tissue swelling and paravertebral abscess formation may be observed. Lesions in BS are usually solitary but may be multiple and multi-segmental.</td>
</tr>
</tbody>
</table>
Table 2 continued. Application of magnetic resonance imaging in native vertebral osteomyelitis.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Sample size</th>
<th>Disease conditions</th>
<th>Research purposes</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crete et al [44]</td>
<td>2017</td>
<td>41</td>
<td>Average age is 42 years</td>
<td>Describes coccidian infections resulting from various spinal manifestations and provides examples of MRI</td>
<td>Fungal spondylitis shows enhancement over the spinal cord membranes, usually diffuse, and can affect the cervical, thoracic, and caudal cones/cauda equina uniformly. Adhesive inflammation appears over the spinal cord membranes, commonly in the lumbar spine, and manifests as nerve root masses. Adhesive arachnoiditis can also occur in the cervical and thoracic spinal cord. Spinal cord edema was observed in 11 patients. True spinal cord cavititation was observed in 3 patients. 14 patients had vertebral osteomyelitis and/or discitis. Common presentations included paravertebral involvement, intervertebral disc involvement, bone destruction, and skip lesions in noncontiguous vertebrae. Intracerebral lesions were present in all patients with extramedullary lesions, of which 27 patients underwent brain MRI, and another 3 patients showed posterior cranial fossa involvement by cervical spine MRI, of which 19 patients demonstrated basal-only or basal-dominant meningeal enhancement.</td>
</tr>
<tr>
<td>Lee et al [53]</td>
<td>2013</td>
<td>60</td>
<td>Average age 56±18 years</td>
<td>Median 4 months, 1 month and 5 months for fungal spondylitis, PS and TS groups, respectively</td>
<td>In fungal spondylitis, disc destruction was seen in 50% of patients, compared to 93% of patients in PS and 28% of patients in TS. In fungal spondylitis and PS, the infection was more extensive and involved a greater number of vertebrae, whereas in TS the infection was less extensive. Inflammatory masses in fungal spondylitis showed low signal intensity on T2WI imaging, whereas in PS inflammatory masses showed high signal intensity on T2WI imaging. Inflammatory masses in TS showed low or high signal intensity on T2WI imaging. Abscess formation was less common in fungal spondylitis and more common in PS and TS.</td>
</tr>
</tbody>
</table>

MRI – magnetic resonance imaging; PS – pyogenic spondylitis; TS – tuberculous spondylitis; T1WI – T1-weighted image; T2WI – T2-weighted image; BS – brucellar spondylitis; STIR – short Tau inversion recovery.
resulted in sufficient time for *Mycobacterium tuberculosis* to cause damage to the discs, which may be the reason for the lack of disc damage between the PS and the TS groups. This may be the reason why there was no difference in the degree of disc destruction between the PS and TS groups. In describing the degree of bone destruction, many studies have concluded that vertebral destruction is more severe in TS than in PS. The diffuse spread of vertebral and epidural infections on T2WI is more pronounced in PS than in T2WI during the early stages of the disease [24,27,29], which is related to the adherence of the causative organisms of PS and the high proteolytic enzyme content of the organisms [30,32].

With the further spread of pathogenic bacteria, involvement of paravertebral soft tissues also becomes characteristic of PS, and there is a high probability that paravertebral abscesses will not appear as well-defined areas in contrast enhancement with lumbar muscle abscesses [27,28,31]. In the study by Galhotra et al [27], the cervical spine became the most common site of involvement in PS due to the consecutive involvement of the cervical spine by retropharyngeal abscesses, skull base osteomyelitis, or dorsal cervical caruncles, which is contrary to the finding that PS tends to involve the lumbar spine [26,32,33]. However, Lee et al [31] and Freil et al [24] found a greater tendency to involve the thoracolumbar spine in PS, and these findings suggest that the uncertainty of the lesion adds to the difficulty of distinguishing PS from TS. For the relatively rare jump lesions of PS, Shroyer et al [32] suggested that the possibility of epidural infection occurring in more than just 1 segment of the spine should be considered and argued for the importance of whole-spine imaging. The findings of Galhotra et al [27] and Lee et al [19] showed that PS involved 2 and more vertebras at a staggering rate of 83.4% and 98%, which directly validates the importance of whole-spine imaging.

