Degenerative Joint Disease of the Spine

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KEYWORDS

• Lumbar • Cervical • Degeneration • Disk • Zygapophysial joint

KEY POINTS

- Degenerative changes are an expression of metabolic stress in spinal joints.
- Genetic factors predispose to degenerative changes, but age is the strongest correlate.
- Degenerative changes do not constitute a diagnosis because there is little, if any, correlation with pain.
- In contrast, the morphologic and biophysical features of internal disk disruption correlate strongly with back pain, as do certain magnetic resonance features.

INTRODUCTION

Throughout the vertebral column, consecutive vertebrae are connected by a triad of joints: an intervertebral disk and a pair of zygapophysial joints. These joints can show changes that have attracted various labels, each using the adjective degenerative. These labels include degenerative disk disease, disk degeneration, and degenerative joint disease. This is an unfortunate adjective because it can imply a hostile process, a noxious process, or a condition that qualifies as a diagnosis for spinal pain. Each of these implications is wrong.

The word degeneration implies falling apart or decaying, with the further implication that the process is inexorable and incurable. This meaning might not be what radiologists intend, but it is what many patients perceive the word to mean.[1–3] Moreover, patients explicitly associate it with poorer prognosis.[3] Yet the biologic evidence shows that the changes in question are neither destructive nor malevolent. What is destructive is the fear that a rubric such as degenerative evokes in patients. It tells them that they have an incurable disease when, in truth, they do not.

> Degenerative joint disease is a disturbing label that patients associate with a poor prognosis.

The most common reason why patients undergo imaging of the spine is pain. In the past, degenerative disk disease, or degenerative joint disease, was invoked as the diagnosis for that pain. It is still maintained in some circles, particularly in medicolegal disputes, that the patient's pain can be attributed to preexisting degenerative changes. Yet there is no known mechanism whereby degenerative changes can be painful, and the epidemiologic evidence shows that they are not. This evidence precludes degeneration from being used as a diagnosis for spinal pain.

DEFINITION

There is no universally accepted, comprehensive definition of degeneration. It means different things to different experts, depending on what they look at and the tools with which they look. To a biochemist, degeneration means changes in proteoglycans,

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changes in the relative proportions of different proteoglycans, changes in the type of collagen, and changes in water concentration. To a pathologist, degeneration means osteophytes, desiccation, fragmentation, and fissures. To a radiologist, degeneration can mean osteophytes, loss of disk height or loss of joint space, subchondral sclerosis, or reduced signal intensity on magnetic resonance (MR) imaging, or altered shape of the disk.

Nevertheless, it is possible to unify this spectrum. Degeneration is not a disease; it is the way that joints express themselves in response to insults. Moreover, connective tissues are limited in how they might express themselves, and degeneration may be the only available means by which a joint might respond to an insult. The clinical significance of degenerative changes lies not in the changes themselves but in what precipitates them. Sometimes the causes are clinically significant; sometimes they are not. Clinical significance arises if and when the changes are a manifestation of a systemic, metabolic disorder. Clinical significance evaporates when the changes are no more than a correlate of age. The responsibility of physicians lies not in simply recognizing degenerative changes, but in determining why they have arisen.

BIOLOGY

At a molecular level, intervertebral disks and synovial joints are essentially similar. The nucleus pulposus is homologous to articular cartilage; the anulus fibrosus is homologous to the joint capsule; and the vertebral end plate is homologous to subchondral bone. The nucleus pulposus and articular cartilage both contain water held by proteoglycans, which, in turn, are bound by collagen. They differ only with respect to the exact type of proteoglycans and the size of the aggregates that they form. Consequently, descriptions of the molecular biology of synovial joints effectively apply to intervertebral disks, and vice versa.

In disks and in articular cartilage, homeostasis is maintained by chondrocytes (**Fig. 1**).[4] Fibroblasts are responsible in joint capsules, and fibroblasts or chondrocytes are responsible in the anulus fibrosus. The chondrocytes exercise both synthesis and degradation. They synthesize the proteoglycans that form the matrix of the nucleus or articular cartilage, and the collagen that binds the matrix or forms the anulus fibrosus or joint capsule. Once formed, the matrix attracts and holds water. The matrix components are in slow, but constant turnover. To make way for refreshed components, old components must be removed. This goal is achieved by metalloproteases than can degrade proteoglycans and collagen. Chemical agents that promote synthesis include transforming growth factor, basic fibroblast growth factor, and insulinlike growth factor. Cytokines that promote degradation are tumor necrosis factor α and interleukin-1. Degradation is also promoted by superoxide radicals and nitric oxide.

