CLASSIFICATION, DIAGNOSTIC IMAGING, AND IMAGING CHARACTERIZATION OF A LUMBAR HERNIATED DISK

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IMAGING OF LOW BACK PAIN

CLASSIFICATION, DIAGNOSTIC IMAGING, AND IMAGING CHARACTERIZATION OF A LUMBAR HERNIATED DISK

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To communicate their findings, scientists must assign names to the object of their study and then arrange them in some order. This process of naming and arranging is called classification. Classification is a descriptive arrangement that allows one not only to communicate about included objects, but also to identify these objects consistently for archiving and retrieval. Uniformity of classification is essential to compare research results regarding diagnosis and treatment of disk disorders. Spine surgeons resort to an impressive number of different terms to describe the same operating room findings. Any discussion of lumbar disk herniations, whether related to diagnosis or management, must define clearly its terminology regarding the pathologic condition of a disk. The absence or disparity of morphologic or pathologic term definitions in the scientific literature is such that comparing published results or meta-analysis is very often impossible. During the last decade, several articles have dealt with the nomenclature and classification of disk
abnormalities in relation to the interpretation of imaging studies.\textsuperscript{[9]} \textsuperscript{[10]} \textsuperscript{[11]} \textsuperscript{[12]} \textsuperscript{[13]} \textsuperscript{[15]} \textsuperscript{[16]} \textsuperscript{[17]} \textsuperscript{[18]} Classifications and glossaries have also been proposed by the American Academy of Orthopedic Surgeons\textsuperscript{[2]} and the North American Spine Society.\textsuperscript{[21]} None of the proposed schemes has succeeded in generating a universal consensus, however, and the usage of language still varies greatly, causing confusion and controversy.\textsuperscript{[18]} The historical lack of interest of traditional physicians, fundamental anatomists, and imaging specialists for the deemed trivial and vulgar issue of low back pain is probably responsible to some extent for this situation.\textsuperscript{[47]} We are still unclear about spinal anatomy, especially in reference to spinal ligaments and membranes.\textsuperscript{[71]} \textsuperscript{[90]} Controversies regarding surgical indications have created undeniable biases. To reassure patients about the good prognosis of an acute back pain episode, certain terms (e.g., ruptured disks) have been considered too alarming by some nonoperative care physicians.\textsuperscript{[14]} Socioeconomic and legal considerations have unfortunately colored many scientific debates and, in many parts of the world, the presence or absence of the term disk herniation in an imaging report has a very significant impact in a litigation context. Some authors have suggested abandoning the term herniation because of its legal implications, but this word has been used in so many scientific, clinical, and lay discussions of the past seven decades and is so firmly established in various lexicons as to make proscription impossible.\textsuperscript{[83]}

DEFINITION OF A DISK HERNIATION

In \textit{Dorland's Medical Dictionary} \textsuperscript{[18]} herniation is defined as an abnormal protrusion of an organ or other body structure through a defect or natural opening in a covering, membrane, muscle, or bone. This definition has been generally accepted over centuries. The definition of the term disk herniation used by radiologists has evolved over the years, particularly during the last decade. This term initially meant a focal extension of nucleus pulposus beyond the margin of the disk.\textsuperscript{[41]} The term herniation of the intervertebral disk was synonymous with herniation of the nucleus pulposus. This restrictive definition has been found impractical because it is generally impossible for observers of imaging studies to determine the exact nature of the material coming out of a disk space. Even surgeons, in the operating room, find it difficult to distinguish torn anulus fragments from nuclear material especially in situations where a herniation has generated an important inflammatory reaction. The definition proposed by Herzog\textsuperscript{[30]} is more realistic: focal displacement of nuclear, anular, or end plate material beyond the normal peripheral margins of the disk delimited by the margins of the vertebral body end plates. The term end plates refers to the entire surface of the vertebral body, and includes both the central cartilaginous plate and the peripheral ring epiphysis. The qualifier normal, in reference to the peripheral margin of the disk, is important and is meant to refer to the initial or original limits of the adult intervertebral space, exclusive of any osteophytes that may have developed. This initial boundary may have been modified by the presence of vertebral body osteophytes. A chronic localized displacement of disk material accompanied by marginal localized vertebral body osteophytes still qualifies as a disk herniation. The bony end plates also delineate the upper and lower boundaries of the
normal intervertebral disk, and displacement of disk material inside a vertebral body through a break in the end plate may be properly named an *intravertebral disk herniation*.

Despite the controversies associated with disk nomenclature, the general modern definition of disk herniation just discussed has gained general acceptance by imaging specialists. Debates most often arise as to whether or not a particular image in a given individual qualifies for this theoretical definition because of the impact on management or compensation previously discussed. Using CT or even MR imaging, some herniations can mimic symmetric or asymmetric disk bulging because the disk material coming out of the disk space, at the disk level, is confined by the anterior or posterior longitudinal ligament and often generates the illusion of a process that is not focal. Because of this, the definition of the disk herniation should probably be broadened to localized displacement of nuclear, anular, or end plate material beyond the normal limits of the disk space. The term *localized* is meant in opposition to *generalized*, the latter term being reasonably applied to displacement of disk material involving more than 50% (180 degrees) of the disk periphery. Localized displacement in the axial (horizontal) plane can be further described as focal, signifying that less than 25% of the disk circumference is involved, or broad-based meaning between 25% and 50% of the disk circumference. As was emphasized by Mink et al.\(^5^3\) the term *disk herniation*, like all anatomic descriptive terms of disk abnormalities, should not by itself imply disability, cause, relation to injury, relation to pain, or the need for treatment or reimbursement. On the other hand, a bulging disk may be defined as a disk in which the contour of the outer anulus extends, or appears to extend, in the horizontal (axial) plane, beyond the edges of the disk space, usually over greater than 50% (180 degrees) of the disk circumference.

