Chapter

# Imaging in Low Back Pain

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## Abstract

Medical imaging plays an important role in the evaluation of low back pain (LBP). The choice of certain radiological method over other depends on many factors like patient's presentation, presence of contraindication, availability, relative cost of the test, and the expected impact of the results on management. Radiological evaluation helps the physician reach the most likely cause of LBP, confirm the provisional diagnosis, provide alternative one, or narrow the differential diagnosis. Plain X-ray radiograph is useful in initial general assessment. Magnetic resonance imaging (MRI) is the imaging modality of choice in the evaluation of LBP because of elegant demonstration of anatomical details and many pathologies. Computerized tomography (CT) can provide high-resolution images of the bony structures and is particularly invaluable in trauma. Other imaging modalities are rarely used usually as problem-solving or in selected conditions. For example, sonography may have a role in the evaluation of soft tissue lesions and the sacroiliac joints. Angiography is useful for vascular evaluation. Isotope imaging may be used in the elucidation of of hidden cause of pain (tumors or fracture). Conventional myelography and discography are virtually obsolete in current clinical practice because of the presence of much safer and accurate new modalities. Finally, interventional radiology has an increasing role in treating certain conditions.

**Keywords:** imaging, radiology, X-ray, MRI, CT scan, sonography, angiography

## 1. Introduction

The main role of imaging in patients with low back pain (LBP) is to help physicians reach the most likely cause of the pain. The use of one or more of the different radiological investigations in a suitable manner will enhance the detection of the underlying cause of the LBP in a timely way. Moreover, radiology has a role not only in the diagnosis but also in the treatment of some conditions that lead to LBP. The rapidly advancing interventional radiology is increasingly utilized as an adjuvant or sole therapeutic option of a variety of conditions like vascular malformations and tumors.

There are many imaging modalities that can be used in the evaluation of LBP. Selection of the appropriate modality depends on different factors, like the patient's conditions, clinical state, availability, and cost of the test and the presence of certain contraindications.

We will discuss each imaging modality from different points of view starting with the most to the least commonly and widely used ones.

## 2. Imaging modalities used in evaluation of LBP

### 2.1 Plain X-ray radiograph

Plain X-ray radiograph is a simple radiological examination that can be used to give initial general picture. Generally it has a limited role in the evaluation of acute LBP [1]. Fluoroscopy (dynamic X-ray) has an important role in guiding interventional procedures and both diagnosis and pain management [2].

#### *2.1.1 Advantages*

1. Low cost (much cheaper than CT and MRI)

2. Availability (it is usually readily available in almost all hospitals and, most of time, in centers, including emergency and far health centers)

3. Noninvasiveness (it involves no risky intervention)

4. Acceptable resolution of bony structures of the spine and pelvis

5. No significant contraindication (apart from pregnancy)

#### *2.1.2 Limitations*

1. Poor visualization of soft tissue structures.

2. Cannot show the details of the spinal canal.

3. Cannot show the intervertebral disc material and hence will not give information about the type nor the severity of herniation [3].

4. Factors like obesity and excessive bowel gases may obscure some abnormalities or make interpretation of X-ray difficult.

5. Source of radiation to the patient.

#### *2.1.3 Techniques*

After appropriate positioning of the patient (usually supine, sometimes prone or lateral), the examination is performed in not more than a few seconds in general.

#### *2.1.4 Diagnostic value*

Generally, plain X-ray can show:

1. General alignment of the spine, any asymmetry, or gross deformity. Straightening of the normal lumbosacral curvature may be considered as an indirect sign of acute spasm or pain.

2. Abnormal position of certain vertebra in the form of foreword (spondylolisthesis) or backward (retrolisthesis) shifting of the vertebral body relative to the vertebrae above and below.