**Tuberculous Spondylitis**

Differential diagnosis of TS is important for clinical management, especially in those with spinal bone destruction. Atypical spinal tuberculosis, including skip multifocal spinal tuberculosis, can be misdiagnosed as a neoplastic lesion or other infectious spondylitis, leading to delayed treatment [31,34]. Spinal tumors tend to involve vertebral bodies and posterior elements, which cannot be strongly differentiated from the variable imaging features of TS. Due to the edema of the lesion in the early stage of TS vs the primary tumor in the vertebral body, the metastatic tumor restricts the diffusion of water molecules and has a low apparent diffusion coefficient, whereas the destruction of the vertebral body as well as the intervertebral discs occurs after the further development of TS, and the apparent diffusion increases, and the grayscale signals are weaker than those of the spinal tumors on the DWI images. The presence of one or more signals in the vertebral body with a subcutaneous-fat-like brightness on the T1WI imaging implies the lesion may be a non-metastatic tumor. The presence of a high-signal rim around a low-signal lesion in the vertebral body on T2WI imaging suggests that the lesion may be a metastatic tumor [35,36]. When the metastatic tumor involves the spinal canal, it is difficult to distinguish it from intraspinal tuberculosis. In adults, tuberculosis balls and metastatic tumors show equal signals on T1WI and slightly higher signals on T2WI, and both involve the entire spinal column and are prone to meningitis and hydrocephalus; however, there is a significant difference between the two, and the well-defined and limited thickened portion of the meninges in extramedullary lesions is suggestive of metastatic carcinoma [37]. Recent studies have shown that the QuantiFERON-TB Gold In-Tube (QFT-GIT) test exhibits good sensitivity and specificity for the diagnosis of spinal tuberculosis, making it an important tool for preoperative differential diagnosis. A new threshold of 1.58 IU/mL for the QFT-GIT test has been found to improve diagnostic efficacy. A multidisciplinary diagnostic approach including histopathologic examination and mycobacterial culture is necessary for accurate diagnosis and early treatment of spinal tuberculosis. In conclusion, MRI is still the method of choice in the diagnosis of spinal tuberculosis [38], and it is meaningful to study and summarize the MRI imaging features of TS.

*M. tuberculosis* prefers to colonize the anterolateral aspect of the vertebral body where the blood supply is abundant, and this has led to the inability to differentiate TS from PS at the beginning of the disease course. However, PS involves the intervertebral discs in the early stages, and probably due to the lack of protein hydrolyzing enzymes of *M. tuberculosis*, the discs will not be eroded in the early stages of TS [24,29]. As the disease progresses, Mycobacterium tuberculosis causes severe bone destruction. In a study by Kanna et al [39], it was noted that vertebral destruction of >50% of the vertebral volume in TS was highly sensitive and specific in the diagnosis of TS, which is in agreement with the results of other studies [27,28]. Interestingly, in a study by Galhotra et al [27], there was a probability that patients with TS had an intraosseous abscess, whereas PS did not develop intraosseous abscesses. Unlike PS, the signal intensity of the involved vertebrae in patients with TS was mixed and heterogeneous on T2WI, while the bone cortex of the involved vertebrae was severely damaged, leading to a loss of definition [27], and these observations have been verified in other studies [24]. The partial bone damage but not extensive damage caused by *M. tuberculosis* may be due to the ability of the bacteria to adapt to the bone environment and alter their gene expression, an adaptive strategy that allows the bacteria to enhance their cell wall and cellular integrity, possibly enabling them to survive within the bone lesion [40]. Mycobacterium infection in bone is driven by increased expression of genes involved in cell wall...
remodeling and DNA damage repair pathways, which are important for its survival [41]. These factors can cause partial bone damage without causing the extensive damage caused by *M. tuberculosis*.

In advanced TS lesions, the subligamentous spread of tuberculous abscesses under the anterior longitudinal ligament appears to be a characteristic feature of spinal tuberculosis with high diagnostic accuracy. Massive cold abscess formation and the presence of protein hydrolases lead to gradual elevation of the longitudinal ligament away from the vertebral body, resulting in a kind of sublimated spread of the TS [31,39]. In the study by Gupta et al [29], thoracic spine involvement, posterior or component involvement, and spinal deformity were considered independent predictors for the diagnosis of tuberculous spondylitis, and paravertebral abscesses were greater with lumbar abscesses than with PS. However, Batiel et al [42] analyzed data from a large sample of TS and found that the lumbar spine was involved in a greater proportion than the thoracic spine, which does not seem to support the notion that thoracic spine involvement is an independent diagnostic factor for TS, while other results confirm the findings of Gupta et al. As the inflammation caused by *M. tuberculosis* is mostly chronic, the paravertebral abscesses caused by TS with lumbar muscle abscesses have thinner walls than those of PS, which is in line with the classical description of TS [24,39]. In addition, meningeval enhancement at the level of the involved spinal segments was found to be more likely to be detected in patients with TS in a study by Frel et al. This observation has likewise been confirmed by other articles [43].