Even though the modern definition of disk herniation can apply to all intervertebral disks, this article deals exclusively with lumbar disk herniations. Some aspects that are discussed can apply to thoracic and cervical disks but, because of the important anatomic differences between the different spinal segments, all extrapolations must be conducted very cautiously. Even in the lumbar area, there are significant anatomic differences between upper and lower vertebrae and certain concepts, like the lateral recess syndrome, are really meaningful only in relation to the L4, L5, and S1 vertebrae.\(^5^8\)

**CLASSIFICATION OF A HERNIATED LUMBAR DISK**

Some classifications of disk herniations that have been proposed to imaging specialists have not met with success essentially because categories were defined in terms of microscopic anatomy and pathology.\(^2\)\(^6^6\) Such models were actually suitable for pathologists performing cryotome sections on postmortem specimens and, to some degree, for surgeons reporting operating room observations, but were not really useful for radiologists describing abnormal findings on myelograms, diskograms, CT, or MR images. Conceivably, a classification of lumbar disk herniations could be based on the clinical staging of the disease. Stage 1: low back pain ± radiating pain; no objective sign. Stage 2: low back pain ± radiating pain; segmental pain; muscle spasm. Stage 3: low back pain ± radiating pain; signs of dural or radicular irritation. Stage 4: low back pain ±
radiating pain; neurologic deficit. Although useful for patient management, this model is not adequate for imaging study interpretation. A useful nomenclature needs to propose categories based on observable distinctions that take into consideration the limitations of present-day imaging techniques.

**Main Categories of Noninfectious Disk Abnormalities**

Ideally, a valid and useful system for classifying noninfectious disk abnormalities should provide categories that correspond to real anatomic and pathologic entities and, if possible, correspond to specific clinical situations. The system should be applicable to all currently used imaging modalities. It should be simple to understand, to memorize, and to teach. It should also be reliable and generate substantial intraobserver and interobserver agreement in terms of Kappa statistics. The nomenclature to describe disk lesions demonstrated by imaging studies has been greatly influenced by our concepts of disk degeneration throughout life (i.e., what is normal aging?) and our understanding of what constitutes a disk lesion likely to generate clinical signs and symptoms. The nomenclature we favor is directly related to our physiopathologic model. The clinical concept that followed the description by Mixter and Barr of herniation of the nucleus pulposus through a ruptured annulus fibrosus was that, should this occur in a posterior or posterolateral direction and encroach on the neural canal, cord or nerve root compression may result with consequent segmental root pain and muscle spasm. Because compression of neural structures was believed to be the only logical explanation for pain, associated or not with a neurologic deficit, imaging strategies have been developed over the last 20 years with a clear focus on identifying displacement of disk material associated with compression of neural structures. Classifications of disk abnormalities that were associated with this concept have obviously been influenced by this bias. In the early 1980s, for the interpretation of myelograms and the first generation of high-resolution CT of the spine, a very simple terminology was proposed that had essentially three categories: (1) the normal disk, (2) the bulging disk without nerve root compression, and (3) the herniated disk with nerve root compression. The definition of disk herniation was very restrictive because nerve root compression was considered by some investigators a sine qua non condition to make the diagnosis. This requirement appeared acceptable, however, because it was estimated that only 10% of herniations occurred in a posterior central direction.

The validity of this model has been questioned in recent years and nerve root compression has been found less important than inflammation in the genesis of painful symptoms. This relatively new concept has led to the development of two nomenclature models based on very different perspectives.

**The Morphologic Model**

This model is essentially based on one parameter, the assessment of the disk contour to determine the degree of disk extension beyond the interspace (DEBIT). The categories are normal disk, bulging disk, protrusion, and extrusion (Fig. 1) . Normal indicates no disk extension beyond the interspace. Bulge refers to circumferential, symmetric DEBIT (around the end plates). Protrusion indicates focal or
asymmetric DEBIT into the canal, the base against the parent disk broader than any other
diameter of the protrusion. Extrusion means focal, obvious DEBIT, the base against the
parent disk narrower than any diameter of the extruding material itself, or no connection
between displaced disk material and parent disk. The use of the term herniation to
designate collectively protrusions and extrusions has been suggested,[15] but maintaining
the distinction may have some clinical relevance because extrusions are rarely found in
asymptomatic individuals, as opposed to protrusions and bulges.[34] It has also been argued
that the term extruded disk is less frightening and emotionally laden than disk herniation
or ruptured disk.[17] This classification is based on very simple geometric concepts and the
categories are mutually exclusive, but the line drawings in Figure 1 (Figure Not
Available) are misleading because they represent the disk as a two-dimensional structure. Disk extrusions, such as the one depicted, are practically never seen at the disk level on
CT or MR imaging axial sections: large posterior displacement of disk material beyond
the margins of the intervertebral space still generally creates images corresponding to the
definition of a protrusion because they are outlined by the posterior longitudinal ligament
(Fig. 2). Significant migration of disk material is usually necessary to generate a typical
extrusion image. Distinction between protrusions and extrusions, at the disk level, is very
often only possible on sagittal sections (Fig. 3), and this distinction is not very practical
for the interpretation of CT because sagittal reconstructions are usually not part of the
routine imaging protocol. On CT or MR imaging, this distinction is difficult in the
presence of a narrow central spinal canal and very often impossible for foraminal
herniations (Fig. 4).

Figure 1. (Figure Not Available) Morphologic nomenclature based on the assessment of the disk contour.
(From Milette PC: The proper terminology for reporting lumbar intervertebral disk disorders. AJNR Am J
Neuroradiol 18:1859-1866, 1997; with permission.)

Figure 2. Axial CT scan section through the L4-L5 disk space showing a relatively large posterior right
central displacement of disk material with dural sac compression and probable right L5 nerve root
compression. Although the overlying posterior longitudinal ligament complex (PLLC) is not seen, it
constrains the displaced disk material and is responsible for maintaining a protrusion shape.
When a relatively large amount of disk material is displaced, distinction between protrusion (A) and extrusion (B or C) will generally only be possible on sagittal MR sections or sagittal CT scan reconstructions. In C, although the shape of the displaced material is similar to that of a protrusion, the greatest cranio-caudal diameter of the fragment is greater than the cranio-caudal diameter of its base at the level of the parent disk, and the lesion therefore qualifies as an extrusion.

Axial CT scan section through the upper portion of the L4-L5 foramina in a 45-year-old man. Abnormal soft tissues likely representing displaced disk material are seen in the right foramen. The material cannot be precisely delineated and the distinction between protrusion and extrusion is difficult. A typical extrusion shape is practically never seen with foraminal herniations.

