UPDATE

Plain-film radiography in the study of spinal pain

F. Ruiz Santiago*, L. Guzmán Álvarez, M. Tello Moreno and P.J. Navarrete González

Radiology Department, Traumatology Hospital, Ciudad Sanitaria Virgen de las Nieves, Granada, Spain

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Abstract
The introduction of tomographic imaging techniques, fundamentally computed tomography and magnetic resonance imaging, has led to a gradual decrease in the indications for plain-film radiography, resulting in fewer patients studied and fewer projections for each patient. Consequently, plain-film studies of the spine have received less attention and radiologists are less familiar with the typical findings in normal and pathologic conditions of the spine. Nevertheless, plain-film radiography continues to be widely used in both primary and specialized care. Thus, radiologists still need to be aware of the normal radiologic anatomy of the spine and of the radiologic manifestations of the diverse pathological processes that can affect the spine and that can cause pain.

The aim of this article is to review the manifestations on plain-film radiography of a wide variety of diseases that can cause back pain, including congenital, traumatic, degenerative, tumor-related, inflammatory, and infectious diseases and processes.

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La radiografía simple en el estudio del dolor de la columna vertebral

Resumen
La introducción de las técnicas de imagen tomográficas, fundamentalmente la tomografía computarizada (TC) y resonancia magnética (RM), ha conllevado una paulatina disminución en las indicaciones de la radiología simple, tanto en el número de pacientes como en la cantidad de proyecciones por paciente. Esto ha podido conllevar una menor atención al estudio y conocimiento de la radiografía simple de la columna vertebral en condiciones normales y patológicas.

*Corresponding author.
E-mail: ferusan12@gmail.com, ferusan@ono.com, ferruizsan@terra.es (F. Ruiz Santiago).

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Plain-film radiography remains one of the most used techniques in the study of spinal pain, although the introduction of new technologies, such as computerized tomography (CT) and magnetic resonance imaging (MRI), have modified its indications in daily practice.

It is well known that plain-film radiography, in the absence of trauma, has limited value, since degenerative changes are very common and the most relevant pathology, tumoral or infectious, can go unnoticed. 1

Regarding uncomplicated spinal pain of a mechanical and/or degenerative etiology, conventional spinal radiography, CT, and MRI, have a limited impact on clinic management and decision making. 2 As a result, the indications for different imaging modalities, including plain-film radiography, are still under review.

When red flags, clinical or epidemiological indications for imaging studies

in the presence of painful symptoms of potential spinal origin, 3 are present, conventional radiology is often the initial study technique. This is recommended in traumatic spinal injuries, in osteoporotic patients and patients older than 70 years of age. 4

In the presence of other concerning clinical signs, such as neurological deficits, suspicion of a tumor, inflammatory disease or infection, there is a growing tendency of physicians to demand MRI as the initial screening technique, due to its greater sensitivity and specificity in the diagnosis of these diseases. 5

This aim of this study is to review the role of plain-film radiography in the study of spinal pain, as well as the most frequent radiologic findings of diseases responsible for such pain.

Technical considerations

A plain-film radiologic study of any anatomical area of the spine should include at least two orthogonal views, generally anteroposterior and lateral. The use of other projections has decreased with the introduction of radiologic techniques such as MRI and CT.

Due to its simplicity, plain-films are still the primary modality by which vertebral instability is evaluated, though methods utilizing CT and MRI have also been described. 6

A precaution to consider when employing plain-film radiography is the radiation dose to the patient. When plain-films are taken of the spine, the effective doses of radiation to the lumbar, thoracic and cervical spine are 1.5 mSv, 1 mSv and 0.2 mSv, respectively, 7 equivalent to the dosage received by natural radiation during 8, 6, and 1 months, respectively.

Although digital radiology has the capacity to reduce radiation exposure, the effective doses are slightly higher for indirect digital radiology (10-15%) and lower for direct (30-40%). 7

Radiation doses in pediatric patients deserve special attention due to their increased radiosensitivity, which, along with their greater life expectancy, raises the risk of radiation-induced cancer to 3-5x that of adults. 8

Teleradiography of the spine is one of the most frequently requested radiologic studies in the pediatric population, with effective doses of radiation that oscillate between 0.05 and 0.14 mSv. 9 Direct digital radiology can play a decisive role in the reduction of these doses. 10

Clinical and radiologic considerations

Pathology of the lumbar spine, especially in cases of mechanical impairment and/or degeneration, does not correspond to the classic disease model, where an organ free of pathology is considered healthy and asymptomatic whereas an organ with apparent pathology is considered responsible for symptoms. 11 There is a percentage of symptomatic patients in which imaging tests do not show structural damage, while asymptomatic patients can demonstrate a broad spectrum of vertebral and disk changes. 12,13 For this reason, radiologic findings should always be evaluated within a clinical context.

