The Relationship Between Symptoms and Abnormal Magnetic Resonance Images of Lumbar Intervertebral Disks

Although numerous tissues may be involved, injury to the lumbar intervertebral disk (IVD) remains as a prominent source of low back pain (LBP) and lower-extremity radiculopathy. For the past 60 years, following the influential article by Mixter and Barr, an extraordinary amount of research has been published regarding the relationship of lumbar disk degeneration to mechanical abnormalities and pain syndromes involving the low back. New data regarding histochemical properties, mechanical behavior, and factors that predispose the IVD to dysfunction are appearing frequently and have led to much debate about the actual role of the IVD in symptom production.

One of the most important advances relating to the evaluation of the IVD comes from the high-resolution in vivo images of the lumbar spine obtained by magnetic resonance imaging (MRI). Recent MRI studies of people with and without LBP have yielded surprising results and have led many authors to reexamine the premise that altered disk morphology results in the production of symptoms. This clinical update briefly reviews the traditional views regarding the IVD's role in LBP and lower-extremity radiculopathy and compares them with recent in vivo findings based on lumbar MRI.

Structure of the Lumbar Intervertebral Disk
The IVD is a composite of mucopolysaccharide and collagen that provides a flexible interspace between adjacent vertebral bodies. The structure is described as consisting of a nucleus pulposus and an annulus fibrosus that are intimately related to one another and to the cartilaginous vertebral end plates. The nucleus pulposus is highly hydrophilic, with water accounting for between 70% and 90% of its mass. It contains collagen fibrils, chondrocytes, mineral salts, and proteoglycans that aggregate to form an elastic gel located within the central portion of the healthy IVD. The annulus fibrosus


Key Words: Intervertebral disk, Low back pain, Lumbar spine, Magnetic resonance imaging.

Paul Beattie
is morphologically similar to the nucleus pulposus, although it has a lower water concentration. It is organized in a series of layers of parallel-arranged collagenous bands that create a strong, cartilaginous ring encompassing the nucleus pulposus. These bands act to support the nucleus pulposus while isolating it from adjacent structures. The annulus fibrosus and the anterior and posterior longitudinal ligaments bind the vertebral bodies to one another, stabilizing lumbar motion segments.1,4,9

Although the nucleus pulposus and the annulus fibrosus are often seen as two separate structures, they contain similar components in different concentrations (ie, the mass of the nucleus pulposus contains more water than that of the annulus fibrosus). Within the IVD, there is no clearly visible boundary between the nucleus pulposus and the annulus fibrosus but rather a gradual transition between the two structures.4 As an IVD ages, the nucleus pulposus becomes less hydrated and more fibrous, resulting in decreased morphologic distinctions between the two regions.1,4,5,7

Mechanically, the IVD acts as a “spacer” to maintain the normal intervertebral disk space, while absorbing and transmitting loads acting on the vertebral column.1,4,8,9 According to Humzah and Soames,4 this function is enhanced by the collagen fibrils within the nucleus pulposus, which form a three-dimensional latticework. This latticework helps to create a hydraulic zone within the center of disk that can transfer compressive loads acting on the vertebral column to the fibrous walls of the IVD by a “radial expansion” of the nucleus pulposus.1,4 This system is linked to the degree of hydration of the nucleus pulposus and the stability of the annulus fibrosus.

Role of the Intervertebral Disk in Low Back Pain and Radiculopathy
Degeneration of the IVD is characterized by a loss of hydration of the nucleus pulposus and disruption of the annulus fibrosus resulting from a variety of mechanical and biochemical factors. A series of degenerative changes may be described as a process of destabilization followed by restabilization (Fig. 1).5,9 A brief summary of this process follows. Initially, tears in the annulus fibrosus result in loss of restraint on the nucleus pulposus. The concomitant internal derangement of the nucleus pulposus results in disk-space narrowing and the potential for a reduced load-bearing capacity of the motion segment. Nuclear material is no longer firmly contained within the IVD and will travel in the direction of least resistance, often migrating posteriorly or posterolaterally. This migration may result in a “bulge” or “contained herniation” of the annulus fibrosus into the vertebral foramen or radicular canal. If the annular restraints lose their stability, nuclear material may extrude. This is the so-called “true herniation” or “noncontained herniation.” It is important to note that both of these types of herniation are the result of a degenerative process. In a nondegenerative IVD, tissue failure following trauma typically occurs at the cartilaginous end plate; a normal IVD that is traumatized will rarely herniate.10