Despite its apparent simplicity, only moderate interobserver agreement has been reported using this nomenclature in three independent studies. It is also incomplete because it considers exclusively the contour of the disk and the shape of the displaced disk material. Disks demonstrating normal contour but abnormal central or peripheral signal patterns have no place in this system, and associated vertebral body bone marrow changes are completely ignored, even though the clinical relevancy of those changes has been well demonstrated. This nomenclature is unfortunately misleading because it creates artificial pathologic entities. The bulging disk category is the most problematic. Obviously, a severely dessicated and atrophic disk may bulge diffusely as the intervertebral space narrows with buckling of the anterior and posterior longitudinal
ligaments. But an impression has been unjustifiably derived from early postmortem studies\(^8\) that, even in young individuals, a disk with an intact anulus may be responsible for a detectable bulge on axial CT sections. It has also been hypothesized that bulging disks are caused by diffuse anular hyperlaxity, which occurs as a result of tears in collagen bridges between the concentric anular fibers while these concentric fibers remain intact.\(^1\) This theory has never been proved because such collagen bridges between the concentric fibers of the anulus have never been found.\(^2\) It is important to realize that a bulging disk is not an anatomic or pathologic entity: it is an image that requires a differential diagnosis. It sometimes represents a normal anatomic variant; this is often the case with the L5-S1 disk. On CT images, it is often an illusion caused by a volume-averaging effect (Fig. 5). It may be associated with remodeling of adjacent vertebral bodies because of osteoporosis (Fig. 6). It may of course result from chronic disk deterioration and collapse. A bulging disk illusion is often created on CT by a posterior anular disk rupture, with displaced disk material peeling off the posterior longitudinal ligament and displacing it backward, creating a posterior wide base protrusion that mimics diffuse symmetric disk bulging on both axial CT and MR imaging sections, and is not differentiated from a bulging disk on sagittal MR images unless close attention is paid to the anterior aspect of the disk (Fig. 7). Except for the fact that extrusions are rarely found in asymptomatic individuals,\(^3\) this system does not really provide categories that correspond to clinical entities.
Figure 5. A, Bulging disk appearance of the L4-L5 disk, shown on a 5-mm-thickness axial CT scan section, in a 57-year-old woman. The height of the intervertebral space was preserved and there was no reactive vertebral body end-plate modifications. This aspect is probably partly due to vertebral body remodeling caused by osteoporosis, but is mostly created by volume averaging. (From Milette PC, Fontaine S, Daniels C, et al: Imaging of Low Back Pain, CD-ROM, SSB Multimedia Medical Series, Montreal, 1997; with permission.) B, Using 4- or 5-mm-thickness CT sections, an intermediate gray shade halo is often computer generated by volume averaging of tissues with different attenuation coefficients in voxels, represented by two-dimensional pixels, located at the disk space periphery. This creates the illusion of a three-dimensional image demonstrating diffuse disk bulging. ST = slice thickness
Figure 6. Axial CT scan section of a L4-L5 disk in a 78-year-old man demonstrating diffuse disk bulging caused by remodeling of the adjacent vertebral bodies due to osteoporosis. The intervertebral space was normal in height and there were no reactive adjacent bony endplate modifications.

Figure 7. A. T2-weighted axial section of a L5-S1 disk showing a left posterolateral wide base protrusion that can be easily confused with diffuse circumferential bulging. B. Corresponding T2-weighted left paracentral and central sagittal sections demonstrating loss of the L5-S1 disk signal intensity with posterior small left-central protrusion; the anterior aspect of the disk does not extend beyond the endplates and, therefore, such a disk should not be labeled *bulging disk*.

*The Pathoanatomic Model*
As opposed to the previous model that can be applied only to the interpretation of CT and MR imaging studies, this model can be used for the interpretation of all imaging modalities, including plain films and diskograms. It consists of five categories that are not mutually exclusive, so that different combinations are possible (Fig. 8) (Figure Not Available). The first three refer to the general state of the disk: (1) normal young disk; (2) normal aging disk; and (3) deteriorated disk (formerly called the scarred disk). The last two refer to localized lesions: anular tear and herniated disk. In this model, the previously discussed definition of disk herniation proposed by Herzog is applicable. The use of this system requires an effort to distinguish the normal aging changes from those of pathologic degeneration. Resnick and Niwayama have emphasized the differentiating features of two degenerative processes involving the intervertebral disk, which had been previously described by Schmorl and Junghanns: (1) spondylosis deformans, which affects primarily the anulus fibrosus and bony ring epiphysis; and (2) intervertebral osteochondrosis, which affects essentially the nucleus pulposus and the vertebral body end plates.

**Figure 8.** (Figure Not Available) Schematic representation of a nomenclature based on a three-dimensional assessment of the anatomic and pathologic characteristics of both disk and adjacent vertebral bodies. The categories are not mutually exclusive and some combinations are possible. A, Categories related to the general aspect of the disk: normal young disk (a), normal aging disk (b), deteriorated disk (c). B, Categories related to local lesions: normal young disk (a), anular tear (b), herniated disk (c). (Adapted from Milette PC: The proper terminology for reporting lumbar intervertebral disk disorders. AJNR Am J Neuroradiol 18:1859-1866, 1997; with permission.)