Causes of spinal pain

Congenital pathology

Congenital alterations of the spine can be simple, without associated deformity, or complex, with associated spinal deformity. These deformities include kyphosis, lordosis and scoliosis, which, in extreme cases, can cause respiratory failure, cor pulmonale, or paraplegia (fig. 1).

Congenital alterations are classified according to their origin 14 as follows:
1. Defects in vertebral formation. The vertebra, or part of it, does not develop properly, resulting in alterations such as agenesis, wedged vertebra, hemivertebra and butterfly vertebra (fig. 1).

2. Segmentation defects. Embryonic vertebrae are not separated, resulting in congenital vertebral blocks (fig. 1).

3. Mixed vertebral formation and segmentation defects.

Among the simple congenital abnormalities, transitional vertebra is a variant of spinal development that is present in 20% of the population. In this condition, the L5 vertebra may be incorporated into the sacrum (sacralization) or, less frequently, the S1 vertebra may be incorporated into the lumbar spine (lumbarization), although the number of vertebrae in the spine always remains constant. When a transitional vertebra is fused with the adjacent vertebra, it is usually asymptomatic due to anatomic fixation. It has been reported, however, that this fixation can promote the development of pathology in the cephalad vertebral segment with greater compensatory mobility. Transitional vertebra conserves its mobility when its transverse apophysis is not fixed, but rather articulated with the caudal vertebra. The result being that the transitional vertebra may be symptomatic at the neo-articulation point and the disc may degenerate (fig. 1).\(^{15}\)

Transitional abnormalities can also affect the cervicothoracic spine. The most frequent manifestation is the presence of a cervical rib, usually at the C7 level, although it has also been described in C5 and C6. It is often associated with the sacralization of L5 and may cause symptoms by narrowing the space of the neurovascular bundle at the level of the scalene muscles\(^ {16}\) (fig. 2).

Another less frequent transition anomaly is the elongation of the anterior tubercle of the cervical transverse processes. This generally affects C5-C6 and may be associated with vertebral blocks, causing mechanical type symptoms\(^ {17}\) (fig. 2).

**Traumatic pathology**

Plain-film radiography continues to be the primary technique used to diagnose vertebral fractures. Its diagnostic capacity is better in traumatic fractures than in osteoporotic or pathologic fractures.

A cervical spine study usually includes a lateral, anteroposterior, and odontoid projection. Visualization of the 7 cervical vertebrae in the lateral projection is...
considered very important and when it cannot be depicted, CT should be utilized.

When examining a lateral plain-film of the cervical spine, there are 5 lines that should be observed in order to rule out spinal fracture. From front to back, these correspond to the prevertebral soft tissues, the anterior vertebral, the posterior vertebral, the interspinous and the spinolaminar lines. Of these, disruption of a posterior vertebral may have the greatest clinical implications due to its proximity to the spinal cord (fig. 3).

When a fracture is detected radiographically, many authors suggest the addition of a CT to the study, as it allows for better definition of anatomy. When considering the cervical spine, previous studies have shown that plain-film radiography miss up to 40% of fractures. For this reason, some authors have recommended CT as the initial radiographic modality for diagnosis.

When examining the thoracic or lumbar spine, although plain-film radiology may reveal imaging signs suggesting wedge fracture, CT has been shown to reveal that in up to 25% of cases it is really a burst fracture, with varying degrees of retropulsion of the posterior wall.

When the clinical presentation suggests a fracture and conventional radiography is not diagnostic, a multi-slice CT can be performed. A prospective study found a CT sensitivity of 99% in detecting fractures compared to 87% in plain-film radiography.

Figure 2  A) Right cervical rib (arrow). B) Elongation of anterior C6 and C7 tubercle joined with each other (arrow).

Figure 3  A) Normal lateral radiograph of the cervical column, with the 5 lines that can be drawn on it. B) Teardrop fracture of C3 produced by a flexion mechanism. The teardrop fragment is appreciated in front (arrow). Back we appreciate disruption in the posterior and spinolaminar vertebral lines in a quadriplegic patient.
The presence of neurologic damage, especially at dorsal spine, is an indication for MRI, due to its greater sensitivity for detecting soft-tissue damage in the spinal cord, ligaments, and muscles.\(^{22}\)

The classification of vertebral fractures is complex and it is not an objective of this study. It is important to determine if the fracture is stable or unstable. Insults to posterior elements of the vertebra are an important factor in the genesis of instability.