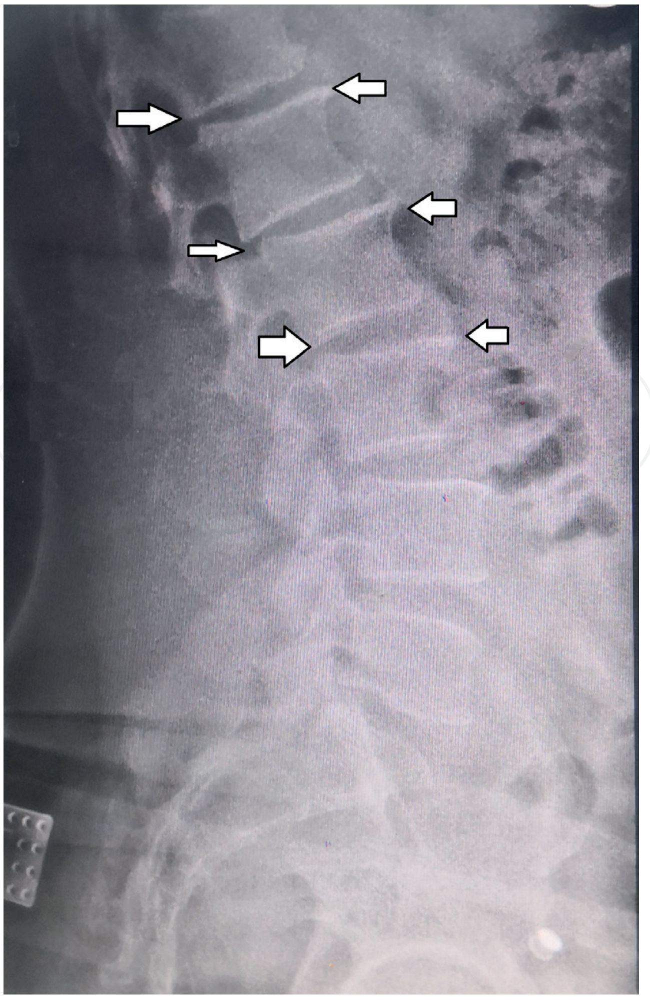

**Figure 1.**
*Lateral X-ray radiograph of the lumbosacral spine of a patient with LBP showing narrowing of multilevel intervertebral disc spaces with marginal osteophytes (white arrows) and juxta-endplate sclerosis, consistent with spinal degeneration.*

3. Some congenital anomalies of the spine like scoliosis, spina bifida (defect in the back of spine), and vertebral deformities in the form of abnormal shape, number, and alignment.

4. Lumbosacral spinal degenerative changes in the form of disc space narrowing, marginal osteophytes (bony protrusions at the margins of vertebra), and bony sclerosis near disc (**Figure 1**).

5. Signs of spinal infections (disc space narrowing with irregularity, bone destruction, vertebral compression, soft tissue swelling).

6. Diseases of sacroiliac joints like ankylosing spondylitis and Reiter's disease in the form of joint space narrowing, irregularity, erosions, and sclerosis.

7. Bone tumors (benign and malignant) affecting the spine or pelvis in the form of lytic (black) or sclerotic (white) lesions.

### 2.2 Magnetic resonance imaging (MRI)

Since its first clinical application in medicine about four decades ago, magnetic resonance imaging (MRI) has revolutionized the imaging evaluation of the human body particularly the musculoskeletal system, brain, and spine. In patients with LBP, MRI is considered as the imaging modality of choice because of its excellent demonstration of both the anatomy of the lower back and most of regional pathologies [4].

*2.2.1 Advantages*

1. No radiation

2. Noninvasiveness

3. Excellent imaging quality of the spine and pelvis

4. Most accurate modality in the demonstration of the neural structures that can be the source of LBP like the spinal cord and nerve roots

*2.2.2 Limitations*

1. Presence of contraindications (see Section 3.5).

2. Imaging quality is affected by the patient's motion, so examination needs a cooperative and stable patient. Agitated and unstable patients result in bad images that are diagnostically not useful.

3. Long examination time, usually 10-20 minutes (longer than X-ray and CT scan).

4. Not so accurate in certain conditions like cortical fractures and calcification (CT scan and lesser extent X-ray radiography are better).

5. Clinical MRI mismatch. Many abnormal findings specially disc degeneration or mild herniation are seen incidentally on spinal MRI of asymptomatic persons and vice versa where MRI can be completely normal in the presence of significant LBP. This has raised the issue of importance of clinical and electrophysiological correlation and the controversial need for more specific diagnostic tests like discography [5].

*2.2.3 Contraindications*

1. Cardiac pacemakers.

2. Metallic object (shells, bullet, orthopedic fixation devices). However, if the fixation devices used were made of MRI-compatible metals (more expensive than regular ones), MRI examination can be safely done despite some artifacts that slightly reduce diagnostic imaging quality.

3. Early pregnancy. However, the chemical material sometimes may be injected intravenously (gadolinium) to enhance the images, and this should not be used throughout pregnancy.

4. Claustrophobia. Seen in about 5–10% of population, when the person is unwillingly afraid of being in closed space. This problem may be resolved by reassurance and careful description of the procedure to the patient. Sometimes the patient will need to be examined using a special type of MRI device called "open type" that has wider aperture and more space around the patient. Rarely sedative/antianxiety drugs may be prescribed.

