UPDATE

Computed tomography and magnetic resonance imaging for painful spinal column: contributions and controversies

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Spine; Magnetic resonance imaging; Column; Computed tomography; Back pain; Spinal column disease; Curvature of the spine

Abstract  The use of tomographic imaging techniques, computed tomography (CT) and magnetic resonance imaging (MRI), to complement or replace plain-film radiography in the study of spine pain is becoming more and more common.

The aim of this paper is to provide a general review of the CT and MRI manifestations of the wide spectrum of lesions that can cause pain in the spinal column. This spectrum includes degenerative disease, malalignment, tumors, inflammatory processes, and infectious processes.

Precise knowledge and accurate reporting of the findings at CT and MRI are fundamental for clinical decision making in patients with spine pain.

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PALABRAS CLAVE
Columna; Resonancia magnética; Raquis; Tomografía computarizada; Dolor de espalda; Enfermedades de la columna; Curvatura espinal

Tomografía computarizada y resonancia magnética en las enfermedades dolorosas del raquis: aportaciones respectivas y controversias

Resumen  Las técnicas de imagen tomográficas, tomografía computarizada (TC) y resonancia magnética (RM) se vienen usando cada vez de forma más frecuente, en sustitución o adición a la radiografía simple, para el estudio del dolor de espalda.

El objetivo de este trabajo es realizar una revisión general de las manifestaciones en TC y RM del amplio espectro de enfermedades que pueden ser responsables del dolor generado en la columna vertebral. Este espectro abarca la enfermedad degenerativa, de la alineación vertebral, tumoral, inflamatoria e infecciosa.

El conocimiento y la descripción exacta y uniforme de los hallazgos con dichas técnicas suponen un soporte fundamental para la toma de decisiones clínicas en los pacientes con dolor de raquis.

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Introduction

The expanding use of tomographic imaging techniques, computed tomography (CT) and magnetic resonance imaging (MRI), has led to a relative decline in the use of plain chest radiography as the first imaging technique in multiple conditions that manifest with back pain.\(^1\)

Clinical guides do not recommend systematic imaging in patients with acute or chronic back pain in the absence of warning signs (red flags), since this does not significantly improve the clinical outcome.\(^2\) Only in the presence of warning signs (fever, weight loss, history of tumor or neurological disorders) imaging techniques assume a central role.

Inter-reader variability in the interpretation of the findings is one of the factors that lead to disagreement in the decision-making process.\(^3\) In the present work, we assess the diagnostic contributions, advantages and limitations of CT and MRI in the evaluation of painful spinal conditions.

Technical considerations

CT provides high spatial resolution for anatomical imaging and it is particularly indicated in the evaluation of bone lesions. From imaging acquisition in the axial plane, multidetector computed tomography (MDCT) allows for isotropic images with no significant spatial distortion in multiplanar and 3D reconstructions.\(^4\)

Spine CT imaging must include a continuous helical scanning across the range of interest, which is determined by clinical criteria or by the presence of a lesion previously identified by other imaging techniques. Submillimeter slices allow for isotropic images; however, for extensive studies, reconstruction thickness of 1-3mm may be acceptable.

The major drawback of CT is radiation dose, much higher than that of conventional radiography, and it may range between 13-26 mSv depending on the instrumentation and technical parameters.\(^5\) The use of low-dose CT with radiation levels of around 1 mSv is not universally spread.\(^6\)

MR imaging offers better characterization of soft-tissue structures than CT. A standard protocol should include axial and sagittal T1 and T2 sequences and, at least, one fat-suppressed T2-weighted sequence, based on techniques of chemical shift and/or of inversion-recovery suppression. Concerning the cervical spine and due to the smaller size of the discs, the axial gradient echo sequence is recommended, which usually allows differentiation between disc (hyperintense) and osteophytes (hypointense).\(^7\) In case of suspected inflammatory, infectious or neoplastic disorders, the examination is completed with additional T1 sequences obtained after gadolinium administration. Fat suppression in at least one plane allows better enhancement evaluation of these pathological processes.\(^8\)