**Brucellar Spondylitis**

*Brucella* colonizes the vertebral body through the paravertebral plexus of the Bastard vein and the nutrient arteries, which results in a rapid spread of the infection throughout the vertebral body, which displays a diffuse high signal on T2WI. In addition, *Brucella* destroys the vertebral endplates at an early stage and relies on phagocytosis and osteoclasts for replication, evading the host’s immune response, inhibiting apoptosis of infected monocytes, suppressing the activation of T cells, blocking dendritic cell activation, and preventing the activation of dendritic cells. Activation, impeding dendritic cell maturation, and impairing the resorptive capacity of osteoclasts provide the conditions for *Brucella* to maintain chronic infection, which determine the relative preservation of the vertebral body in the acute and chronic phases of BS. Divergent bacilli deficient in protein hydrolases severely erode the endplate, and the formation of caseous dead bone obliterates the possibility of new bone production, presenting a heterogeneous high signal near the uneven endplate on T2WI [44-48]. Li et al [33] found that acute PS infection was more likely to show diffuse and endplate inflammatory reaction lines than was chronic BS, and the use of DWI can differentiate acute PS from chronic BS. Meanwhile, several papers pointed out that most of the affected areas of PS and TS were consistent with water signal intensity on T2WI, due to inflammation, and a few TS and PS might show mixed signals on T2WI, due to therapeutic interventions [26,27,39]. While *Brucella* does not involve protease activity that destroys vertebral bone and discs in comparison to purulent bacteria and *M. tuberculosis*, the intensity of localized inflammation due to *Brucella* infection is lower than that of purulent bacteria and *M. tuberculosis*, and the signal intensity of the infected area of BS is lower than that of water on T2WI [25,33]. Furthermore, a study by Hammami et al [25] showed that the incidence of arch involvement, vertebral compression, and spinal cord compression was significantly higher in the TS group than in the BS group. A study by Koubaa et al [49] suggested that multifocal involvement, severe bone destruction and epidural abscesses are suggestive of TS, whereas focal bone destruction and limited paravertebral involvement are suggestive of BS, and that the prevalence of epidural abscess in TS provides conditions in which spinal cord compression is common, which corroborates the views of Hammami et al. BS has been found to involve the lower lumbar spine in all imaging studies of BS in the last decade [25,33,49-52], while studies by Liang et al [51] and Koubaa et al [49] found that single-segment lumbar spine involvement was more common.