### *2.2.4 Techniques*

The patient is asked to remove any removable metallic objects like rings and watches. The examination usually takes 10–20 min to complete according to the clinical indication and requested sequences. MRI examination is usually composed of two or more of "sequences." Body tissues and pathologies appear differently on each sequence, and the most commonly used are T1-weighted and T2-weighted sequences. Other sequences used are Short tau inversion recovery (STIR) (suppresses fat signal in the bone marrow and fatty areas), diffusion-weighted image (DWI) (to assess certain features of some lesions according to water molecules diffusion) and fluid attenuation inversion recovery (FLAIR) (suppresses signal of the fluid). Sometimes, when vascular assessment is important, magnetic resonance angiography (MRA) is also conducted. Spinal pathologies can cause both structural and morphological changes. Degeneration of the intervertebral disc, for instance, can be diagnosed when the normal high signal (white) of the disc is lost (disc appears black). Disc prolapse is diagnosed when a part of the disc is seen outside the normal contour of the disc bulging into the spinal canal or compressing the nerve roots within the intervertebral canal.

### *2.2.5 Diagnostic value*

From the diagnostic point of view, MRI can help in:

1. Comprehensive evaluation of the lower back (lumbosacral region) in which the most common causes of LBP arise. Variable pathologies from degenerative, neoplastic, infective, and congenital abnormalities can be elegantly demonstrated. Important and common causes of LBP like intervertebral disc herniation, nerve root compression, lumbar canal stenosis, and degeneration of the small joints at the back of the spine (facet or apophyseal joints) and intraspinal ligaments (ligamentum flavum) can be seen (**Figure 2**).

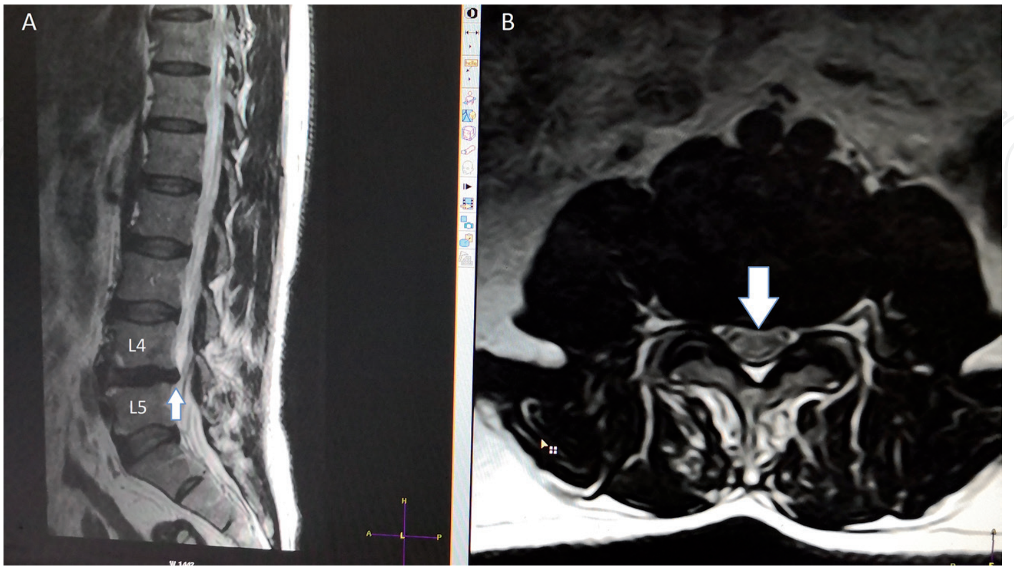


**Figure 2.**
*Sagittal (A) and axial (B) T2-weigted MRI images of the lumbosacral spine of a patient with LBP showing hypointense (dehydrated) intervertebral disc between the L4 and L5 vertebrae with posterior protrusion (white arrows) causing bilateral neural canal narrowing and root compression. Note the normal signal (hyperintense with hypointense cleft) of other discs.*

2. Complete evaluation of the spinal canal including the presence of any narrowing, stenosis or abnormal widening. Measurement of the cross-sectional area of the canal is preferred to objectively assess stenosis.

3. Detection of any mass within or outside the spinal canal that may have effects on the spinal cord, nerve roots, soft tissues, or bones including vertebral bony tumors, nerve sheath tumors, lipomas, vascular malformations, etc. [6].