Innovative MRI techniques are being developed that try to provide metabolic, functional and physiological information to the anatomical image of the standard methods. Some of these techniques are diffusion, perfusion, in-phase and opposed-phase sequences, etc. Their use is less common and usually reserved for tumor imaging.\(^9\)

Clinical and radiological considerations

Spine CT and MRI studies in asymptomatic patients have reported a high percentage of vertebral disc disease. On the other hand, there are also symptomatic patients that show no pathological changes on imaging studies.\(^9\)

Many of these disorders are age-related and may be asymptomatic or show a symptomatic period of variable duration that may sometimes become chronic. One of the great challenges of imaging techniques is to reliably differentiate between symptomatic and asymptomatic conditions. Modic changes, particularly type I, seem to be strongly associated with back pain, whereas weaker association is found with disc disorders.\(^9\) As for facet joint osteoarthritis, some authors consider it rare in asymptomatic patients,\(^11\) but others fail to find a statistically significant association between this condition and back pain.\(^12\)

Causes of back pain

The causes of back pain can be classified into mechanical and non-mechanical. Mechanical pain is secondary to anomalous stress and tension on the spine and may be triggered or worsened by certain movements or physical activities.\(^13\) It accounts for 97% of the causes of vertebral pain, including sprain, degenerative disc and facet joint disease, spinal stenosis, spondylolisthesis and osteoporotic fractures. Non-mechanical causes account for 1%, including inflammatory, infectious and tumor diseases.\(^14\) Pain secondary to trauma fractures, surgery and referred pain secondary to visceral lesions are excluded from this study.

Sprain or soft tissue strain (fig. 1)

Muscle strain and ligament sprain are the most common causes of acute lumbar and cervical pain in the general population.\(^14,15\)

Muscle pain may appear without previous trauma or may be secondary to trauma strain or direct muscle contusion. In muscles and ligaments, the severity of the lesions ranges from overstretching to partial or complete rupture.

Spine imaging is indicated only in cases of sprain secondary to injury severe enough to make us suspect a spinal fracture, in instability secondary to ligament rupture, or damage to nervous structures.

MRI demonstrates edema of the paravertebral muscles that may resolve or progress to atrophy of the involved muscles.\(^15\) In more severe cases, MRI shows ligament and capsular involvement or signs associated with instability, including interspinous widening, vertebral subluxation, vertebral compression fracture and loss of cervical lordosis.\(^17\)
Facet joint disease (fig. 2)

CT provides detailed imaging of the structural lesions secondary to facet joint degeneration: osteophytes, subchondral sclerosis and geodes, facet joint impingement, capsular and ligamentous calcifications. MRI underestimates bone changes but is very sensitive to the presence of joint effusion, synovial cysts or bone edema. Increased intra-articular fluid and facet edema are associated with instability of the involved segment and with the presence of symptoms.

Synovial cysts extending into the paravertebral muscles or into the spinal canal may result in nerve compression. MRI reveals the fluid content (synovial or hemorrhagic) of the cyst, while TC is better for air content or calcifications.

Degenerative disc disease

Degenerative disc disease has two basic patterns: spondylosis deformans and intervertebral osteochondrosis. The former involves essentially the annulus fibrosus and epiphyseal rings while the disc height remains normal, and it is considered a consequence of the natural aging of the disc. Intervertebral osteochondrosis involves the disc, endplates and subchondral bone.

MR is the most sensitive technique for the detection of early changes secondary to this condition. T2-weighted sequences show a progressive loss of the homogeneous hyperintensity of the nucleus pulposus progressing to a loss of differentiation between nucleus pulposus and annulus fibrosus. The disc loses height and extends beyond the endplate margins contributing to marginal osteophyte formation.
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Figure 2  Facet joint disease. A) CT scan shows arthrosis with void phenomenon and subchondral erosions. B) Axial T2. Paravertebral synovial cyst (*). C) and D) T1 and STIR sequences show a facet edema pattern (arrows).