There is convincing evidence in the scientific literature that the features of spondylosis deformans represent the normal aging process, whereas intervertebral osteochondrosis denotes true pathologic disk degeneration. Schmorl and Junghanns found spondylotic changes in 60% of women and almost 80% of men over the age of 50. In a series of 400 dried skeletons, Nathan found anterior vertebral body osteophytes, which constitute the main feature of spondylosis deformans, in 100% of individuals over age 40, whereas posterior osteophytes were found in only 39% of individuals even after the age of 80. Twomey and Taylor have found that loss of disk height is unusual in a normal aging population and that loss of stature in the elderly is attributable to loss of intervertebral body height rather than loss in disk height. During the normal aging process, the mucoid matrix of the nucleus pulposus is progressively replaced by fibrous tissue, but the intervertebral height is preserved and the disk margins remain regular. Dessication and thinning of disks or "disks that bulge like an underinflated automobile tire" are not typical of elderly spines. Slight symmetric bulging may occur if there has been vertebral body remodeling resulting from osteoporosis. Small amounts of gas can be detected on plain films or CT images near the insertion of the anulus on the ring epiphysis, and this gas is probably located in transverse anular tears adjacent to the ring epiphysis. During the fourth decade anterior and lateral marginal vertebral body osteophytes constitute normal findings, comparable with having gray hair, but end plate erosions with osteosclerosis, or chronic reactive bone marrow changes type 2 or 3 as described by Modic et al. should not be seen. Slight to moderate decrease in central signal intensity can be detected on T2-weighted MR images as part of the normal aging process, but the changes should involve uniformly all lumbar disks.
Deteriorated disks represent real pathologic degeneration, which is sometimes referred to as *chronic diskopathy*. On microscopic examination, they show total structural disorganization and general replacement of normal disk material by scar tissue. For this reason, they were initially labeled *scarred disks* by the members of a joint committee on spinal nomenclature created by the Quebec Association of Radiologists.\(^{14}\) Because of possible confusion with postoperative changes, the term *deteriorated disk* has been proposed as an acceptable substitute. Strictly speaking, the term *degeneration* could be used to designate this entity but this latter term has such a broad nonspecific meaning that it is best avoided. The deteriorated disk is characterized by narrowing of the intervertebral space, irregular disk contour generally associated with symmetric or asymmetric bulging, abundant presence of gas in the central portion of the intervertebral disk space, multidirectional osteophytes that do not respect the central spinal canal or the foramina, end plate erosions with reactive osteosclerosis, and chronic bone marrow changes. On T2-weighted MR images, the central disk signal intensity is usually markedly decreased and the number of affected lumbar disks is variable. Even though transverse, concentric, and radial anular tears have been identified on postmortem specimens,\(^92\) the anular tear category in this model refers essentially to the radial tears that are generally demonstrated by diskography in symptomatic patients. For a more precise description of those tears, this model may be supplemented by the Dallas Discogram Description system,\(^{70}\) with or without its recently proposed updates.\(^4\)\(^72\)\(^80\)

It should be emphasized that the pathoanatomic model is not based on direct identification of a particular geometric pattern, but on the anatomy and pathology that are expected as a result of the analysis of specific criteria. Using this model, the conclusion of any imaging report does not consist of terms related to the shape of the disk contour or the displaced disk material, but on a pathologic diagnosis that should be presented with an appropriate confidence level (possible, probable, or definite). The diagnosis of a probable major radial anular tear may be inferred from the presence of a definite central signal intensity loss because, as a result of diskographic MR imaging correlations, the positive predictive value of this sign has been estimated at 96%.\(^{48}\) The use of this model requires an effort to understand the criteria allowing differentiation of normal aging from true pathologic degeneration, so this system is slightly more complicated than the morphologic model. Its reliability has never been tested. Some intraobserver or interobserver disagreement would probably occur trying to distinguish anular tears without herniation from anular tears with small herniations. With respect to correspondence to clinical situations, this scheme, like the morphologic model, has limited interest: it has been shown that disks demonstrating the features of the deteriorated disk are likely to be responsible for symptoms, but this relationship has been statistically established to be significant only for the L4-L5 disk.\(^{24}\)

*Which Model Should Be Used?*

In other areas of diagnostic radiology, the aim of image analysis is always to predict what the pathologist would find if he or she could be provided with an adequate specimen immediately following the imaging study: radiologic diagnoses are presented with a pathologic perspective. There is no reason why the reporting of disk disorders should be
any different. Terms like bulging disk are meaningless to a pathologist and I personally favor the pathoanatomic model. Nomenclature standardization, however, is not a task that can be achieved by an individual or even a single group of authors. To have any impact, recommendations have to emanate from well established national or international societies. The multiplicity of scientific societies with an interest in the spine all over the world creates a special problem but new joint committees have recently been set up, combining efforts to come up with a practical unified system that it is hoped could be proposed jointly by the North American Spine Society, the American Academy of Orthopedic Surgeons, the American Academy of Neurological Surgeons, the American Society of Spine Radiology, and the American Society of Neuroradiology. Agreeing, in North America, on a classification of disk disorders that could gain universal acceptance, like the TNM classification of neoplastic diseases, would be a major achievement. Meanwhile, the choice of the nomenclature is up to the best judgement of each practicing radiologist and the essential issue, in a given hospital or community practice, remains clear communication between radiologists and referring physicians by way of a local agreement as to the meaning of words.

A major problem frequently occurs because observers of imaging studies try to combine elements of the morphologic classification with those of the pathoanatomic classification. Trying to differentiate a bulging disk (morphologic qualifier) from a disk herniation (pathologic diagnosis) cannot work because a bulging disk aspect is a common feature of the aging disk, the deteriorated disk, and some posterior central disk herniations (Fig. 9). Trying to make the distinction is doomed to failure because it defies formal logic. On the other hand, it is theoretically possible to differentiate a radial anular tear (without herniation) from a disk herniation because these are two different pathologic entities, although one may be the continuum of the other. It is best to adopt either one of the two systems and avoid trying to straddle the two. A general classification of disk disorders attempting to conciliate the morphologic and the pathoanatomic model is proposed in Table 1.
**Figure 9.** A bulging disk aspect often conceals a posterior central herniation. *A,* Complete rupture of the outer anular fibers allowing nuclear material to escape and peel off the posterior longitudinal ligament (and sometimes a few intact peripheral anular fibers) from the torn disk, creating a detectable focal or asymmetric extension of the disk margin beyond the interspace, which qualifies as a protrusion. *B,* With more gelatinous nuclear material escaping underneath the rigid posterior longitudinal ligament, the focal bulge is no longer detectable as its radius increases and, if the tear occurs in the posterior midline or paramedial direction, the aspect mimics symmetric disk extension beyond the interspace. *C,* Since, in most cases, only the outline of a diffusely hypointense disk is perceived on MR images, this creates the illusion of circumferential disk bulging on axial sections. *D,* The real nature of a bulging disk of this type may be suspected by scrutinizing the sagittal sections and appreciating that, unless one is dealing with a chronically degenerated scarred disk, the bulge is not symmetric but limited to the posterior aspect of the disk.