**Fungal Spondylitis**

FS is often associated with immunocompromised patient status and has a long course, which needs to be differentiated from other types of NVO [53]. FS has a low incidence of subligamentous spread of infection, which also results in a low incidence of jump-diffusion, in contrast to TS, which is favored by jump metastases [53]. Because patients are immunocompromised and the virulence of the causative organisms is generally low, the inflammatory response caused by FS is not very strong, resulting in high signal loss in T2WI of abscesses and infection due to inflammation, and a few TS and PS might show mixed signals on T2WI, due to therapeutic interventions [26,27,39]. While *Brucella* infection is lower than that of purulent bacteria and *M. tuberculosis*, and the signal intensity of the infected area of BS is lower than that of water on T2WI [25,33]. Furthermore, a study by Hammami et al [25] showed that the incidence of arch involvement, vertebral compression, and spinal cord compression was significantly higher in the TS group than in the BS group. A study by Koubaa et al [49] suggested that multifocal involvement, severe bone destruction and epidural abscesses are suggestive of TS, whereas focal bone destruction and limited paravertebral involvement are suggestive of BS, and that the prevalence of epidural abscesses in TS provides conditions in which spinal cord compression is common, which corroborates the views of Hammami et al. BS has been found to involve the lower lumbar spine in all imaging studies of BS in the last decade [25,33,49-52], while studies by Liang et al [51] and Koubaa et al [49] found that single-segment lumbar spine involvement was more common.
<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Sample size</th>
<th>Disease conditions</th>
<th>Research purpose</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smid et al [18]</td>
<td>2017</td>
<td>68</td>
<td>Median age 64</td>
<td>To investigate the diagnostic value of 18F-FDG PET, CT and MRI for spondylitis and its complications</td>
<td>18F-FDG- PET/CT shows increased 18F-FDG uptake in the spinal region compared to uptake in the bone marrow, or increased 18F-FDG uptake in the soft tissues surrounding the spine. PET-CT can show the early stages of spinal inflammation because it visualizes increased glucose metabolism, whereas MRI relies only on anatomical changes. PET-CT can detect other foci of infection on a systemic scale and may even recognize endocarditis (which occurs relatively often in conjunction with discitis).</td>
</tr>
<tr>
<td>Kim et al [66]</td>
<td>2018</td>
<td>81</td>
<td>–</td>
<td>Evaluating the performance of DCNN for differentiating tuberculous and septic spondylitis on MRI imaging</td>
<td>In PET-CT images, spondylolisthesis is manifested by increased uptake of 18F-FDG, shown as a hypermetabolic region. This increased uptake can be observed in the vertebral body, intervertebral discs, and surrounding soft tissues. The sensitivity, specificity, PPV, and NPV of 18F-FDG-PET/CT for the diagnosis of spondylolisthesis were 100%, 83.3%, 90.9%, and 100%, respectively.</td>
</tr>
<tr>
<td>Ioannou et al [58]</td>
<td>2013</td>
<td>10</td>
<td>–</td>
<td>To determine the role of F-18 FDG PET/CT scanning in the diagnosis of BS and monitoring its treatment outcome</td>
<td>In this study, initial MRI in all patients showed increased F-18 FDG activity in the infected vertebral region. Compared with MRI, F-18 FDG PET/CT provided additional information in 4 patients. It revealed additional vertebral lesions (3 patients), lymphadenitis, arthritis, and organomegaly, as well as new paravertebral soft tissue involvement and epidural masses. This additional information had an impact on the duration of treatment in these patients.</td>
</tr>
<tr>
<td>Gunes et al [59]</td>
<td>2016</td>
<td>32</td>
<td>–</td>
<td>Exploring the value of FDG-PET/CT in the diagnosis of spondylitis</td>
<td>FDG-PET/CT can show increased FDG uptake in the patient’s intervertebral discs and vertebral bodies, correlating with inflammatory activity. FDG-PET/CT can show increased FDG uptake in the patient’s peripheral paravertebral soft tissues, suggesting the presence of a soft tissue infection. FDG-PET/CT can help to differentiate between chronic osteomyelitis and implant infections, and also has high diagnostic accuracy in patients with metallic implants. FDG-PET/CT also has high sensitivity and accuracy in the diagnosis of postoperative patients. FDG-PET/CT can help to rule out other diseases such as malignant tumors.</td>
</tr>
</tbody>
</table>

18F-FDG – 18-fluorodeoxyglucose; PET – positron emission tomography; CT – computed tomography; MRI – magnetic resonance imaging; DCNN – deep convolutional neural networks; PPV – positive predictive value; NPV – negative predictive value.
Diagnosis Value of Positron Emission Tomography for NVO