Figure 3  Annular tears. Sagittal T2-weighted MRI shows a concentric (A), transverse (B) and radial tear with extrusion (C). D) Sagittal CT scan shows transverse tear in L3-L4 and radial tears in the two lower discs (arrows).
Three distinct types of annular tears have been described: concentric, transverse, and radial. Concentric tears result from the separation of the lamellae of the annulus. Transverse tears are horizontal fissures that occur in the periphery of the annulus close to the endplates. Both types of tears are common findings in autopsy studies of individuals older than 60 and are considered manifestations of spondylosis deformans or aging of the disc.26 (fig. 3).

Radial tears extend from the nucleus through the annulus and are not age-related. They are associated with loss of chondroid matrix, disc impingement, and instability, and are considered the critical factor in the genesis of intervertebral osteochondrosis.27

Annular tears have been described in 39% of people who suffer from lumbar pain, and most commonly involve L4-L5 and L5-S1 levels.28 CT is not very sensitive; however, it can depict these tears when occupied by air or fluid. On T2 MRI sequences, tears appear as linear areas of high signal. Some authors have found correlation between high-intensity signal and clinically active lesion,29 while others have found no correlation.10

Disc disease nomenclature is still a matter of debate. The project of nomenclature of the North American Spine Society is still not universally accepted. In the axial plane, the disc may be classified as normal, bulging, protruded, and extruded.24 Protrusion and extrusion are also described according to their position in the axial plane. In 90% of cases they are central or paramedial (subarticular in the new nomenclature), and foraminal and extraforaminal in 10% of the cases (fig. 4).

The term bulging disc refers to a deformity $\geq 180^\circ$ of the circumference of the entire disc. This bulging usually extends $< 3$ mm beyond the outer ridges of the endplates.24

Protruded disc refers to a deformity or displacement $< 180^\circ$ of the circumference of the disc where the nucleus pulposus is presumably contained by the annulus. The term focal protrusion refers to protrusions involving less than 25% of the circumference of the disc, otherwise the term diffuse or broad-based protrusion is used. In the sagittal plane, the distance between the edges of the protruded material must not be more than the distance between the edges of the disc of origin and, in the axial plane, the diameter of the protruded material must not be more than the diameter of the neck or the base.31

Extrusions are focal abnormalities in which the nuclear material extends beyond the entire annulus fibrosus. In the
Figure 5  Disc disease in the sagittal plane. T2 MRI. A) Protruded disc. The disc does not extend beyond the endplates. B) Extruded disc. The disc exceeds the height of the disc. C) Extruded disc that migrates cranially (arrow). D) Contrast-enhanced sagittal T1 MRI. Sequestrated disc in the central canal (arrow).

Figure 6  Modic changes. Sagittal T1 (A), T2 (B), STIR (C) and CT scan (D) show type III sclerotic changes (arrows) surrounded by type I edematous changes in a patient with listhesis. Sagittal T1 (E), T2 (F), STIR (G) and CT (H) sequences in a patient with fatty changes in type II. CT scan only shows the presence of sclerosis in both cases.
sagittal plane, the distance between the edges of the disc material is greater than the height of the parent disc, or the extruded fragment shows at least one dimension greater than the base. The nuclear material may migrate cranially and/or caudally or maintain no continuity with the nucleus of origin; this is known as sequestrated disc (fig. 5).

Focal protrusions and extrusions are traditionally referred as “disc herniations”. The new nomenclature considers disc herniation a generic term that includes both protrusions and extrusions.