4. Accurate depiction of variable congenital spinal malformations that may present as LBP, like scoliosis, spina bifida, myelomeningocele, dermoids, splitting of the cord, low-lying tethered spinal cord, and absence of the sacrum.

### 2.3 Computerized tomography (CT) scan

The main physical principle underlying CT scan is X-radiation. The use of CT scan in the assessment of the patients with LBP is limited to certain conditions that either need further evaluation after MRI, patients who cannot be examined by MRI, or when the clinical scenario necessitates CT from the start (like trauma).

#### *2.3.1 Advantages*

1. Excellent depiction of the bony anatomy and bony changes at the lower back including lumbosacral spine and pelvis [7]. Bony changes can be readily seen on CT even before appearance on X-ray radiographs.

2. Can compete with MRI in the visualization of lumbar disc prolapse and bony spinal canal stenosis.

3. Relatively more widely available and accessible than MRI.

4. Lesser cost than MRI.

5. Less affected by the patient's motion during examination than MRI.

6. Short time of examination (usually less than minute).

7. Can be safely done for patients with metallic implants, shells, and magnetic fixation devices (but some image compromise).

#### *2.3.2 Limitations*

1. High risk of radiation exposure [7]. This is indeed the most important disadvantage of CT scan. CT scan delivers a huge amount of radiation dose to the patient (almost 100 times that of chest X-ray).

2. Poor demonstration of intraspinal neural content like cord and nerve root and early bone marrow infiltration [8].

3. Artifacts from metallic fixation devices or shells may badly affect the quality of image and can obscure some anatomical and pathological findings.

*2.3.3 Techniques*

The patient is routinely examined in supine position (back on the table), and the exposure done while the patient is asked not to move. The examination is relatively rapid (less than minute).

*2.3.4 Diagnostic value*

Considering a case of LBP, CT scan can show:

1. Abnormal bone densities of the lower spine and pelvis including osteolytic (blacker) and osteoblastic (whiter) lesions, with a lot of possible causes, from incidental nonsignificant (bone islands), benign (hemangiomas, osteomas) to malignant (metastases, multiple myeloma) lesions.

2. Abnormal configuration and deformity, whether of congenital origin or as sequel of old trauma or surgery.

3. Traumatic findings like linear fracture, partial or complete vertebral compression, and burst vertebra (**Figure 3**). CT scan can detect even tiny fractures of the bony cortex particularly of the posterior spinal elements (laminae and pedicles) which are usually difficult to be seen and may be missed on X-ray radiographs [3].

4. Size, shape, and exact location of the metallic foreign body or shell or bullet.

5. Bone erosion secondary to inflammation, infection, or tumor.

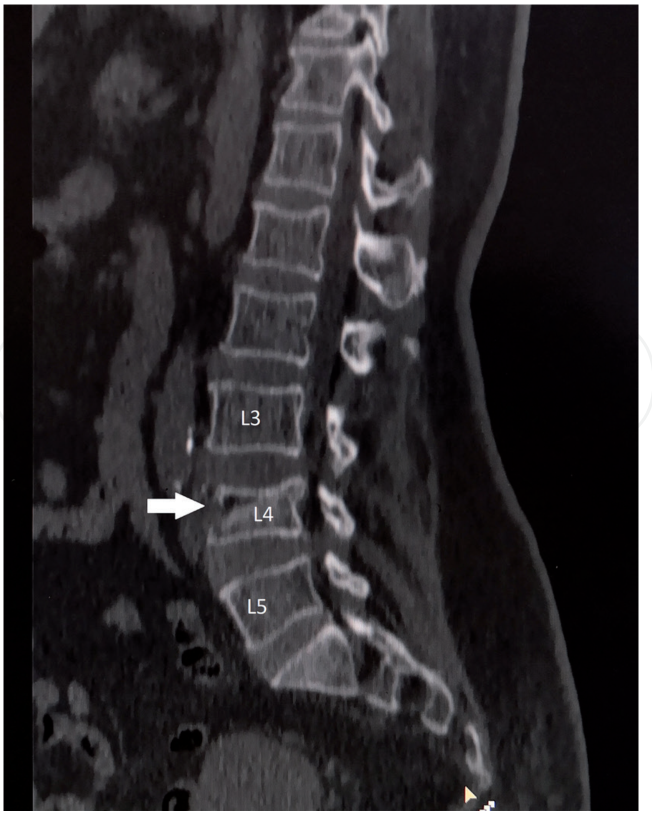


**Figure 3.**
*Sagittal reconstructed image (bone window) of lumbosacral spinal CT scan of a patient with LBP after trauma, showing burst fracture of L4 vertebra.*

6. Many (but not all) features of spinal degeneration like intervertebral disc space narrowing, marginal osteophytes, and facet joints sclerosis.