Some patients who have certain implants or foreign bodies, often ferromagnetic items, are usually unable to undergo MRI, which is one of the main reasons for limiting the use of MRI for NVO. In 2000, positron emission tomography (PET) combined with fluorodeoxyglucose (FDG) was first applied in the examination of TS and was found to be able to differentiate between bone and soft tissue infections [55]. In 2002, when the combination of PET and FDG was widely used in the diagnosis of various infectious diseases, Stumpe et al used this technique for the first time in the diagnosis of spinal infections and measured its specificity and sensitivity to be 100%, however, the small sample size of this study was not sufficient to draw definitive conclusions [56]. In the same year, in a study by Gratz et al, the combined use of FDG and PET for the diagnosis of NVO had a higher sensitivity, specificity, and accuracy than other imaging findings, especially the 67-Ga combined bone scan, which had been used for the evaluation of discitis but was not as effective as 18F-FDG-PET/CT, due to interference from tumors and non-inflammatory diseases. The authors recommended that once NVO is detected, it should be detected immediately by combined FDG and PET/CT to better visualize the area of infection (Table 3) [57-59]. In 2015, Fuster et al found that SUVmax quantification should be used to correct for background SUVmin, a move that significantly improved the discrimination between infected and noninfected areas [60]. However, these studies did not address the time of symptom onset vs the time of imaging, and all patients in the study by Kouijzer et al were taken for MRI vs 18F-FDG-PET/CT within 48 h. The results showed that the sensitivity, specificity, positive predictive value, and negative predictive value of the 2 examinations were 100%, 83.3%, 90.9%, 100%, and 100%, respectively, and 91.7%, 95.2%, and 100%, respectively, with no significant difference, which also suggests that both MRI and 18F-FDG-PET/CT examinations have high value for NVO examination, and the uptake of 18F-FDG at the lesion is higher than that at the periphery of the lesion. The results demonstrated that 18F-FDG-PET/CT could also be used to differentiate infection from degeneration. A study by Smids et al confirmed that MRI should be preferred for epidural and spinal abscesses and that 18F-FDG-PET/CT is more sensitive for the detection of paravertebral abscesses, lumbar muscle abscesses, and metastatic abscesses, which is the same as the findings of Kouijzer et al. This also suggests that 18F-FDG-PET/CT in combination with MRI, as a new imaging technique, can be used as a good combination, thus providing a high diagnostic value [18,19]. Gallium-67 combined with MRI or PET/CT has been increasingly studied in the diagnosis of NVO, and the old technique of technetium-99m in combination with MRI or PET/CT has been used relatively less often because gallium radiography is more reliable than technetium-99m. However, recent studies have confirmed that gallium-67 in combination with technetium-99m is more specific than gallium-67 alone [61].

Artificial Intelligence Applications and the Future

Machine learning is a branch of artificial intelligence (AI). There are numerous classifications of machine learning, and those applied in the field of spine surgery include classification and regression trees, linear models, support vector machine, and deep learning (Figure 2). Deep Learning in turn includes artificial neural networks, convolutional neural networks (CNNs), deep neural networks, recurrent neural networks, and the latest transformer model [62,63]. Among the many classifications in AI, CNNs can automatically learn representative features from images to perform classification tasks [64]. The developed automatic spine segmentation system and fracture detection software are examples of practical applications of CNNs [65].

In 2018, Kim et al [66] used the deep convolutional neural network (DCNN) technique for the first time to classify PS vs TS, and through this study initially demonstrated that the DCNN classifier has comparable performance with skilled imaging physicians in distinguishing PS vs TS using MRI images. However, the study had many drawbacks, such as using only cross-sectional images and not sagittal images, which are commonly used in clinical work, using a pre-trained DCNN model, insufficient number of cases, and uneven image quality. Several factors led to the model not being successfully applied in the clinic, and the DCNN model was not trained from scratch, which suggests that the potential of DCNN in the diagnosis of NVO has not been fully exploited. Unfortunately, this is the only study involving the use of CNNs for NVO classification. In 2023, Mukaihata et al used CNNs to differentiate between PS and spinal Modic alterations in MRI images, and a total of 50 patients’ MRI images were included in the modeling. The final results were also satisfactory, with the diagnostic accuracies of T1WI and STIR images being significantly higher than those of clinical physicians [67].
<table>
<thead>
<tr>
<th>NVO type</th>
<th>Early stage</th>
<th>Terminal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PS</strong></td>
<td>Decreased intervertebral space height, bone defects (Figure 3A)</td>
<td>Loss of intervertebral space height, vertebral bone defects, vertebral body slippage, etc. (Figure 4A)</td>
</tr>
<tr>
<td></td>
<td>Diffuse increase in signal in the affected vertebrae, decrease in the height of the intervertebral space, and partial osteolysis (Figure 3B, 3C)</td>
<td>Abnormal signal shadowing near the calcaneus, involvement of 2 or fewer vertebrae, reduced intervertebral space height, localized bone loss, possible slip of the spine (Figure 4B, 4C)</td>
</tr>
<tr>
<td></td>
<td>Diffuse enhancement of the infected vertebral body on T2WI imaging, disc erosion, and increased susceptibility of the infection to spread to the epidural space (Figure 3D)</td>
<td>Poorly demarcated anomalous signal in the paravertebral area, abnormal signal shadows near the lesser joints, thick and irregular walled abscesses, involvement of 2 or fewer vertebrae (Figure 4D)</td>
</tr>
<tr>
<td><strong>TS</strong></td>
<td>Bone defect near endplate (Figure 5A)</td>
<td>Severe bone loss, loss of intervertebral space height, spinal deformity (Figure 6A)</td>
</tr>
<tr>
<td></td>
<td>Localized bone loss around the endplate, possible formation of bone abscesses, uneven signal enhancement in infected vertebrae (Figure 5B)</td>
<td>Severe bone loss, loss of intervertebral space height, spinal deformity, involvement of posterior elements, jumping distribution of infected vertebrae, decreased signal value of localized bone infection due to calcification (Figure 6B)</td>
</tr>
<tr>
<td></td>
<td>The infected vertebral body showed heterogeneous enhancement on T2WI imaging, and the endplate showed localized severe bone destruction (Figure 5C, 5D)</td>
<td>Severe disruption of the endplate margins with osteolysis, localized formation of calcified bone without regenerative bone formation, spread of the abscess by sublimation involving three or more vertebrae, more likely to form a paravertebral abscess, thin and smooth walled abscess (less than 2 mm), lesion unevenly enhanced. A spinal deformity is present, involving the posterior elements (Figure 6C, 6D)</td>
</tr>
</tbody>
</table>
Table 4 continued. Characterization of common NVO types.