Signal intensity changes in subchondral marrow of the vertebral endplates are associated with disc degeneration and were divided into three groups by Modic et al. 32 Type I changes demonstrate subchondral edema with decreased low signal on T1 and increased signal on T2 and STIR sequences. These changes correlate well with lumbar pain and instability. 33

Type II changes involve instability and lipid marrow replacement. They are represented by increased signal on T1 and T2 that is suppressed on STIR sequences. Type III changes correlate with bone sclerosis at radiography and CT, and show decreased signal on all MRI sequences. Studies on

### Table 1 Radiological signs that help differentiate between pathologic and insufficiency fractures.

<table>
<thead>
<tr>
<th>Sign</th>
<th>Pathologic fractures</th>
<th>Insufficiency fractures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior border</td>
<td>Convex</td>
<td>Vertebral margin retropulsion</td>
</tr>
<tr>
<td>Vertebral Cyst or fissure</td>
<td>No</td>
<td>Common</td>
</tr>
<tr>
<td>Intravertebral</td>
<td>Asymmetric</td>
<td>No/Fine symmetric</td>
</tr>
<tr>
<td>Paravertebral and/or epidural mass</td>
<td>Diffuse, patchy or nodular</td>
<td>Band-like</td>
</tr>
<tr>
<td>Edema pattern</td>
<td>Common</td>
<td>Common</td>
</tr>
<tr>
<td>Spared areas of marrow</td>
<td>Uncommon</td>
<td>Common</td>
</tr>
<tr>
<td>Cortical or trabecular fracture</td>
<td>Uncommon</td>
<td>Common</td>
</tr>
<tr>
<td>Cortical or trabecular destruction</td>
<td>Common</td>
<td>Uncommon</td>
</tr>
</tbody>
</table>

**Figure 7** A) Sagittal CT shows cervical Schmorl’s node (arrow). B) Sagittal CT scan shows lumbar Schmorl’s nodes (arrows). Posterior marginal herniation (arrowhead). C) Sagittal STIR MR imaging shows Schmorl’s node and mild edema (flecha). D) Sagittal T2 MRI sequence shows posterior marginal disc herniation (arrowhead) and endplate irregularities (arrows) in a patient with lumbar Scheuermann disease.
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the correlation between MRI-CT have demonstrated that endplate sclerosis exists in all types of Modic types, particularly in mixed changes. MRI is not sensitive to sclerosis detection (fig. 6).

Modic changes are considered different stages of the same pathological condition. Conversion from one type to another may occur, mixed types probably being intermediate stages of this conversion. Conversion from type I into type II is the most common. Modic changes occur in 20-50% of patients with low back pain and their incidence increases with age. However, these changes are present in 10-25% of asymptomatic patients, although with different distribution and morphology. In these patients, the changes are usually focal and located at the anterior superior endplates of the mid-lumbar spine, with preserved adjacent disc. In symptomatic patients, the lower back is most commonly affected and the changes appear in the endplates adjacent to a degenerated disc.

Schmorl’s nodes are defined as herniations of the nucleus pulposus into the endplates. They are more common in the thoracic than in the lumbar spine. On CT and MRI Schmorl’s nodes appear as bone defects of the endplates into which the disc herniates. When they occur between the endplate and the epiphyseal ring, they are known as postero marginal herniation or limbus vertebra (fig. 7).

Spinal stenosis (fig. 8)

Spinal canal stenosis most often results from degenerative changes in the spine. A congenitally narrow canal promotes early development of symptoms secondary to disc and facet degeneration. MRI provides similar information to that of a CT myelogram for the assessment of the causes of stenosis. However, the myelogram provides higher resolution images of the osseous component and its imprint on nervous structures. MRI provides direct visualization of nerves and spinal cord.