7. Calcification. CT scan is the best imaging modality in defecting calcification in paraspinal soft tissues, ligaments, muscles, or within a mass. The presence of calcification has important diagnostic impact as it helps narrow the differential diagnostic list or may reach final diagnosis like hydatid cyst or para-articular calcification in some chronic arthropathies.

## 2.4 Sonography

Sonography (or ultrasound scan, echography) utilizes sound waves of very high frequency that are normally not audible by human beings. Its application in the evaluation of patients with LBP is limited because the ultrasound waves are badly affected by tissues like the bone and air.

### *2.4.1 Advantages*

1. Cheap

2. Readily available (almost everywhere, anytime), repeated easily

3. Generally safe (no exposure to ionizing radiation)

4. Noninvasiveness

5. No significant risk or contraindication

### *2.4.2 Limitations*

1. Highly operator-dependent. Examination in general and of the musculoskeletal system in particular needs expertise and adequate training. Both false-positive and false-negative results are common by inexperienced examiners.

2. Highly device-dependent. The quality of the ultrasound machine has high impact on the quality and subsequent diagnostic outcome of the examination, particularly of the musculoskeletal ones. Many advanced technologies (both software and hardware) are currently emerging that help improve diagnosis which are typically supplied to the mid or even only high-level (expensive) machines.

3. Demonstrates only selected anatomical details of lower back.

### *2.4.3 Techniques*

No special preparation is usually required. Routinely, a gray-scale (B-mode) scan is applied. Color Doppler scan is used when the assessment of blood flow and vascular imaging is required. Advanced techniques like 3D, 4D, and elastography are increasingly utilized both in research and specialized centers in musculoskeletal imaging.

#### *2.4.4 Diagnostic value*

Using different technologies, ultrasound can help physician improve the management of the LBP in both diagnostic and therapeutic aspects:

1. Can easily show the content and vascularity of any superficial soft tissue mass that may be related to the LBP.

2. Can show some details of some congenital anomalies at the lower back like cysts or fatty (lipomas, dermoid) and vascular (hemangiomas) lesion.

3. Can show some abnormal features of sacroiliac joints like effusion, bone surface erosion, and soft tissue swellings [9].

4. It may help detect some pelvic conditions that may be directly or indirectly related to the cause of LBP including gynecological condition (inflammatory, tumors, cysts, etc.), bowel masses, and other peritoneal pelvic lesions.

### 2.5 Isotope imaging

Isotope imaging involves the administration of certain radioactive material into the body (usually intravenously), and then images are created according to the metabolic activity of the targeted tissue/organ.

It usually provides additional diagnostic information to other "structural" imaging modalities (like CT or MRI) to narrow the differential or reach the final diagnosis. Considering the LBP, the most commonly useful isotope imaging modalities used are bone scan and posterior emission tomography (PET).

#### *2.5.1 Advantages*

1. Provision of highly useful information about the "metabolic" or "physiological" activity of the lesion, which cannot be obtained by any of the conventional imaging like X-ray, CT scan, or MRI.

2. Can detect hidden causes of pain originating from the bony components of the lower spine and pelvic like stress fracture or metastases in patient with known cancer [10].

#### *2.5.2 Limitations*

1. Not cheap examination.

2. It is not readily available as it is commonly present in specialized centers; PET scanners required very sophisticated measures to prepare the isotope material on site just before examination.

3. It is a source for radiation to the patients as well as to medical personals.

4. Has very limited spatial resolution so that interpretation should be correlated with anatomical images. Therefore, most of currently used devices are merged with the conventional anatomical modalities resulting, for example, in hybrid or fusion PET/CT or PET/MRI.

*2.5.3 Techniques*

Depending on the purpose of the examination, the isotope material (usually incorporated with another carrier substance) is administrated to the patient. The patient is then imaged by the device.

*2.5.4 Diagnostic value*

1. Generally, metabolically active lesions appear of higher signal than adjacent tissues, so-called "hot spots," and vice versa, inactive lesions have lower signal, so-called cold spots.

2. Can provide invaluable decision about the nature of a vague or suspicious lesion, for example, in the pelvis or lower spine, and whether it is significant and metabolically active or not by assessing its activity.