**TABLE 1 -- GENERAL CLASSIFICATION OF DISK LESIONS**

<table>
<thead>
<tr>
<th>Category</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal (excluding aging changes)</td>
<td></td>
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<tr>
<td>Congenital/developmental variants</td>
<td></td>
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<tr>
<td>Inflammation/infection</td>
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<tr>
<td>Neoplasia</td>
<td></td>
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<tr>
<td>Degenerative/traumatic:</td>
<td></td>
</tr>
<tr>
<td>Degeneration:</td>
<td></td>
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<tr>
<td>Anular tear</td>
<td></td>
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<tr>
<td>Herniation:</td>
<td>Protrusion</td>
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<tr>
<td>Extrusion</td>
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</table>
Degeneration:

<table>
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<tr>
<th>Spondylosis deformans</th>
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</thead>
<tbody>
<tr>
<td>Intervertebral osteochondrosis</td>
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**Further Qualifying the Displaced Disk Material Beyond the Disk Space**

Regardless of the basic system that is used, the type of herniation should be assessed. The volume and location of the displaced disk material beyond the normal peripheral margin of the intervertebral space also need to be specified. In certain cases, it is also possible to determine the composition of this material. For the sake of simplicity, the term *herniation* is used consistently in the remainder of this article to refer to all displaced disk material, but what is discussed can also be applied to protrusions and extrusions, if one wants to use the morphologic nomenclature.

**Type of Herniation**

Upward or downward migration of nuclear material may occur through a break in a vertebral body end plate, creating an intravertebral herniation, sometimes referred to as an *intraspongy herniation* or a *Schmorl's node* [67] (Fig. 10). Although a herniation occurring in any horizontal direction is likely to cause symptoms because of the presence of pain-sensitive nerve endings in the outer anulus, [7] [8] [65] herniations occurring in a posterior or posterolateral direction deserve special consideration because of the added possibility of dural sac or individual nerve root compression.
Figure 10. Various types of intravertebral herniations (Schmorl's nodes). A, Intravertebral herniation through the inferior end plate of the L3 vertebral body demonstrated by diskography in a 35-year-old man suffering from chronic low back pain. The patient's typical pain was reproduced during injection and the lesion was considered responsible for the patient's symptoms. B, T2-weighted sagittal section demonstrating an intravertebral herniation through the inferior end plate of the L4 vertebral body in a 24-year-old woman presenting with chronic low back pain. The high signal intensity of the lesion associated with the loss of normal central signal intensity of the parent disk suggests that the lesion is a bona fide acquired intraspongy herniation and not just a developmental defect. C, T2-weighted sagittal section demonstrating an intravertebral herniation through the inferior end plate of the L3 vertebral body (arrow). Because both the herniation and the parent disk show normal signal intensity, the abnormality was
considered a probably asymptomatic developmental defect.

Other characteristics of disk herniations have become relevant with the development of new therapeutic possibilities (e.g., chemonucleolysis and percutaneous diskectomy). The term *sequestration* is confusing and has often been used to indicate displacement of disk material away from the parent disk. The term *sequestered disk* should be used restrictedly to designate a fragment of diskal tissue that has migrated from the disk space and has no connection by diskal tissue to the disk of origin. Sequestration refers to loss of continuity with disk tissue still present in the intervertebral disk space. The term *migration* has a broader meaning, indicating displacement of disk material away from the edge of the rent in the outer anulus, either in the central spinal canal at the disk level, or above or below the disk level. This difference is illustrated in Figure 11. The terms *communicating* and *noncommunicating* derive from a different perspective and are mostly used in the context of intradiskal therapeutic injections: They refer to the interruption of the periphery of the disk allowing fluid injected into the disk to leak into the spinal canal and reach displaced disk material. The terms *contained* and *uncontained* are unfamiliar to most radiologists: in a contained herniation, the displaced disk material is still covered by a few intact but distended outer anular fibers, or by a capsule formed by outer anular fibers and the adherent posterior longitudinal ligament.

**Figure 11.** Various types of posterior central herniations. *A,* Small subligamentous herniation (protrusion) without significant disk material migration. *B,* Subligamentous herniation with downward migration of disk material under the PLLC. *C,* Sub-ligamentous herniation with downward migration of disk material and sequestered fragment (*arrow*).

The terms *subligamentous* and *extraligamentous* (or *transligamentous*) refer to the position of the displaced disk material with respect to the posterior longitudinal ligament. The anatomy of the posterior longitudinal ligament has been recently revised. It is a membranous structure that has multiple components: a deep layer attached to disks and vertebral bodies; a superficial layer attached to the dura by fibrous tissue (Hoffmann's
ligament); and lateral extensions known as the lateral membranes or peridural membranes (Fig. 12) (Figure Not Available). It should probably be referred to as the posterior longitudinal ligament complex (PLLC). It actually divides the epidural space into the perithecal space and the anterior epidural space, where displaced disk material can be entrapped (Fig. 13). A potential space allowing accumulation of displaced disk material has also been detected between the outer anular fibers and the deep fibers of the PLLC, on the posterior central aspect of the disk. Posterior midline herniations seldom rupture the PLLC and are generally subligamentous. The lateral membranes are less resistant and transligamentous herniations are usually the result of posterior off-center herniations or postero-lateral herniations.

**Figure 12.** (Figure Not Available) The PLLC is portrayed here in relation to various types of subligamentous disk displacement. At the disk level, posteriorly displaced disk material frequently occupies the midline. Below and above the disk, an anterior epidural space (AES) exists between the PLLC and the posterior aspect of the vertebral bodies. In this space, disk fragment motion across the midline is curtailed by a sagittal midline septum (*dashed line*). A delicate, translucent membrane (shown only on left side of drawing) is stretched between the free edge of the deep layer of the posterior longitudinal ligament and the lateral spinal canal. *(From Schellinger D, Manz HJ, Vidic B, et al: Disk fragment migration. Radiology 175:831-836, 1990; with permission.)*