Figure 8 Sagittal T1 (A) and T2 (B) images show central canal stenosis and myelopathy (arrow). C) Axial T2 image shows central canal stenosis (arrow). D) Sagittal T2 image shows foraminal stenosis (arrow). E) Coronal CT. Uncarthrosis (arrow). F) Sagittal CT. Uncarthrosis with foraminal stenosis (arrows).
Increased intramedullary signal on T2 weighted and STIR sequences is often seen in patients with myelopathy suggesting edema, ischemia, myelomalacia or cystic degeneration.\(^4\)

Spinal stenosis may occur in the central and/or lateral canal. In the lumbar spine, a sagittal diameter < 12 mm is very suggestive of stenosis;\(^6\) however, the axial area of the thecal sac is considered more effective in the diagnosis of stenosis. In this respect, values < 76 mm\(^2\) are considered severe stenosis and 76-100 mm\(^2\) are considered moderate.\(^4\)

In the lateral canal, the stenosis may occur at the proximal entrance of the root or lateral recess, or at the exit or foramen. Nerve root involvement in the lateral recess ranges from contact of the disc with the nerve root to nerve root deviation and root compression between the disc and the posterior osseous structures.\(^4\) As for foraminal stenosis, obliteration in the vertical or transverse direction is considered mild stenosis and obliteration in both vertical and transverse axis with no deformity of the nerve root is considered moderate. Severe stenosis shows morphological changes secondary to compression.\(^4\)

The estimated minimum sagittal diameter of the cervical spinal canal between C3 and C7 is 12 mm. Lower values increase the risk of degenerative spinal stenosis.\(^4\) In the foramen, uncarthrosis is the main cause of stenosis. Uncinate joints are found from C2-C3 to C6-C7 and they hypertrophy as a result of the mechanical overload caused by disc impingement. Osteophytes may project into the foramen resulting in stenosis with radiculopathy.\(^4\)
Low-energy vertebral fractures (fig. 9)

Fractures secondary to tumor are called pathologic fractures and those secondary to osteoporosis, insufficiency fractures. Differentiation between the two types using imaging techniques is based on bone marrow signal and morphology of the fractured vertebra (table 1). On MRI, pathologic fractures usually show complete replacement of the bone marrow of the vertebral body. Incomplete replacement shows patchy or nodular appearance. Convex vertebral margins secondary to tumor expansion and the presence of an asymmetric paravertebral or epidural mass are characteristic of malignancy.

In osteoporotic fractures, medullary signal changes depend on the age of the fracture. Acute fractures usually show edema with bandlike pattern in the subchondral endplate. The linear image corresponding to the fracture may be often identified within the edema pattern. Fissures and cysts with air or fluid content may also appear. In chronic fractures, there is reversion to normal fat signal from the bone marrow. Retropulsion of a bone fragment toward the canal is very suggestive of benignancy.

MRI morphological signs are usually conspicuous on CT. Fracture lines within the trabecular and cortical bone are characteristic of osteoporotic fractures, while bone destruction is typical of pathologic fractures. Pedicle involvement, described in pathologic fractures, is also a common finding in insufficiency fractures.

Diffusion and perfusion techniques have been used in the differentiation between pathologic and insufficiency fractures, albeit with controversial results. In-phase/opposed-phase imaging, based on the assumption that malignant lesions completely replace fat, unlike benign lesions, is the most promising modality. Significant differences in the signal intensity ratio between both types of fractures have been reported.

PET-TC has shown an accuracy of 92% in differentiating benign and malignant fractures. This modality is considered an additional tool in equivocal cases, although biopsy, with or without vertebroplasty, may be necessary for final patient management.

Kyphosis and scoliosis (fig. 10)

Scheuermann’s disease or idiopathic kyphosis accounts for 90% of cases of juvenile kyphosis. Diagnostic criteria for this condition are kyphosis > 45° and at least one vertebra with wedging > 5°. Irregular endplates and Schmorl’s nodes are associated findings.

Scoliosis is defined as a lateral curvature of the spine > 10° as measured by the Cobb method on a standing radiograph. Scoliosis can be classified as congenital, neuromuscular, degenerative, or idiopathic, with the last being the most common and usually not painful.