3. Helps detect many lesions that are metabolically active (like cancer, active inflammation, healing fractures, postoperative) and that are not well or difficult to be seen by the common modalities (CT scan and MRI) [9, 11].

4. Monitoring the response of cancer after radiotherapy and/or chemotherapy and assessing the presence of a residual/recurrent tumor mass after surgical resection.

## 2.6 Angiography

Many methods are utilized in angiography (visualization of the vascular system), commonly by injecting a contrast material into the vessels and then taking images. In the assessment of patient with LBP, angiography generally has very limited role like in further evaluation or treatment of a vascular lesion [12].

*2.6.1 Advantages*

1. Provision of details about of the vascular component of the lesion

2. Opportunity of the therapeutic option as some lesions can be treated directly by the angiography by, for example, injecting a special material to occlude and "embolize" the feeding vessel of the mass or vascular anomaly. This is useful for patients who cannot undergo the surgery and with difficult or risky surgical access.

*2.6.2 Limitations*

1. Not cheap.

2. Not widely available.

3. Needs expertise.

4. High radiation exposure both to patient and staff.

5. Risk of contrast material particularly the iodine-based material (in conventional angiography and CT angiography (CTA)) like allergy and renal dam-

age. These are much less in MRI (gadolinium) but this carries risk of "systemic progressive sclerosis."

### *2.6.3 Techniques*

Conventional angiography involves injection of iodine-based contrast material through an arterial catheter under fluoroscopy. CTA is less invasive, involving the injection of the contrast material intravenously and the patient is imaged by CT scanner. MR angiography can be done both with and without the use of intravenous chemical contrast material (gadolinium).

### *2.6.4 Diagnostic value*

1. Can help reaching the final diagnosis of a vascular lesion (whether vascular tumor, vascular malformation, hemangiomas)

2. Provides a road map which can be of great value to the surgeon before operating on certain mass by showing detailed vascular anatomy of the region and vascular component of certain mass

3. Has a great value in the therapy of certain vascular lesions and tumors by either treating or reducing the bulk of mass

4. Can also help alleviating the pain in advanced cancer that is not responding to medical treatment and beyond surgical treatment specially in those in end-stage disease

## 2.7 Myelography

The visualization of the spinal canal lumen is called myelography. It is usually done as a complimentary to other imaging modalities in the evaluation of spinal lesion or canal stenosis.

### *2.7.1 Advantages*

1. More accurate localization of the intraspinal lesion

2. Provision of additional delineation of the spinal canal stenosis

3. Improvement in the diagnosis of some types of nerve root compression

### *2.7.2 Limitations*

1. The conventional and CT myelography techniques are invasive with risk of infection, pain, and radiation exposure.

2. The image quality and resolution of MR myelography (MRM) are not so high and affected by artifacts and depend on the technique used.

### *2.7.3 Techniques*

This can be achieved invasively by injecting a radiopaque iodine-based contrast material into the cerebrospinal fluid (CSF) space of the spinal canal through a needle inserted at the lower back, and the patient is imaged by either conventional X-ray (conventional myelography) or by CT scan (CT myelography) [10]. With the advent of MRI, it became possible to do myelography noninvasively (without need for any intraspinal injection). This so-called MRM is a great advance in spinal imaging. Nowadays, conventional myelography is mostly superseded by CT myelography which is in turn mainly reserved to those who cannot undergo MRI.

#### *2.7.4 Diagnostic value*

The interpretation of myelography is usually done after the complete evaluation of other imaging modalities like X-ray, CT, and MRI. The main diagnostic values are:

1. Filling defects in the myelography can be caused by many intraspinal lesions. Therefore, accurate localization of these lesions whether they are extradural, intradural, extramedullary (outside the cord), or intramedullary (within the cord) has great diagnostic value in reaching the most probable cause.

2. MRM can improve the inter-observer and intra-observer agreement in the assessment of lumbar spinal canal stenosis [13], helping more consistent diagnosis when surgical intervention is considered.

### **2.8 Discography**

Discography means the visualization of the content of intervertebral disc after injection of a radiopaque iodine-based contrast material directly into the disc. It is considered as the most accurate method in deciding which disc level is responsible for the LBP and used as reference test in medical researches. However, because it is a very invasive and painful test with many complications and contraindications (like infection, bleeding and severe spinal compromise), its clinical use now is highly restricted for carefully selected patients (e.g., continuous pain with normal noninvasive imaging or sometimes before surgery) and only under experienced interventionalists [14].

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