<table>
<thead>
<tr>
<th>NVO type</th>
<th>Early stage</th>
<th>Terminal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plain radiograph</td>
<td>CT</td>
</tr>
<tr>
<td>BS</td>
<td>Decreased intervertebral space height</td>
<td>Inflated disc sign, decreased intervertebral space height, increased signal from infected vertebrae, and diffusion throughout the vertebral body</td>
</tr>
<tr>
<td>FS</td>
<td>No special findings (Figure 8A)</td>
<td>Localized abnormal signals in infected vertebrae (Figure 8B)</td>
</tr>
</tbody>
</table>

NVO – native vertebral osteomyelitis; BS – brucellar spondylitis; FS – fungal spondylitis; T2WI – T2-weighted image; CT – computed tomography; MRI – magnetic resonance imaging.

Conclusions

In this paper, we describe the imaging manifestations of different NVOs based on the respective characteristics of different pathogens and the physiological structure of the spine. PS, TS, BS, and FS present unique features on images according to their different periods, infection ranges, and degrees of destruction (Table 4). Kim et al [66] applied CNN for the first time to differentiate between PS and TS in 2018, and achieved good predictive results, which demonstrates the ability of AI to handle complex NVO images; however, the study did not fully stimulate the potential capabilities of CNNs. The great potential of CNNs to assist in the diagnosis of NVOs remains to be further exploited, which will also improve the efficiency of clinical decision making.