CT is indicated for the assessment of surgical correction of congenital scoliosis. The most severe curves appear with unilateral bars; moderate curves with hemivertebra and congenital blocks and wedged vertebrae are present in mild patterns.

MRI is indicated in children younger than 10 that develop scoliosis (infantile and juvenile forms) because of its frequent association with neural axis abnormalities. In general, tomographic imaging techniques are not indicated for adolescent scoliosis (11 to 17 years), the most common type of idiopathic scoliosis, except when it is painful or unusual symptoms are present, such as headache or neurological involvement (ataxia or pes cavus). Causes of pain include spondylolysis, Scheuermann kyphosis, syringo/hydromyelia, herniated disc, tethered cord or bone or medullary tumors.
Local abnormalities of the vertebral alignment (fig. 11)

Spondylolisthesis refers to the anterior displacement of a vertebra in relation to the vertebra below. Causes of spondylolisthesis include: developmental (dysplasia), trauma (stress or acute fracture), degenerative (disc and facet joint) and pathologic (infection, tumor).

The most severe displacements occur in dysplastic spondylolisthesis. The most common are spondylolisthesis secondary to isthmic lysis and degenerative spondylolisthesis. Differentiating signs are summarized in table 2.

Multislice CT with multiplanar reconstructions is the optimum technique for diagnosis of spondylolisthesis. MRI imaging is the modality of choice to demonstrate nerve impingement, generally in the lateral recess or in the foramen.

Meyerding classified the degree of displacement into 4 grades based on the position of the posterior margin of the upper vertebra over the upper endplate of the inferior vertebra, which is divided into four equal parts posteroanteriorly.

Retrolisthesis is also a manifestation of segmental instability usually secondary to loss of disc material associated with intervertebral osteochondrosis and extruded nucleus pulposus.

Baastrup’s disease refers to the development of a neo-arthritis between the spinous processes generally secondary to degenerative disc disease with loss of height and alignment abnormalities. Erosions and sclerosis are better depicted on CT, while MRI is useful to assess for bone edema or interspinous bursitis.

Seronegative spondyloarthropathies (fig. 12)

Seronegative spondyloarthropathies comprise a group of multisystemic inflammatory diseases, with mainly lumbar and sacroiliac involvement, including ankylosing spondylitis and spondyloarthropathies secondary to inflammatory bowel disease, psoriasis and reactive arthritis (formerly named Reiter’s syndrome). Patients present with inflammatory back pain typically accompanied by morning stiffness that improves with activity. However, degenerative disc or facet disease may also present with stiffness. Imaging techniques are thus essential for differential diagnosis.

CT demonstrates structural bone changes (sclerosis, erosion and joint fusion) but it lacks sensitivity to depict inflammatory changes that may be, however, visible on MRI, even several years before structural changes develop. Therefore, MRI is the modality of choice in early phases and in inflammatory episodes, while MRI should be reserved for structural changes.

Enthesopathy refers to an inflammatory process at the site of insertion of ligaments, tendons or articular capsule into bone and it is a characteristic feature of spondyloarthropathies. This condition presents with edema and erosions (osteitis) in the vertebral margins and in the anterior longitudinal ligament insertion and it progresses to vertebral body squaring. Later on, during the post-reactive phase, the edema pattern is replaced by fatty or sclerotic areas with syndesmophyte formation (paravertebral vertical ossifications leading to bone bridging). Late changes result in a so-called “bamboo spine”. Diffuse idiopathic skeletal hyperostosis also shows paravertebral ossifications but with more prominent and coarser bone bridging than ankylosing spondylitis and with no sacroiliac involvement.