When a vertebra is wedged anteriorly, it is usually due to a compression and flexion mechanism (fig. 4). When the vertebra loses height in a uniform manner, this is usually caused by axial compression and often results in a burst fracture with involvement in both the anterior and posterior walls of the vertebra.

MRI is more sensitive and specific in differentiating osteoporotic from pathological fractures; however, conventional radiography can guide diagnosis. Osteoporotic vertebral fractures usually present in 2 ways, wedge and concave (fish vertebra or diabolo-shaped vertebra), while pathological fractures often demonstrate predominately osteolytic changes. The presence of air collections within a vertebral body is considered a sign of vertebral necrosis (Kummel’s disease) and suggests a benign osteoporotic fracture\(^{23}\) (fig. 4).

Morphologic changes that allow for the diagnosis of an osteoporotic fracture may require time for their development. Therefore, the absence of a fracture on plain-film radiography in an osteoporotic patient does not rule it out, and when symptoms persist, a MRI should be performed.\(^{24}\) MRI can detect fractures without vertebral deformities and can better discriminate between benign and malignant fractures.\(^{25}\) Additionally, MRI provides valuable information on factors such as the degree of edema, vertebral deformities, and impact on the spinal canal, all of which are useful data for planning medical, percutaneous or surgical treatment.

**Degenerative pathology**

The influence of radiologic studies in the treatment and prognosis of mechanical vertebral pain has not been demonstrated.\(^{26,27}\) The most frequent findings are degenerative discs and facets, present in both symptomatic patients and asymptomatic controls.\(^{28}\) Even though these degenerative changes increase with age, pain does not increase proportionally. The greatest incidence of back pain is during the middle years of life.\(^{29}\)

Degenerative pathology of the lumbar spine can affect the following locations:

1. Synovial joints: atlanto-axial, apophyseal, costo/vertebral and sacroiliac.
2. The intervertebral disc as a whole, resulting in invertebral osteochondrosis or scarred disk.
3. The annulus fibrosus and vertebral margins, resulting in a condition known as spondylosis deformans.
4. The ligaments and their insertions at the bone, resulting in diffuse idiopathic skeletal hyperostosis.

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**Figure 4**  
A) Osteoporotic wedge fracture (arrow).  
B) Osteoporotic diabolo shaped fracture (arrows).  
C) Osteoporotic fracture with intravertebral vacuum (arrow).  
D) Pathologic fracture, secondary to metastases, with lytic and blastic areas.
These conditions are often concurrent in a given patient. The typical findings of osteoarthritis in synovial joints are similar to those of other peripheral joints. They consist of osteophytes, sclerosis, subchondral geodes, and narrowing of the joint space (fig. 5).

Disc degeneration has been classified into the following 2 categories. 30,31

1. Spondylosis deformans, or aging disc, is usually observed in people older than 40 years of age. Radiologic signs often include symmetrical anterolateral osteophytes, preservation or mild reduction of disc height, peripheral vacuum phenomenon, sclerosis, and/or amputation of the epiphyseal ring. Disc protrusion is generally mild and uniform, and is a generalized process that affects the majority of the discs (fig. 5).

2. Intervertebral osteochondrosis, or scarred disc, can be observed at any age. Radiologic signs include osteophytes in any direction, significant asymmetric or irregular narrowing of intervertebral space, central vacuum phenomenon, and sclerosis of the vertebral platform and subchondral bone (fig. 5).

The spinal vacuum phenomenon is produced when air enter inside discal tears. When these tears are filled with liquid, they are not visible on conventional radiography.

The differential diagnosis for degenerative disk disease includes diffuse idiopathic skeletal hyperostosis (Forestier’s disease), which presents with osteophytes and osseous bridges without sclerosis or narrowing of the joint space. The clinical course is generally milder and is rarely as disabling as intervertebral osteochondrosis (fig. 5).

Canal stenosis

Stenosis has classically been categorized as congenital or acquired. However, even in the most severe forms of congenital stenosis, symptoms are not always present. However, if components of acquired stenosis exist, symptoms are likely.

Acquired stenosis is usually a complication of degenerative disease of the spine. Hypertrophy of the structures that surround the canal and shifting of the disk contribute to the appearance of stenosis. This stenosis can affect the central and lateral canal. In the latter case, it can affect the entrance of the canal or lateral recess, or, more frequently, its exit, or foramen. 12

Plain-film radiography shows osseous causes of canal stenosis (fig. 6), whereas tomographic techniques, CT and MRI, are better demonstrating osseous and soft structures, respectively, responsible for stenosis and, therefore, its direct effect on nervous structures.