Declaration of Figures’ Authenticity

All figures submitted have been created by the authors, who confirm that the images are original with no duplication and have not been previously published in whole or in part.
Figure 3. (A) Pyogenic spondylitis (PS) early plain radiograph. No significant narrowing of the lumbar spinal space was seen. (A-D) Images of the same patient, who presented with 9 days of low back pain. (B, C) Plain and enhanced computed tomography in early PS. Marker 1 in both images shows poorly defined bony margins on the anterosuperior margin of the L4 vertebral body, and marker 2 shows swelling of the surrounding soft tissues. (D) Magnetic resonance imaging in early stages of PS. Marker 1 shows disc erosion, and marker 2 shows diffuse infection of the L4 vertebral body (Adobe Illustrator 2022. 26.5. Adobe Inc.).
Figure 4. (A) Plain radiographs of late pyogenic spondylitis (PS). Marker 1 shows severe narrowing of the L2-3 intervertebral space, with bony hyperplasia and sharpening of the vertebral margins. (A-D) Images of the same patient, with 42 days between onset of symptoms and the time of the radiograph. (B, C) Plain and enhanced computed tomography in late-stage PS. Marker 1 shows marked narrowing of the L2-3 intervertebral space, and marker 2 shows rough and blurred edges of the L3-L4 vertebral body with osteolytic changes. (D) Magnetic resonance imaging of late PS. Osteolysis of the anterior margin of L3 is shown at marker 1, severe narrowing of the L2-3 intervertebral space is shown at marker 2, osteophytes of the small joints are shown at marker 3, and high signal of the lumbar attachments is shown at marker 4 (Adobe Illustrator 2022. 26.5. Adobe Inc.).
Figure 5. (A) Plain radiograph of early tuberculous spondylitis (TS). No abnormal vertebral changes. (A-C) Images of the same patient, with an interval of 120 days between onset of symptoms and the first radiograph. (B) Plain computed tomography in early TS. There is a less dense lesion with poorly defined borders and no obvious sclerotic bands at marker 1, and an uneroded disc is visible at marker 2. (C) Magnetic resonance imaging (MRI) in early stages of TS. Marker 1 shows that the disc has not received erosion and marker 2 shows an abnormal high signal lesion in the T8 vertebral body. (D) MRI in early stages of TS. Marker 1 shows an abnormally reinforcing shadow in the paravertebral soft tissue, and marker 2 shows relative preservation of the disc, at 120 days between symptom onset and radiograph in this patient (Adobe Illustrator 2022. 26.5. Adobe Inc.).
Figure 6. (A) Plain radiographs of late tuberculous spondylitis (TS). Marker 1 shows narrowing of the L2-3 intervertebral space, dysmorphism of the L2 vertebral body, and osteophytes on the margins. (A-C) Images of the same patient, with an interval of 210 days between the onset of the disease and the radiographs. (B) Plain computed tomography in late-stage TS. Markers 1 and 2 show severe bone destruction at the lower edge of the L2 vertebral body and the upper edge of the L3 vertebral body, narrowing of the L2-3 intervertebral space, and free osteolysis. (C) Magnetic resonance imaging (MRI) of late TS. Marker 1 shows abnormal signal in the paravertebral region, and marker 2 shows bone destruction at the opposite edges of the L2 and L3 vertebrae. (D) MRI of late TS. Marker 1 shows sublimated spreading of an abscess under the anterior longitudinal ligament, and marker 2 shows thoracic vertebral deformity. This is an image of a patient who was approximately 130 days from the onset of symptoms to radiography (Adobe Illustrator 2022. 26.5. Adobe Inc.).
Figure 7. (A) Plain radiographs of late *Borrelia burgdorferi* spondylitis (BS). Marker 1 shows a decrease in the height of the intervertebral space, marker 2 shows osteophytes on the margins of the vertebral body, and marker 3 shows a slight forward displacement of the L3 vertebral body. (A-D) Images of the same patient, with an interval of approximately 120 days between the onset of symptoms and the time of the radiograph. (B) Plain computed tomography in late BS. In both figures, Marker 1 shows a decrease in the height of the intervertebral space, and marker 2 shows hyperplasia of the anterior margin of the vertebrae. (C) Magnetic resonance imaging (MRI) of late BS. This image is a T1-enhanced image showing abnormal signal in the vertebral body at marker 1 and reduced intervertebral space height in the vertebral body at marker. (D) MRI of late BS. Density at marker 1 is 54, marker 2 shows diffuse infection of the vertebral body with a density of 37, and marker 3 shows an infected disc. The time between the onset of this patient’s disease and the radiograph is about 2 years. (ITK-SNAP. Version 4.0.2. Paul Yushkevich, Jilei Hao, Alison Pouch, Sadhana Ravikumar et al at the Penn Image Computing and Science Laboratory; Adobe Illustrator 2022. 26.5. Adobe Inc.).
Figure 8. (A) Plain radiograph of early fungal spondylitis (FS). Markers 1 and 3 show localized bone destruction at L5-S1, and marker 2 shows no significant narrowing of the intervertebral space. (A-C) Images of the same patient, who had an interval of approximately 30 days between the onset of symptoms and the time of the radiographs. (B) Plain computed tomography in early FS. Bone destruction is seen in the margins of the L5-S1 vertebrae at markers 1 and. (C) Magnetic resonance imaging (MRI) in early stages of FS. This image is a T2WI sequence. A small intraosseous abscess is shown at marker 1, a striated shadow under the vertebral endplate is shown at marker 2, and an infected disc is shown at marker. (D) MRI in early stages of FS. This image is a short Tau inversion recovery (STIR) sequence. Density at marker 1 is 376, marker 2 shows diffuse high signal in the vertebral body with a density of 312, which is lower than the cerebrospinal fluid density value, and marker 3 shows a relatively preserved intervertebral space height (ITK-SNAP. Version 4.0.2. Paul Yushkevich, Jilei Hao, Alison Pouch, Sadhana Ravikumar et al at the Penn Image Computing and Science Laboratory; Adobe Illustrator 2022. 26.5. Adobe Inc.).


References:

Zhu W. et al: Imaging diagnosis of native vertebral osteomyelitis
© Med Sci Monit, 2024; 30: e943168

REVIEW ARTICLES

This work is licensed under Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0)