Sacroiliitis is also a typical finding of this group of diseases. The initial sign is edema that may progress to structural changes: erosions, subchondral sclerosis and bone bridging with joint fusion. STIR and contrast-enhanced T1 MRI sequences, preferably with fat suppression, are the most sensitive modalities for the detection of these inflammatory changes. Generally, STIR sequences alone are sufficient for detecting edema, but the enthesis, synovitis and capsulitis are better characterized on contrast-enhanced T1 sequences, which are not routinely recommended except to ensure maximum diagnostic confidence in early stages.

Vertebral tumors

The most common causes of tumor involvement of the spine are metastatic disease and multiple myeloma. Lymphoma and leukemia are much less common.

Although primary vertebral tumors are rare, accounting for 3-9% of all primary bone tumors, we review the osteoid osteoma, osteoblastoma, giant cell tumor, aneurysmal bone cyst, osteochondroma and hemangioma.

Osteoid osteoma and osteoblastoma are generally painful conditions that produce an osteoid matrix and may result in scoliosis and abnormal gait. CT typically shows an osteolytic lesion (nidus), which may be calcified, surrounded by sclerosis and usually located in the posterior elements of the spine, and on the concave side if associated with scoliosis. Size is essential to differentiate between the two conditions, osteoid osteoma is < 2 cm and osteoblastoma > 2 cm in size. MRI shows bone and soft tissue edema that may lead to overestimation of the size of the lesion and suspicion of an aggressive or malignant lesion (fig. 13).

Hemangiomas are tumors that occur frequently in the spine. The most common lesions, which show predominantly fatty content, are usually asymptomatic and discovered incidentally on MRI. Therefore, they appear as areas of high intensity signal on T1 and T2 that is suppressed on STIR sequences. Hemangiomas with greater vascular content, which extends to posterior elements or to soft tissues, are more likely to be symptomatic. They show hypo- or isointense signal on T1 and hyperintense on T2 and STIR. Occasionally, symptomatic hemangiomas may increase in size and compress paravertebral and epidural soft tissues causing neural compression, simulating malignant or metastatic lesions.

CT scanning shows sclerotic reinforcement of the remaining trabeculae mixed with fatty and vascular areas. These trabeculae give a polka-dot appearance in axial imaging or a latticelike pattern in sagittal imaging (fig. 14).

Chordoma, chondrosarcoma, Ewing’s sarcoma and osteosarcoma are among malignant spinal tumors. CT is the modality of choice for identification and characterization of the mineralization of the tumor matrix. MRI is useful for the evaluation of the extent of the lesion, particularly with soft-tissue component and involvement of the canal and neural structures (fig. 15).
Figure 11  Isthmic lysis with spondylolisthesis. Axial T2-weighted MRI (A), sagittal central (B) and sagittal lateral CT (C) scans show the lytic process (arrows), widening of the central canal and loss of foraminal height. The spinous process step-off is formed with the upper spinous process. D), E) and F) Degenerative listhesis. Axial T2 MRI (D), sagittal central (E) and sagittal lateral (F) CT scans show slip of the articular processes (arrows), central canal stenosis and mild foraminal involvement. The spinous process step-off is formed with the lower spinous process. G) Retrolisthesis (arrow) on sagittal lumbar CT. H) and I) Bastrup’s disease (arrow). Spinous neo-arthrosis on sagittal CT (H) and on sagittal STIR (I).

Table 2  Radiological signs helpful in the differentiation between degenerative spondylolisthesis and isthmic spondylolisthesis.

<table>
<thead>
<tr>
<th></th>
<th>Degenerative spondylolisthesis</th>
<th>Lytic spondylolisthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isthmic lysis</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Displacement of spinous process</td>
<td>Anterior, with the vertebral body</td>
<td>No, or posterior displacement</td>
</tr>
<tr>
<td>Spinous process step-off</td>
<td>With the spinous process of the lower vertebra</td>
<td>With the spinous process of the upper vertebra</td>
</tr>
<tr>
<td>Sagittal diameter of the central canal Foramen</td>
<td>Decreased</td>
<td>Increased</td>
</tr>
<tr>
<td></td>
<td>Variable stenosis secondary to osteoarthritic changes</td>
<td>Stenosis secondary to loss of height and pseudo disc bulging</td>
</tr>
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</table>
Vertebral infection