It has been proposed that, following the internal disruption of the IVD, the resulting loss of disk height as well as the reduction in the stabilizing capacity of the annulus fibrosus lessens the inherent stability of the motion segment (ie, segmental instability).11 In response to this condition, reactive bone formation often occurs at both the margins of the vertebral body and the neural arch and leads to the classic radiographic findings of osteophytosis and subchondral sclerosis.5,12

The process of degeneration is defined by structural changes, but which of the changes will cause symptoms is less obvious. Theories can be generated as to how, for each stage in the degenerative process, clinical manifestations of pain may occur. The outer annulus fibrosus has been shown to contain free nerve endings and vascular channels; thus, sprains of this tissue with and without displacement of nuclear material have been proposed as a cause of acute LBP.1,2,13 The concept of a disk bulge that results from internal disruption of the IVD has been theorized as a primary cause of LBP.5,14 Disk-space narrowing associated with degenerative changes of the IVD influences the mechanics of joint movement from the perspective of the motion segment and has been postulated as a primary cause of segmental instability, which may be associated with LBP.5,12 The herniated lumbar IVD is frequently implicated as a cause of LBP.
The formation of osteophytes in the bony elements of the spine along with hypertrophy of the ligamentum flavum can result in stenotic changes in the vertebral and intervertebral foramina. These changes, in turn, can affect the mobility of neural tissues and in extreme cases cause sustained compression, leading to lower-extremity paralysis, anesthesia, and bowel and bladder dysfunction.

The model of degeneration described has some face validity relative to possible pain production at the various stages of degeneration. In some instances, further validation has been established based on elimination of symptoms following injection or surgical procedures. The distinction, however, between anatomical changes of the motion segment and the symptoms of LBP or radiculopathy remains unclear.

Magnetic Resonance Imaging of the Lumbar Spine
Over the last 15 years, advances in biomedical imaging have resulted in the widespread use of MRI as an evaluative tool in the diagnosis of painful spinal disorders. Magnetic resonance imaging provides high-resolution, multiaxial images that represent thin “slices” of tissue. Because MRI is noninvasive and does not use ionizing radiation, it provides less risk to the patient than other commonly used spinal imaging procedures such as computerized tomography, diskography, or myelography.

To create the images, tissues are contrasted based on their relative concentration of hydrogen ions, with the resulting signal being a function of a tissue’s degree of water content. Because of the regional differences in hydration of the IVD, MRI is an extremely useful modality for contrasting the nuclear and annular regions. For example, the nuclear region creates a “high” or bright signal intensity on T2-weighted MRI, whereas the annular region generates a “low” or dark signal. This contrast is illustrated in Figure 2. Examiners can easily identify degenerative disks by the presence of reduced signal intensity of the nucleus pulposus. Additionally, disk bulges and herniations can be identified based on their characteristic morphology (Fig. 3).

Figure 1.
The sequence of events occurring during the process of degeneration of the intervertebral disk.

Findings of Lumbar Intervertebral Disk Abnormalities in People With and Without Low Back Pain
Because of the limited availability of MRI scanners and the cost associated with each examination, most early work in lumbar MRI was obviously focused on symptomatic individuals. Examiners, however, began to question the specificity of disk degeneration and herniation for LBP and sciatica when a high prevalence of these findings was noted in asymptomatic individuals. Table 1 summarizes the findings of studies that examined the nature and prevalence of disk abnormalities in subjects without LBP. When evaluating the data from these studies, it becomes apparent that some form of single or multilevel degeneration or disk bulge is visible on the MRIs of between 28% and 85% of the adult male and female population who do not have activity-limiting LBP. The prevalence of these findings is dramatically higher in the elderly population, with the two lower
lumbar segments involved substantially more than the upper three levels. Disk degeneration and bulge can occur independently or in combination with one another.