Alignment alterations secondary to degenerative disease can also contribute to the development of canal stenosis. Retrolisthesis, the posterior shifting of a cephalad over caudal vertebra, is generally secondary to the loss of disk material caused by intervertebral osteochondrosis or a acute herniation of the nucleus pulposus31 (fig. 6).

Degenerative spondylolisthesis is the anterior shifting of the upper vertebra over the lower, secondary to facet and
disk arthrosis. It is generally associated with central canal stenosis (fig. 6) and on lateral radiographs, the spinous process is also anteriorly displaced, indicating that the vertebral arch is intact.

Spondylolisthesis can more frequently be secondary to lysis of the isthmus or pars interarticularis. In this case the spinous process does not shift with the vertebral body and, contrary to degenerative spondylolisthesis, the central canal widens, while foramina are usually narrowed33 (fig. 6).

Occasionally, when there is a vertebral displacement, pain can be secondary to instability. Flexion and extension images can confirm this if they show a variable relationship between adjacent vertebrae. Diagnostic criteria are not universally accepted; however instability is often diagnosed in cases where, more than 3 mm of vertebral displacement is found in the sagittal plane, or when vertebral rotation greater than 10° is measured between the 2 vertebral platforms of the affected disc4 (fig. 7).

Alterations of spinal curvature

The normal curvatures of the spine are lordosis (anterior curvature) at the cervical and lumbar levels, and kyphosis (posterior curvature) at the dorsal level. Diagnoses such as cervical or lumbosacral hyperlordosis should be made with precaution and are only attributable to the cause of the symptoms when other diseases have been excluded.

Pathological kyphosis is defined as a posterior curvature of the spine greater than 45°. Scheuermann's disease and idiopathic kyphosis constitute approximately ninety percent of juvenile kyphosis (fig. 8).

The currently accepted criteria for the diagnosis of Scheuermann's disease are the existence of a kyphosis greater than 45° and at least one vertebra with a wedging of greater than 5°. Irregularity of the vertebral platforms and the presence of nucleus pulposus or Schmorl hernias are associated findings.34

The degree of kyphosis is established using the Cobb method. It measures the angle formed by a line parallel to the upper platform of the more superior vertebra involved in the kyphosis and another line parallel to the lower platform of the more inferior vertebra of the kyphosis. Vertebral wedging is determined from the angle formed by lines parallel to the 2 vertebral platforms where the normal value should be 0.35

Scoliosis is defined as the curvature of the spinal in the coronal plane, with true scoliosis being a curvature equal to or greater than 10°. At an angle below 10°, it is considered spinal asymmetry or vertebral rotation.36

Idiopathic scoliosis is the most common type of scoliosis and is not always painful. It is divided in 3 types according to age of onset: infantile (before 4 years of age), juvenile (between 4-9 years of age), and adolescent (age > 10). The latter accounts for 85% of idiopathic scoliosis (fig. 9).
Scoliosis of congenital origin, secondary to vertebral malformations, accounts for 10% of all cases. Scoliosis can also be secondary to neuromuscular, infectious, tumor diseases, etc (fig. 9).

The diagnosis and management of scoliosis are generally done with plain-film radiography and usually include anteroposterior and lateral standing films of the entire spine. The anteroposterior view should include the iliac crests, which serve to assess skeletal maturation through the Risser method. Projections with lateral inclination (bending) are usually performed to assess which portions, if any, are correctable (soft).

The degree of scoliosis is measured using the Lippman-Cobb angle, between the upper and lower vertebrae limiting the scoliotic curve. These vertebrae are the most tilted in a frontal view.

When the existence of vertebral malformations is suspected, CT provides greater anatomic information.

Similarly, MRI is more useful for the evaluation of the spinal cord and soft tissues.

**Seronegative spondyloarthropathies**

Seronegative spondyloarthropathies pertain to a group of multisystem inflammatory diseases that includes diagnoses such as ankylosing spondylitis, lumbar and sacroiliac involvement secondary to inflammatory bowel disease, psoriatic arthritis, and Reiter's disease. 37

In plain-film radiograms of ankylosing spondylitis, one of the earliest findings is the squaring of the vertebral bodies. This is best seen on lateral projections and is secondary to enthesitis, inflammatory and erosive changes of the vertebral margins at ligamentous insertions. If the condition progresses, the spine forms syndesmophytes which are vertically oriented thin calcifications that form.
osseous bridges between the vertebral bodies. They also tend to affect facet joints, evolving during the final stages of disease into “bamboo spine”, in which disc and facet fusion occur (fig. 10).