MRI is the most sensitive and specific technique for the diagnosis of spondylodiscitis demonstrating decreased signal intensity in the disc and endplates on T1-weighted images. After contrast administration, the inflammatory areas enhance while abscess areas remain hypointense (ring enhancement). On STIR and T2 sequences, the involved areas appear hyperintense. The degree of destruction of the endplates depends on the progression of the disease and extension into the soft tissues is variable (Fig. 16).

Findings of pyogenic spondylodiscitis may be indistinguishable from those of tuberculous spondylodiscitis. However, the latter has a longer clinical course, with less initial involvement of the disc space in relation to the vertebral body, resulting in more vertebral deformity and larger paravertebral masses with neurologic deficit. Isolated involvement of the vertebral body or posterior elements may be difficult to distinguish from a tumor.

The differential diagnosis includes intervertebral osteochondrosis in type I Modic changes, fractures in block vertebrae present in seronegative spondyloarthropathies, neuropathic spondyloarthropathy and chronic hemodialysis. Laboratory tests including white blood cell count, ESR and C-reactive protein allow for confirmation of the infection. However, guided biopsy may be needed to isolate the etiologic pathogen, particularly when blood cultures yield negative results.

Figure 12  Ankylosing spondylitis. A) Sagittal STIR sequence shows edema of the vertebral margins and costovertebral joint (arrows). B) Coronal STIR image shows areas of edema in the sacroiliac joint (arrows). C) CT scan demonstrates subchondral erosions and sclerosis. D) Late stage with sacroiliac fusion. Diffuse idiopathic skeletal hyperostosis. Sagittal CT (E) shows the coarse prevertebral ossifications (arrows) and sagittal STIR MRI (F) demonstrate edema in the anterior aspect of the vertebral bodies (arrows).
**Figure 13** Osteoid osteoma. A) STIR MRI shows hyperintense edema (arrow). B) Sagittal CT scan shows a small lytic lesion (arrow). C) Coronal CT. Osteochondroma. D) Sagittal T2 MRI. Giant cell tumor in the spinous process.

**Figure 14** A) and B) Atypical vertebral hemangioma, with hyperintensity on T1 and STIR. B) and C) Typical vertebral hemangioma, with hyperintensity on T1 and hypointensity on STIR. E) and F) Hemangioma on CT.
Figure 15  A) Coronal CT. Chordoma with paravertebral extension (arrow). B) Axial CT. Ewing’s sarcoma of the right sacral wing (arrow). C) Axial contrast-enhanced T1 MRI. Mass in the vertebral body and vertebral arch secondary to myeloma. D) Sagittal T1 MRI. Hypointense lesions secondary to lymphoma (arrows).

Figure 16  Spondylodiscitis. Unenhanced sagittal (A) and contrast-enhanced (B) T1 images, STIR (C) show pyogenic infection with edema pattern and epidural abscess (arrow). D) CT scan shows destruction of endplates in a different patient with discitis. E) and F) Sagittal T1 MRI (E) and sagittal CT (F) show endplate destruction in erosive intervertebral osteochondrosis secondary to degenerative listhesis. Presence of intradiscal air helped in the diagnosis.
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Conclusion

In this paper, we reviewed the main CT and MRI manifestations of the most common causes of spinal pain. An adequate clinical approach, an expert understanding of the pathological manifestations demonstrated by these imaging techniques and a comprehensive report based on a universally accepted nomenclature represent the indispensable tools to improve the diagnostic approach and the decision making process in patients with spinal pain.

The superior soft tissue characterization of MRI may be complemented with the high-resolution of CT for evaluating bone, although it exposes the patient to ionizing radiation.

Authorship

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Conflict of interest

The authors declare no conflict of interest.

References