If, for whatever reason, the balance between synthesis and degradation is disturbed to favor degradation, so-called degenerative changes occur (see **Fig. 1**). These changes are expressed at the molecular level by changes in the nature and concentration of various proteoglycans, and their ability to hold water; cross-linking occurs in the collagen both in the matrix and in the capsule or anulus fibrosus. At the microscopic level, the components fibrose, and can crack or tear. Macroscopically, the matrix can thin and fragment. Cross-linking of collagen stiffens it, which can be detected biomechanically or expressed clinically as reduced range of movement. Dehydration depressurizes the matrix, and is reflected as reduced signal intensity on MR imaging.

> Degenerative changes are the expression of an imbalance between synthesis and degradation of the matrix of intervertebral disks or articular cartilage.

These changes occur as a final common pathway, essentially irrespective of what triggers it. Triggers could act on the chondrocyte, or directly on the matrix or the enzymes that degrade it. The chondrocyte might be impaired genetically, by metabolic factors, or by physical factors. Toxins might accumulate in the matrix. Cytokines, superoxide, or nitric oxide could be released into the matrix by exogenous inflammatory cells, such as macrophages, that invade the matrix in response to injury. Each of these triggers results in the same consequences, but the appearance of those consequences does not reflect the trigger.

Perplexing, as a feature of degeneration, are osteophytes. They do not share the negative properties of other features. They are not breaches of integrity as are cracks and tears; they are not deficiencies as are dehydration and thinning. Rather, they are new, and have to be synthesized (as opposed to degraded). Teleologically, osteophytes are easier to view as adaptive remodeling. They are attempts to increase the surface area of the joint so as to reduce the point pressure throughout a joint that is suffering excessive compression loads. That remodeling might occur in a relatively normal joint that is exposed to excessive external loads, or it might occur as a response in a joint in which the

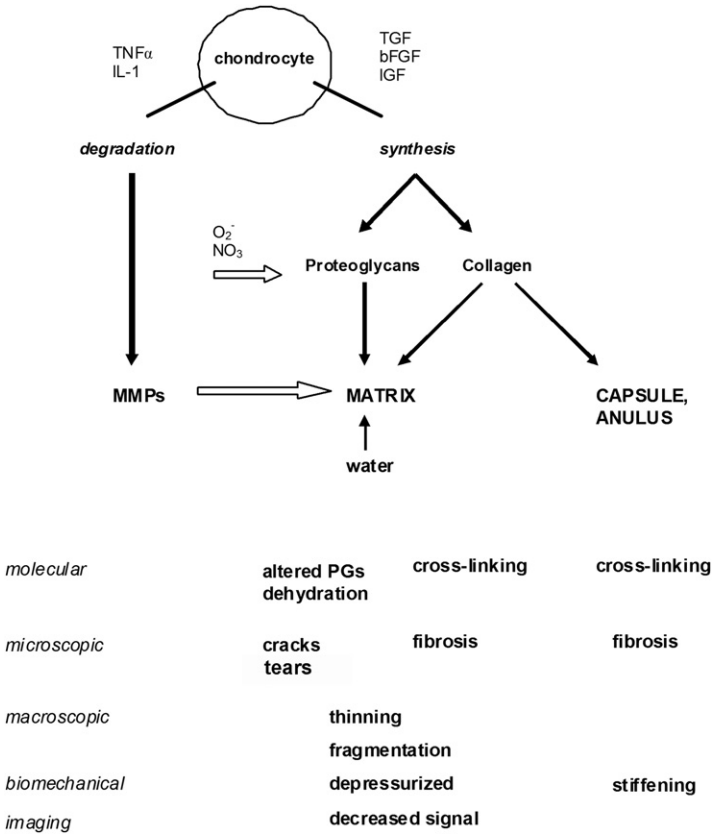

Fig. 1. The biology of degenerative changes in the disk and synovial joints. In a normal joint, the chondrocytes maintain a balance between the synthesis and degradation of the matrix and the collagen of the joint capsule or anulus fibrosus. Synthesis is promoted by growth factors such as transforming growth factor (TGF), basic fibroblast growth factor (bFGF), and insulinlike growth factor (IGF). Degradation is achieved by the action of metalloproteases, whose synthesis is activated by tumor necrosis factor α (TNFα) and interleukin-1 (IL-1). Other molecules that can degrade the matrix are superoxide (O_2^-) and nitric oxide (NO_3). Degradation of the matrix, and associated changes in the joint capsule, can be expressed by various molecular, microscopic, macroscopic, and biomechanical features, and some can be shown by medical imaging.

capacity to bear loads has been compromised by degradation of the matrix.