A logical question that arises is, “What are the MRI findings that are specific to patients with LBP?” Much work has been published recently comparing MRI findings with symptom reproduction at various spinal levels during diskography. Additionally, authors have reported comparisons of MRI findings obtained before and following lumbar disk excision. An in-depth review of this literature is beyond the scope of this article; however, the findings of a few recent studies are of great interest. For example, the prevalence of abnormal lumbar MRI findings appears to be higher in people with low back symptoms than in those without such symptoms. Paajanen et al. when examining 20-year-old military recruits, reported that one or more disks were abnormal (degenerative) in 57% of patients with LBP (n=75) and in 35% of subjects without symptoms (n=34). Parkkola et al. reported that 43% of the lower three disks were degenerated in control subjects without low back symptoms (n=60), whereas 60% of the lower three disks were degenerated in age-matched patients with LBP (n=48). Disk bulge was present in 15% of the control subjects compared with 42% of the patient group. The authors, however, did not differentiate between disk bulge and other types of disk displacement such as protrusion or extrusion.

Buirski and Silberstein compared the MRI findings of 115 patients with LBP with those of 63 patients with no history of LBP. Disk degeneration was classified on a six-point scale (1-6) based on the increasing degree of...
Table 1.
Summary of Studies Showing Prevalence of Disk Abnormalities in Asymptomatic Subjects

<table>
<thead>
<tr>
<th>Authors and Year of Study</th>
<th>Sample (No. of Subjects)</th>
<th>Dependent Measures</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powell et al., 1986</td>
<td>302 nonpregnant women</td>
<td>Disk degeneration, bulge</td>
<td>33% of subjects aged 21–40 y had abnormal disks</td>
</tr>
<tr>
<td></td>
<td>82 pregnant women</td>
<td></td>
<td>Disk bulge and degeneration independent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No increase in disk abnormalities in pregnant women</td>
</tr>
<tr>
<td>Weinreb et al., 1989</td>
<td>41 nonpregnant women</td>
<td>Disk bulge, herniation</td>
<td>54% of nonpregnant women had disk abnormalities</td>
</tr>
<tr>
<td></td>
<td>45 pregnant women</td>
<td></td>
<td>53% of pregnant women had disk abnormalities</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No increase in disk abnormalities in pregnant women</td>
</tr>
<tr>
<td>Boden et al., 1990</td>
<td>67</td>
<td>Disk bulge, herniation</td>
<td>28% of subjects had substantial disk abnormalities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disk degeneration</td>
<td>Spinal stenosis</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>78 abnormal disks in entire sample</td>
</tr>
<tr>
<td>Buirski and Silberstein, 1993</td>
<td>63</td>
<td>Disk degeneration</td>
<td>84% of patients had disk abnormalities</td>
</tr>
<tr>
<td>Jensen et al., 1994</td>
<td>98</td>
<td>Disk bulge</td>
<td>64% of patients had at least one disk abnormality</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disk protrusion</td>
<td>52% of patients had disk bulge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disk extrusion</td>
<td>27% of patients had disk protrusion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1% of patients had disk extrusion</td>
</tr>
<tr>
<td>Boos et al., 1995</td>
<td>46</td>
<td>Disk degeneration</td>
<td>85% of patients had at least one degenerative disk</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Disk herniation</td>
<td>76% of patients had at least one herniated disk</td>
</tr>
</tbody>
</table>