Involvement of the sacroiliac joints is often bilateral and symmetric with erosions, and subchondral sclerosis that may progress to complete fusion. Radiologic findings of spondyloarthropathy secondary to inflammatory bowel diseases can be indistinguishable from those of ankylosing spondylitis. However, in spondyloarthropathy secondary to psoriasis or Reiter’s disease, the involvement of the sacroiliac joints, which may included syndesmophytes, may be asymmetric (fig. 11). On radiographs, these often appear prominent and coarse.

In sacroilitis, simple radiography has a specificity of 98%, but a sensitivity of 54% when seronegative spondyloarthropathies are present. As a result, CT or MRI are indicated in cases where positive clinical signs are present, but radiography is negative.

**Vertebral tumors**

The most frequent causes of tumor involvement in the spine are metastatic disease and multiple myeloma. Primary

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**Figure 9** A) Idiopathic scoliosis. B) Congenital scoliosis secondary to hemivertebrae (arrows).

**Figure 10** Ankylosing spondylitis. A) Vertically oriented syndesmophytes bridging vertebral bodies. B) Bamboo spine in the final phase of ankylosing spondylitis.
Plain-film radiography in the study of spinal pain

Vertebral tumors are relatively uncommon, accounting for 3-9% of all primary osseous tumors.\hspace{1em}^{40}

Plain-film radiography is often the first technique utilized for back pain, often before a cancerous lesion is suspected. Tumor lesions can manifest, on simple radiography, as lesions that destroy bone (osteolytic), as bone-forming lesions (sclerotic or osteoblastic), or as a mixed pattern. Once detected, a CT or MRI should be performed.

Plain-film radiography is somewhat insensitive regarding the visualization of the bone destruction or marrow replacement, requiring, depending on the size of the lesion, between 30-50% loss of bone density before the lesions become visible.\hspace{1em}^{41,42} Destruction of the pedicle typically indicates that the lesion is advanced, since it rarely occurs in a primary or isolated form.\hspace{1em}^{43}

The differential diagnosis for osteolytic lesions in the spine includes benign lesions such as osteoid osteoma, osteoblastoma, hemangioma, and aneurismal bone cysts. Among malignant lesions, chordoma and metastases are the most common. Lung, thyroid and kidney metastases are fundamentally osteolytic lesions (fig. 12).

Hemangiomas are among the most frequent benign tumor lesions seen in the spine. It is often made up of vessels and fat. On plain-film radiography, they are observed when sufficient destruction of the spongy bone marrow occurs. The remaining trabeculae thicken, revealing a classic “corduroy cloth” pattern within the osteolytic area.\hspace{1em}^{44}

Sclerotic lesions can be either benign or malignant. Benign etiologies include bone island (enostosis), sclerosis secondary to osteoid osteoma, or healed benign lesions such as cysts or fibromas.

Among malignant lesions, malignant osteosarcoma often presents with calcification of the tumor matrix, and metastases, most commonly from the breast and prostate, presents in a sclerotic pattern (fig. 13).
Bone island, or enostoma, is often considered a variant of normality. It appears when compact bone develops within bone marrow and, although not malignant, is difficult to differentiate from more malignant osteoblastic lesions. The detection of blastic lesions may also be delayed with simple radiography. One study reported that in the case of breast cancer, radiography detection of blastic lesion may be delayed by 3-6 months.

Vertebral infection

Spondylodiscitis accounts for 2-4% of osteomyelitis. MRI is the most sensitive and specific imaging technique, leading to a much earlier diagnosis than conventional radiography. Findings on plain-film radiography include destruction of 2 adjacent vertebral platforms with narrowing or disappearance of the disc space, which, in turn, can cause an acquired vertebral block.

In pyogenic infections, evolution is much faster than in tuberculosis or brucellosis, which usually follow a more chronic form. Subligamentous spread of tuberculosis occurs through erosion of the anterior wall of the vertebral bodies. Brucellosis can affect the anterior vertebral margins with changes similar to those of degenerative disc disease (fig. 14). In these cases, analytic studies can be of great assistance in confirming the diagnosis.

Conclusion

Despite the introduction of CT and MRI, plain-film radiography continues to play an important role in the study of back pain. However, interpretation of the radiologic findings should be conducted with caution as they only reveal anatomic alterations, many of which may not be related to the clinical symptoms of the patient.

On the other hand, when neurologic symptoms are present, or if tumor or infectious etiologies are suspected, complementary studies with CT or MRI are warranted.

Conflict of interest

The authors declare no conflict of interest.
References


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