REGIONAL DIFFERENCES

At a macroscopic level, the structure and biomechanics of joints in the cervical spine and lumbar spine differ. These differences modify the expression of degenerative changes at different sites in the vertebral column, and their potential causes.

> Cervical disks differ from lumbar disks in their anatomic structure and their expression of degenerative changes.

Cervical disks differ in structure from lumbar disks.[5] Cervical disks lack a concentric anulus fibrosus; the anulus is well developed only anteriorly, where it serves more as an interosseous ligament, and not as a circumferential constraint around the nucleus.[5] The nucleus pulposus is relatively small at birth and persists until the second decade of life, but thereafter it gradually disappears,[6] leaving a firm, dry plate of fibrocartilage. As a result, cervical disk changes are harder, drier, and more physical in nature than those of lumbar disks. They tend to express themselves as internal cracks and fissures, and slowly developing, fibrocartilaginous bulges and osteophytes.[7] Transverse fissures across the posterior segments of cervical disks are normal.[7,8] They appear in childhood and are fully established by the third decade.

They are essential for allowing axial rotation of the typical cervical spinal segments.[9] In contrast, degenerative changes in lumbar disks are more chemical in nature: expressed as changes in the proteoglycans and hydration of the nucleus, which are reflected by demonstrable changes in the internal structure and signal intensity of these disks, when viewed with MR imaging.

The cervical zygapophysial joints face upwards as well as backward and, therefore, share equally with the intervertebral disks in bearing axial, compression loads. Therefore, mechanical insults affecting these joints are most likely to arise from weight bearing. Degenerative chances in the cervical zygapophysial joints occur at all segmental levels but more commonly in the joints of the C3 and C4 vertebrae.[7]

The lumbar zygapophysial joints face posteriorly and laterally, and share little of the axial load, which is borne almost entirely by the intervertebral disks. The zygapophysial joints resist axial rotation, and their anterior ends resist anterior translation (listhesis). Consonant with the latter, degenerative changes arise earlier, and are more advanced, in the anteromedial regions of the joints, which resist translation.[10] Degenerative changes are more common in the joints of the L4 and L5 vertebrae.[11]

Cervical and lumbar zygapophysial joints differ in their biomechanics and the factors that might initiate degenerative changes.

CAUSE

Specific metabolic causes of degenerative disk disease are rare. They are limited to diabetes mellitus and ochronosis.[4] The disks of patients with diabetes mellitus have reduced hexosamine content, deficiencies of proteoglycan synthesis, and reduced concentrations of keratosulfate, which is a critical component of proteoglycans.[4] Ochronosis produces deposits of a black pigment derived from homogentisic acid, which ostensibly impedes the normal metabolism of the disk matrix.[4]

Impaired nutrition has been promoted as a cause of disk degeneration, largely from laboratory studies, but incriminating, epidemiologic evidence is lacking. Measurable parameters of impaired nutrition, such as vascular disease and smoking, correlate only weakly with degenerative changes.[4]

Low-grade infection has been explored as a cause of disk degeneration, but studies to date have not yielded consistent results. Whereas some have incriminated certain organisms, others have not been able to confirm the findings.[4]

Specific metabolic causes of degenerative changes are rare, and the evidence is weak for nutrition or infection as a cause.

The strongest relationship with degenerative changes (both in intervertebral disks and in zygapophysial joints) is with age. The prevalence of disk degeneration clearly increases with age, both in the cervical spine[12–14] and in the lumbar spine,[15–17] as does the prevalence of osteoarthritis of cervical[18] and lumbar[19] zygapophysial joints (**Tables 1–4**). This relationship implies a variety of possible, causative factors acting alone or in combination.

Age is the strongest correlate of degenerative changes.

Degenerative changes are normal age changes.

Chondrocytes might be subject to an innate senescence. With the passage of time they become less able to maintain the homeostasis of the matrix. They might have genetic abnormalities that affect the quality of the matrix that they produce, or the function of otherwise normal cells might become impaired by the accumulation over time of toxins or mechanical stresses.