Boos et al. compared the lumbar MRI findings of 46 subjects scheduled to undergo diskectomy with those of 46 individuals without symptoms who were matched by age, gender, and physical risk factors. The authors ranked the severity of disk degeneration and displacement within the vertebral and intervertebral foramina. The presence of neural compromise also was assessed (Tab. 2). The authors noted that the prevalence of disk abnormalities in both groups was much higher than previously described. Differences were found between groups for disk herniation, which was present in 76% of the asymptomatic subjects and in 96% of the patients. There was no significant difference in the presence of disk degeneration between groups. Disk degeneration was present in 85% of the asymptomatic subjects and in 96% of the patients. The authors reported that the only substantial morphologic difference was the presence of neural compromise. Minor neural compromise was present in 17% of the asymptomatic subjects and in 28% of the patients. Major neural compromise was present in only 4% of the asymptomatic subjects compared with 54% of the patients. The authors concluded that disk herniation had a much higher prevalence in individuals without symptoms than was previously believed. They suggested that their use of a more sensitive rating scale than those used by previous authors may have contributed to this finding.

Tullberg et al. recently reported the results of lumbar MRI with gadolinium enhancement obtained from 36
patients 1 year after disk resection for lower-extremity radioculopathy. Noticeable disk herniation was still present in 8 subjects, 4 of whom had no appreciable radioculopathy. The authors reported no consistent correlation between postoperative symptoms and MRI findings. Fraser et al. reported 37% (15/42) of patients had MRI evidence of persistent disk herniation 10 years after laminectomy or chymopapain injection. The authors noted that the presence or absence of disk herniation had no bearing on successful long-term outcome following these procedures. Bozzao et al. reported that in patients with MRI findings of disk herniation who had undergone nonoperative treatment for LBP, 48% had a reduction of the herniation of greater than 70%, 15% had a reduction between 30% and 70%, 29% had no change, and 8% had an increase in the degree of herniation.

An interesting issue relates to the predictive value of MRI findings in discriminating between good and poor candidates for lumbar disk surgery. Gill and Blumenthal reported that patients (n=14) who had normal MRIs obtained preoperatively had dramatically higher pain and self-rated disability (Oswestry Index) at 20 months following lumbar interbody fusion at L5-S1 than did those subjects (n=39) who had abnormalities visible on MRI preoperatively. The authors concluded that the role of surgical intervention for patients with normal MRIs should be reexamined.

**Clinical Implications**

Although patients with LBP represent a large subset of patients receiving outpatient physical therapy, consensus is lacking regarding the optimal methods by which to classify and treat these individuals. The data on MRI findings further illustrate how the use of pathoanatomic findings for classification or treatment is problematic. Although the availability of high-resolution in vivo MRI has the potential to provide enormous amounts of information relating to spinal morphology, therapists must be careful not to make premature clinical judgments regarding the etiology or severity of a patient’s condition based on these findings.

All but the most severe findings of disk degeneration or herniation visible on MRI are nonspecific for LBP or radioculopathy. The finding of disk abnormality, however, may have a profound effect on a patient’s beliefs regarding the severity of his or her clinical condition. A patient who has incorrectly been told that the finding of a degenerative or bulging disk is responsible for his or her symptoms may perceive a higher degree of morbidity than is actually warranted. This perception may lead the patient to believe that his or her spine is permanently damaged and that he or she will be permanently disabled. This phenomenon is especially true for patients with conditions such as disease conviction, low self-efficacy, and high degrees of fear-avoidance behavior. Convincing a patient that the prognosis for acute LBP remains favorable despite the abnormalities observed on MRI can be a difficult task.

Another important consideration for clinicians relates to the patient whose symptoms do not correspond neurologically to the level and side of a disk herniation. For example, patients are often encountered who complain of pain contralateral to a posterior-lateral disk herniation observed on MRI. Considering this observation, clinicians must be careful not to make premature judgments based on MRI findings of disk degeneration, bulge, or herniation without confirmation from the clinical examination.

There are numerous medical-legal implications of MRI findings. The morphologic abnormalities observed on MRI are often considered as “hard signs” and may be quite important in such instances as personal injury litigation. An examiner must consider that a visible disk abnormality may have been present prior to the onset of a patient’s symptoms and may not necessarily be causally related to the patient’s current clinical condition.