**Figure 13.** Relationship of typical posterior disk herniations with the PLLC. *A* Midline sagittal section: unless very large, a posterior midline herniation usually remains entrapped underneath the deep layer of the PLLC and sometimes a few intact outer anulus fibers joining with the PLLC to form a capsule. The deep layer of the PLLC (*arrow*) also attaches to the posterior aspect of the vertebral body so that no potential space is present underneath. *B* Sagittal para-central section: the PLLC extends laterally at the disk level (*arrowhead*) but, above and below the disk, an anterior epidural space (as), where disk fragments are frequently entrapped, is present between the lateral (peridural) membranes and the posterior aspect of the vertebral bodies.
Quantifying the herniated disk material by measuring in millimeters its greatest diameter, or by evaluating its cross-sectional area in square millimeters, is rarely done. The resulting figures could be misleading without relating this measurement to the size of the spinal canal and the exact location of the lesion. A purely qualitative and subjective statement that a mild, moderate, or severe herniation is present, however, does not give the person reading the imaging report any indication as to the potential of the lesion to cause significant compression of the dural sac or individual exiting nerve roots. A reasonably precise scheme has been proposed, in 1995, by the Nomenclature Committee of the North American Spine Society. Measurements are taken from an axial CT or MR imaging section at the site of most severe compromise: canal compromise of less than 25% at that section is qualified as mild, 25% to 75% is moderate, 76% to 90% is moderately severe, and greater than 90% is severe. It is understood that such characterizations describe only the cross-sectional area at one level and do not account for the total volume of displaced material, displacement of neural tissue, or clinical significance. The usefulness of having four categories is questionable and can likely generate poor interobserver or intraobserver agreement, especially in situations where the central spinal canal is relatively narrow. Bonnevilles scheme should generate greater reliability (Fig. 14) . Separation of the cross-sectional area in three thirds can be applied to both the central spinal canal and the foramina. It can be agreed, by way of convention, that the terms mild, moderate, and severe lumen compromise by a disk herniation designate extension of the displaced disk material in the anterior, middle, or posterior third of the central canal or foramen, depending on the specified location of the herniation.

Figure 14. (Figure Not Available) The size of the herniation in the horizontal plane is assessed and designated by the numbers 1, 2, or 3, by establishing its extension in the anterior, middle, or posterior third of the spinal canal. (From Bonnevilles JF: Plaidoyer pour une classification par l’image des hernies discales lombaires: la carte-image. Rev Imag Med 2:557-560, 1990; with permission.)

Location of Herniated Material

Bonneville has also proposed an interesting and simple alpha-numerical system to classify, according to their location, the position of disk fragments that have migrated in the horizontal or sagittal plane (Figs. 15 (Figure Not Available) and 16) (Figure Not Available). Using more precise anatomic boundaries, unfortunately more familiar to surgeons than radiologists, Wiltse et al have proposed another system, which has been supported by the North American Spine Society. Anatomic zones and levels are defined using the following anatomic landmarks: medial edge of the articular facets; medial, lateral, upper, and lower border of the pedicles; and coronal plane at the disk center. On the horizontal plane (Fig. 17) (Figure Not Available), these landmarks determine the boundaries of the central zone; the subarticular zone; the foraminal zone; the extraforaminal zone; and the anterior zone (anterior to the coronal plane at the center of the disk). In the sagittal plane, they determine the boundaries of the diskal level, the infrapedicular level, the pedicular level, and the suprapedicular level (Figs. 18 (Figure
Not Available) and 19) (Figure Not Available). Radiologists interpreting axial CT or MR images may find it difficult to use the medial edge of the facets as the landmark that separates the central zone from the subarticular zone because the superior articular facets are generally not included in axial sections at the disk level. The alternative is to use the expression *posterolateral* to designate collectively all posterior herniations that are not midline but do not extend into a foramen, as was proposed by Bonneville.\(^9\) \(^10\) \(^11\)

**Figure 15.** (Figure Not Available) In the horizontal plane, herniations are labeled midline (a), posterolateral (b), foraminal (c), and extra-foraminal (d). (*From Bonneville JF: Plaidoyer pour une classification par l'image des hernies discales lombaires: la carte-image. Rev Imag Med 2:557-560, 1990; with permission.)*

**Figure 16.** (Figure Not Available) In the craniocaudal direction, disk migration is labeled +1, +2, +3, or -1, -2, -3, by referring to the height of a vertebral body, divided in thirds. (*From Bonneville JF: Plaidoyer pour une classification par l'image des hernies discales lombaires: la carte-image. Rev Imag Med 2:557-560, 1990; with permission.)*

**Figure 17.** (Figure Not Available) The anatomic zones identified on axial images. The *anterior zone* (not shown) is delineated from the *extraforaminal zone* by an imaginary coronal line in the center of the vertebral body. (*From Wiltse LL, Berger PE, McCulloch JA: A system for reporting the size and location of lesions in the spine. Spine 22:1534-1537, 1997; with permission.)*

**Figure 18.** (Figure Not Available) The anatomical levels identified on craniocaudal images. (*From Wiltse LL, Berger PE, McCulloch AJ: A system for reporting the size and location of lesions in the spine. Spine 22:1534-1537, 1997; with permission.)*

**Figure 19.** (Figure Not Available) Coronal view of the main zones and levels. (*From Wiltse LL, Berger PE, McCulloch JA: A system for reporting the size and location of lesions in the spine. Spine 22:1534-1537, 1997; with permission.)*

**Composition of Herniated Material**

Displaced disk material may consist of glycosaminoglycans, type 1 or 2 collagen, end plate cartilage, and bone fragments avulsed from the ring epiphysis. A reactive inflammatory reaction usually results in edematous tissue followed by granulation tissue, which may undergo calcification (Fig. 20). Necrotic and partially resorbed displaced disk material sometimes produces a large fluid-filled pouch, distinguishable from the common high-intensity zone, because of its size (Fig. 21), or a gas-filled cavity generally in continuity with gas in the intervertebral space (Fig. 22).\(^{42}\) These characteristics may be meaningful if intradiskal injection therapy is considered. In imaging reports, herniations exhibiting calcium deposits, and those exhibiting replacement of disk material by gas or a relatively large fluid collection, can be qualified as chronic herniations.
Figure 20. A. CT scan demonstration of a small posterior central L4-L5 calcified subligamentous herniation. The resistant deep layer of the PLLC restrains displacement of the disk material in the posterior central direction and does not allow a detectable distortion of the disk contour. In this particular case, the presence of the calcification is actually the only evidence that a posterior midline anular tear and a small subligamentous herniation are present. B. Posterior right central and sub-articular L5-S1 calcified disk herniation in same patient. Posterolateral herniations are generally more conspicuous than posterior midline herniations because the deep layer of the PLLC gets thinner away from the midline.