In this regard, the zygapophysial joints have not been explicitly studied, but it seems reasonable to include these joints under the umbrella of synovial joints in general. The prevailing view is that osteoarthrosis is the result of various combinations of factors such as genetic predisposition, obesity, previous injury, abnormal biomechanics, and overload on the joint.[20]

For lumbar disk degeneration, the evidence is more explicit. Studies of twins have provided major insights into the cause of lumbar disk degeneration. Studies of twins have the advantage of providing natural controls for demographic, anthropometric, and social factors, which allows other factors of interest to be brought into relief. Such studies have examined the determinants of certain signs of disk degeneration such as signal intensity on MR imaging, disk height, and disk bulging. They have shown that biomechanical factors, such as lifting heavy loads or heavy leisure activities, account for only some of the variance between presence and absence of degenerative changes. Larger proportions are explained by genetic factors.

At upper lumbar levels, age, occupational, and environmental factors account for only 16% of the variance, whereas genetic factors account for

Table 1
The number of asymptomatic individuals who show features of spondylosis, by gender and age

Feature	20–25	30–35	40–45	50–55	60–65
Men by Age Group (y) (N = 20 in each group)					
Narrowing	0	1	4	13	15
Sclerosis	0	1	1	10	13
Anterior osteophytes	1	5	7	16	19
Posterior osteophytes	0	1	4	10	14
Any of the above	1	5	7	16	19
Women by Age Group (y) (N = 20 in each group)					
Narrowing	0	2	6	9	13
Sclerosis	0	0	5	7	6
Anterior osteophytes	0	3	6	13	11
Posterior osteophytes	0	1	5	8	12
Any of the above	0	4	7	14	14
Men and Women by Age Group (y) (N = 40 in each group)					
Narrowing	0	1	4	13	15
Sclerosis	0	1	1	10	13
Anterior osteophytes	1	5	7	16	19
Posterior osteophytes	0	1	4	10	14
Any of the above	1	5	7	16	19

Data from Gore DR, Sepic SB, Gardner GM. Roentgenographic findings of the cervical spine in asymptomatic people. Spine 1986;1:521–4.

61%.[21] At lower lumbar levels, age and physical loading account for 11% of the variance, and genetic factors account for 32%.[21] The remaining 57% of the variance remains unexplained.[21] Genetic factors may be more influential in women.[22]

Genetic factors constitute a predisposition to degenerative changes, but are not the sole cause.

The relationship to genetic factors is complex. Candidate genes include variants of the genes for proteoglycans, different types of collagen, various interleukins, metalloprotease-3, and the vitamin D receptor.[23,24] Each variant creates a difference in the molecular composition of the structure that it produces, which in turn compromises the function of that structure. Although statistically more common, individual variants occur in only a few individuals affected by disk degeneration,[21] and their prevalence differs in different ethnic populations.[4] Whereas some are common in Scandinavian populations, they are uncommon or absent in Chinese populations; other genes have a converse relative prevalence.[4] However, no single gene is responsible. Rather, the effects of various genes seem to be summative. Certain variants affect signal intensity, whereas other variants affect disk height; and whereas certain variants affect all segmental levels, others affect only lower lumbar levels.[25] Consequently, the phenotype expressed depends on how many and which variants occur in the genotype.

Multiple genetic factors interact in a summative manner, but the prevalence of different genetic aberrations differs in different populations.

However, disk degeneration is not a congenital disease. The evidence does not show that genetic factors cause disk degeneration. Rather, it shows that genetic factors predispose individuals, or render them susceptible, to developing degenerative changes. What those factors are has yet to be determined. However, although an explanation for degenerative changes remains an intellectual puzzle, for clinical purposes an explanation

Table 2
The prevalence of radiologic features of the cervical spine in asymptomatic individuals

	Number of Subjects by Age (y)			
Feature	<30	30–40	40–50	>50
Normal	24	18	18	2
Osteophytes	0	3	7	14
Narrowing of disk space	0	0	7	18
Sclerosis of articular surface	0	0	0	7
Osteoporosis	0	0	0	4
Calcification of anterior ligament	0	0	0	4
Loss of lordosis	0	0	0	4
Number of patients	24	21	32	25
Males	5	7	20	18
Females	19	14	12	7

Data from Elias F. Roentgen findings in the asymptomatic cervical spine. N Y State J Med 1958;58:3300–3.

becomes effectively irrelevant, because degenerative changes are not symptomatic.

CORRELATIONS

One method of determining if a morphologic feature is responsible for pain is to compare its prevalence in people who have pain and people who do not have pain. If the prevalence is significantly higher in those with pain, an association is established and a search for the mechanism that links the 2 features can be undertaken. On the other hand, if the prevalence is not significantly higher, the morphologic feature is refuted as having any association with pain. Such studies have been conducted in the context of degenerative changes of joints of the spine. The literature is most abundant for the lumbar spine, but is not lacking for the cervical spine. The thoracic spine has not been studied in the same way.