The majority of people with LBP report an increase in symptoms with increased spinal loading, such as when standing, sitting, or bending. During MRI, the patient is usually in a static supine position, often for several minutes prior to imaging. Images obtained in this manner may not reflect the actual tissue relationships that provoke symptoms. Preliminary data have indicated differences in the position of the nucleus pulposus in different supine postures; thus, it is logical to assume that measurable differences in the relationship of the IVD to other spinal tissues occur between supine and various upright postures. Therefore, it may not be the degree of disk degeneration or herniation but rather its overall effect on the stability of the motion segment that is the critical element in symptom production. Other nonmechanical factors such as the concentration of various inflammatory by-products and neurogenic mediators as well psychosocial issues have an enormous influence on the patient’s report of pain.

Magnetic resonance imaging remains an essential procedure for the identification of a wide variety of pathologies of the spine and its associated tissues. The results of the studies reviewed in this article suggest that the MRI findings of disk degeneration and bulge/herniation are often present in people without back pain, inferring a low degree of specificity for these findings as they relate to LBP. These findings, however, are rarely absent in those with LBP, inferring a high degree of sensitivity. Because of methodological differences in classification...
systems for disk abnormalities, comparison across studies is difficult.

Several strategies are being used to more clearly define the specificity and sensitivity of MRI findings of disk degeneration or herniation. The expanded classification system for disk abnormalities described by Jensen et al (Tab. 3) may provide examiners with an improved method for discriminating among various levels of abnormality. Boos et al reported that the most notable difference between the MRIs of asymptomatic individuals and those of individuals with LBP and sciatica was the dramatic difference in neural compromise. The authors postulated that the overall degree of the disk herniation is not as important in pain production as is the location of the disk herniation in relation to the size of the spinal canal.

Perhaps there are other markers that have a high specificity and sensitivity for LBP. For example, April and Bogduk and Schelhas et al have described a "high-intensity zone" in the posterior annulus fibrosus that frequently identifies IVDs that may result in symptom reproduction during diskography. Improvements in resolution and contrast as well as "fast-scan" technology continue to generate more detailed MRI images. Prototypes exist for large-bore magnets to allow patients to be imaged in a variety of postures, and "dynamic MRI" is currently being perfected. These advances will have an extraordinary influence on our knowledge of pathokinesiology.

**Summary**

The finding of various degrees of lumbar disk degeneration or herniation is common in people who have no complaints of LBP. These findings may be present in the majority of people without activity-limiting LBP. Although MRI findings can be very useful in cases of severe back pain, clinicians must avoid biasing themselves toward the belief that a lumbar disk abnormality is causally related to a patient's symptoms and signs without the corroboration of other physical findings. Continued advances in imaging technology will improve the diagnostic usefulness of lumbar MRI in detecting the sources of LBP and lower-extremity radiculopathy.

**Acknowledgments**

I thank Stuart Rubin, MD, and Christopher Maher, PT, for their kind assistance in the preparation of this article.

**References**


---

**Going to Minneapolis?**

**Don’t miss these events sponsored by Physical Therapy:**

**Abstracters and Book Reviewers Workshop**
Saturday, June 15, 1996
3:00-5:00 pm
Interested in becoming involved in the Journal but unsure where to start?
Physical Therapy Associate Editor Chuck Ciccone, PhD, PT, shows you the ropes, including how to write a book review and an abstract of an article, in this interactive workshop.

**“Ask the Journal”**
Sunday, June 16, 1996
3:30-5:00 pm
Everything you always wanted to know about the peer review process and about the Journal—how to read it, use it, and submit articles to it. An open forum for exchanging ideas, suggestions, criticisms. The Editor and the Editorial Board want to hear from you!

**Manuscript Reviewers Workshop**
Monday, June 17, 1996
3:30-6:30 pm
Follow the manuscript review process—using an actual manuscript—from start to finish in this interactive workshop led by Editor Jules Rothstein, PhD, PT, FAPTA, and the Journal’s Editorial Board. This year’s focus: the case report. Everyone is welcome—writers and potential writers, readers, reviewers, students. A wine-and-cheese reception follows.