Figure 21. Posterior central midline L4-L5 herniation in a 52-year-old man demonstrated on a T2-weighted midline MR sagittal section. There is intervertebral space narrowing with loss of normal central disk signal
intensity, while the herniated disk material demonstrates high signal intensity consistent with a predominantly fluid consistency.

Figure 22. CT scan demonstration, in a 51-year-old woman, of a left posterolateral L5-S1 disk herniation consisting essentially in a gas-filled pouch (white arrow). Gas is also present in the central portion of the intervertebral disk space (black arrow).

DIAGNOSTIC IMAGING AND CHARACTERIZATION OF A HERNIATED LUMBAR DISK

Assessing the validity of the currently used imaging procedures to diagnose a herniated lumbar disk is not an easy endeavor. The validity of a measurement is the extent to which it corresponds to the true biologic value or some accepted gold standard. With the exception of postmortem studies, evaluation of the pathoanatomy by the surgeon in the operating room has always been considered the gold standard but this does not constitute an ideal situation. Inspection of the disk through a small laminectomy incision to determine, for instance, if nuclear fragments lie within or outside the anular fibers may not be very reliable. Also, unbiased intraoperative determination of a normal, degenerated, or herniated disk in a patient with sciatica may also be difficult. Because the validity of diskography has been previously established by postmortem studies and surgical correlations, it is sometimes used as a gold standard in situations where no surgery has been performed.

Conventional Radiographs

Lumbar disk herniations can exceptionally be diagnosed directly on good quality lateral projections because the x-ray attenuation is slightly greater in displaced disk material than in epidural fat. Occasionally, a calcified rim outlines the displaced disk fragment.
In most situations, however, narrowing of an intervertebral disk space in the absence of other evidence of chronic diskopathy is the only detectable sign suggesting the presence of a disk herniation. To my knowledge, the sensitivity and specificity of this sign has never been assessed. The accepted rule of thumb is that the height of a given lumbar intervertebral disk space should always be slightly greater than the height of the above located interspace. This rule does not apply to the transition disk immediately above the sacrum (usually L5-S1). The specificity of this sign is probably quite high but a few false-positives are seen, especially at the L4-L5 level, because of minor congenital hypoplasia. The presence of posterior or foraminal vertebral body osteophytes, associated or not with disk space narrowing, is a definite sign of a chronic disk herniation.

**Figure 23.** *A.* Chronic left L3-L4 extraforaminal disk hernation in a 54-year-old man, suspected on an AP radiograph demonstrating a calcified shell on the left side of the intervertebral disk space (white arrow). *B.* Axial CT scan section confirming the diagnosis of a chronic extraforaminal L3-L4 herniation.

**Myelography**

Myelography is essentially an exploration of the subarachnoid space. Disk herniations are demonstrated only indirectly, because they can cause thecal sac deformity and individual nerve root sleeve filling defects (Fig. 24). Of all the special imaging procedures,
myelography is the only one that allows upright projections with full weight bearing. It is not unusual to demonstrate in this way small posterior central or posterolateral herniations that are undetectable on CT sections. Interestingly, the overall sensitivity of myelography to detect disk herniations has been found to be higher than that of CT, whereas its specificity has been found to be lower. In comparison with standard CT examination, which usually includes only the three or four lower lumbar disks, myelography easily allows coverage of the entire lumbar area and assessment of the intrathecal structures (cauda equina and conus medullaris). Far lateral foraminal herniations, extraforaminal herniations, and anterior herniations, however, are not detected. The sensitivity for detection of posterior central L5-S1 herniations is also relatively poor because of the greater distance between the thecal sac and the posterior aspect of this particular disk.

**Figure 24.** L5-S1 disk herniation in a 25-year-old man, detected by indirect signs using lumbosacral myelography. *A,* Upright oblique projections showing a filling defect of the left S1 root sleeve (white arrow), suggesting significant nerve root compression by a left posterolateral disk herniation. The right S1 root sleeve fills normally with contrast (black arrow). *B,* Subtle compression of the anterior wall of the dural sac by displaced disk material (small arrows), demonstrated on upright lateral projection. This sign is usually absent in the presence of a large amount of fat and venous structures in the anterior epidural compartment.

**CT**

The sensitivity of CT to diagnose a herniation of the nucleus pulposus at the L5-S1 interspace is greater than that of myelography if images in the exact plane of the disk can be obtained. Otherwise, the superiority of plain CT over myelography to demonstrate disk herniations has not been established, but CT has the distinct advantage of being
noninvasive and provides direct anatomic information. Large herniations are easily detected but, as explained previously, the distinction between protrusions and extrusions is often difficult without sagittal reconstructions. CT essentially allows an assessment of the contour of the disk. The diagnosis of very small herniations, in the absence of direct or indirect evidence of a radial tear, is hazardous and associated with a high percentage of false-positives and false-negatives. The diagnosis of moderate and large size herniations in different directions is usually possible but anterior herniations are rarely diagnosed, not because they are not detectable but because observers pay little attention to the anterior contour of the disk (Fig. 25). Because the PLLC cannot usually be identified, the distinction of subligamentous from transligamentous herniation can only be suggested, in most cases, by the size of the herniated material. A definite diagnosis of sequestration is rarely possible. Calcifications within the displaced material are readily seen but may be difficult at times to differentiate from an accompanying osteophyte or an avulsed bone fragment from the vertebral body ring epiphysis (Fig. 26). The presence of gas in the herniated material is easily detected.

**Figure 25.** Anterior L4-L5 herniation demonstrated by CT scan in a 51-year-old woman with chronic low back pain. Although sometimes quite conspicuous, such herniations are rarely reported because observers pay little attention to the anterior contour of the disk.
Figure 26. CT scan demonstration of a posterior right central L4-L5 disk herniation in a 38-year-old woman, with avulsion of a bone fragment from the ring epiphysis and adjacent part of the superior L5 end plate. Reactive osteosclerosis is seen around the vertebral body defect (arrows), suggesting a chronic lesion.

**CT Myelography**

This association combines the advantages of both imaging modalities. The fact that its accuracy has been reported as being less \[22\] higher \[1\] or equivalent \[82\] to MR imaging is a reflection of the differences in technologic advancement and pathologic nomenclature that hamper valid comparisons between different studies.

**MR Imaging**

Most reported studies establish MR imaging as the first choice modality to diagnose a herniated lumbar disk \[5\] \[22\] \[32\] \[46\] The associated intravenous injection of a paramagnetic agent has been found useful to demonstrate some anatomic features of disk disease in patients with no previous lumbar disk surgery \[56\] \[68\] \[90\] MR imaging provides a better assessment of disk morphology than CT or CT myelography because sagittal sections are routinely obtained. Assessment of foraminal involvement by displaced disk material is more accurate (Fig. 27) and anterior disk herniations can be detected more easily than with CT or CT myelography. If one is looking specifically for herniated lumbar disks associated with nerve root compression, however, it has been demonstrated that CT is equally accurate \[82\] Alterations of the central or peripheral disk signal intensity on T2-weighted images are seen in most disks afflicted with an anular tear \[48\] and alert the observer to scrutinize the disk contour in search for local modifications indicative of a herniation. Because the signal of the displaced disk material is usually very similar to that of the outer anulus, PLLC, and vertebral body cortical bone, small herniations are generally more conspicuous on axial CT sections than on corresponding axial MR imaging sections. Gas and calcium deposits within the displaced fragment cannot usually
be detected but associated vertebral body bone marrow changes are typically seen and are helpful in differentiating acute from chronic processes. The occasional presence of a high-intensity zone in the herniated material, with an occasionally enhancing border after contrast injection, is probably caused by a mixture of displaced nuclear material, acute and subacute inflammatory tissue, and neovascularized reactive tissue. Contradictory reports have been published regarding the accuracy of MR imaging to differentiate subligamentous from transligamentous herniations. Understanding the anatomy of the PLLC is helpful to make the distinction (Fig. 28) (Figure Not Available). Masaryk et al. have suggested that MR imaging is accurate to distinguish sequestered disks from other forms of lumbar disk herniations, but most observers find this distinction difficult to establish.

Figure 27. A, Left L4-L5 foraminal herniation well seen on an intermediate-weighted left parasagittal MR section (arrow), in a 47-year-old man. B, The lesion is much less obvious on intermediate-weighted (left) and T2-weighted (right) axial sections, and was in fact more conspicuous on the corresponding CT scan section.

Figure 28. (Figure Not Available) A, Subligamentous disk herniation. Left, T1-weighted image demonstrating displaced disk material with a smooth outline, imposed by the demarcation of the anterior epidural space (AES) by the lateral membrane of the PLLC. Right, Correlative drawing. B, Transligamentous disk herniation. Left, T1-weighted image of a large disk herniation (cervical in this case) which has ruptured through the posterior confines of the AES. Penetration of the right lateral membrane can be observed (arrow) and the disk fragment contour is serrated. Right, Correlative drawing. (From Schellinger D, Manz HJ, Vidic B, et al: Disk fragment migration. Radiology 175:831-836, 1990; with permission.)
During 30 years (1950 to 1980) when myelography was the only available imaging technique to demonstrate lumbar disk herniations, diskography was an invasive but efficient way to demonstrate posterior central L5-S1 herniations and other large herniations (other than posterior central and paramedial) that could not be detected by myelography. These herniations are now usually well demonstrated by CT and MR imaging. Comparing the accuracy of five imaging modalities (excluding MR imaging) for the diagnosis of lumbar disk herniation, Jackson et al found that CT diskography (Fig. 29) was the most accurate test (87%) compared with 77% for CT myelography, 74% for CT, 70% for myelography, 64% for pain reproduction during diskography, and 58% for diskography without CT. Disk injection reproduced the patient's clinical pain pattern in only 36% of herniated disks. This clinical test, isolated from the images, had high specificity (89%), but low sensitivity (43%) for the diagnosis of disk herniation. The reported low sensitivity of diskography images (unassociated with CT) to diagnose disk herniation is to be expected, the purpose of the intradiskal injection being primarily the demonstration of an anular tear: the contrast leaking through the tear only occasionally delineates an extruded fragment. When a disk herniation has been diagnosed by other imaging modalities, diskography allows to determine if the herniation is contained or noncontained (Figs. 30 and 31); this information may have clinical relevance. It also allows to establish if the displaced disk material is communicating or not with the parent disk, and establishes the likelihood that it is sequestered or not. There always remains a possibility that the contrast, injected under pressure, may reach a disk fragment that is nevertheless sequestered by leaking through the associated anular tear. CT diskography also allows assessment, in most cases, of the integrity of the PLLC. The superior sensitivity of diskography over MR imaging to demonstrate anular tears has been well established. The presence of a radial tear and the inflammatory reaction it creates may be symptomatic despite the absence of true disk herniation.

Figure 29. L4-L5 CT diskogram demonstrating a large left posterolateral radial anular tear associated with
a left foraminal and extraforaminal herniation (same patient as in Figure 28) (Figure Not Available).

Figure 30. Contained posterior L4-L5 and L5-S1 disk herniations in a 57-year-old man, demonstrated by diskography. The L3-L4 disk is normal.

Figure 31. Noncontained L4-L5 disk herniation in a 23-year-old woman. Reflux of injected contrast is seen in the anterior epidural space above and below the disk space. The L5-S1 disk also demonstrates incomplete anterior and posterior radial anular tears.

SUMMARY
The absence of universal nomenclature standardization with respect to the definition of a disk herniation and its different categories, especially regarding type and location, is still a major problem that will only be overcome when major national or international scientific societies join efforts to support a particular scheme. Meanwhile, it is important to realize that the two models that are currently most used are based on a different perspective. Trying to straddle the two by opposing, for instance, bulging disk and herniation is doomed to failure because this exercise defies formal logic. MR imaging is currently the most accurate noninvasive imaging modality to diagnose a disk herniation and to determine its exact location. The determination of some pathoanatomic characteristics of herniated disks (type and composition) may require the use of CT, diskography, or CT diskography.

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