Table 3
The prevalence of abnormalities on MR imaging of the cervical spine in asymptomatic individuals

	Prevalence (%)			
	Age <40 y N = 167		Age >40 y N = 97	
Feature	Major	Minor	Major	Minor
Herniated disk	3	4	1	4
Bulging disk	0	5	1	5
Foraminal stenosis	3	4	9	14
Disk narrowing	2	11	16	22
Degenerated disk	8	—	37	—
Spondylosis	3	14	6	34
Cord impingement	9	9	1	18

Data from Boden SD, McCowin PR, Davis DG, et al. Abnormal magnetic-resonance scans of the cervical spine in asymptomatic subjects: a prospective investigation. J Bone Joint Surg Am 1990;72:1178–84.

Table 4
The prevalence of lumbar disk degeneration in asymptomatic individuals of various ages

Source (Ref.)		Age Group (y)			
	Degeneration	18–29	30–39	40–49	≥50
17	Severe	0.28	0.31	0.35	0.59
	Mild	0.14	0.17	0.35	0.29
	Total	0.42	0.48	0.70	0.88
15	Any	0.34		0.59	0.93
		20–39		40–59	60–80
		Age Group (y)			

Data from Boden SD, Davis DO, Dina TS, et al. Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects. A prospective investigation. J Bone Joint Surg Am 1990;72:403–8; and Cheung KM, Karpinnen J, Chan D, et al. Prevalence and pattern of lumbar magnetic resonance imaging changes in a population study of one thousand forty-three individuals. Spine 2009;34:934–40.

Another method is to anesthetize joints that express degenerative changes, in patients with spinal pain. If the pain is relieved, then the target joint is implicated as the source of pain, and the degenerative changes might be responsible. On the other hand, if anesthetizing the joint does not relieve the pain, then the joint and the degenerative changes are refuted as being responsible for the pain.

For the cervical spine, a study conducted in a hospital radiology department matched patients presenting with neck pain with control patients who had cervical spine radiographs for other reasons, such as barium swallows.[26] Across all ages, there were no statistically significant differences between cases and controls in the prevalence of spondylosis, severe disk changes, or degenerative changes in the synovial joints (**Table 5**).

A similar study found a significantly higher prevalence of degenerative changes in the C5-6 disk of symptomatic patients, but not at any other level

Table 5
The prevalence of spondylosis and associated features in patients with and without neck symptoms attending a hospital radiology department over a 12-month period

	N		Spondylosis (%)		Severe Disk Changes (%)		Severe Joint Changes (%)	
Age (y)	Case	Control	Case	Control	Case	Control	Case	Control
Men								
<40	63	29	21	10	6	3		
40–59	98	64	65	58	41	39	1	8
>60	93	54	90	89	88	62	28	21
Women								
<40	127	31	14	13	6	3		
40–59	166	98	58	56	39	29	7	5
>60	106	89	85	88	79	61	16	21

Data from Heller CA, Stanley P, Lewis-Jones B, et al. Value of x-ray examinations of the cervical spine. Br Med J 1983;287:1276–8.

(**Fig. 2**).[27] That study also showed no significant differences in the prevalence of degenerative changes in the cervical zygapophysial joints at any segmental level; the prevalence tended to be higher in asymptomatic individuals (see **Fig. 2**).

Degenerative changes in the cervical intervertebral disks or zygapophysial joints do not correlate with neck pain.

Two lines of evidence have refuted osteoarthrosis of the lumbar zygapophysial joints (facet arthropathy) as a cause of back pain. A large population study using plain radiography[28] and a smaller one using computed tomography (CT)[19] found osteoarthrosis to be equally prevalent in individuals with no pain as in patients with back pain (**Tables 6** and **7**). Osteoarthrosis was more common in older patients, irrespective of pain (see **Table 7**).[19] A third study graded the severity of arthropathy, as seen on CT, of joints that were anesthetized using placebo-controlled intra-articular blocks.[29] It found no difference in the grade of arthropathy between joints that were painful and those that were not.

Many studies have studied the prevalence of disk degeneration in individuals with and without back pain. A systematic review rated these as either low-quality or high-quality studies.[30] Using only the data from high-quality studies, no clinically significant association between degenerative changes and low back pain emerges (**Table 8**). The association is even less if all studies are included.

The statistics associated with these data reveal clinically insignificant correlations. A specificity of 0.58 means that 42% of the population have asymptomatic degenerative changes. A sensitivity

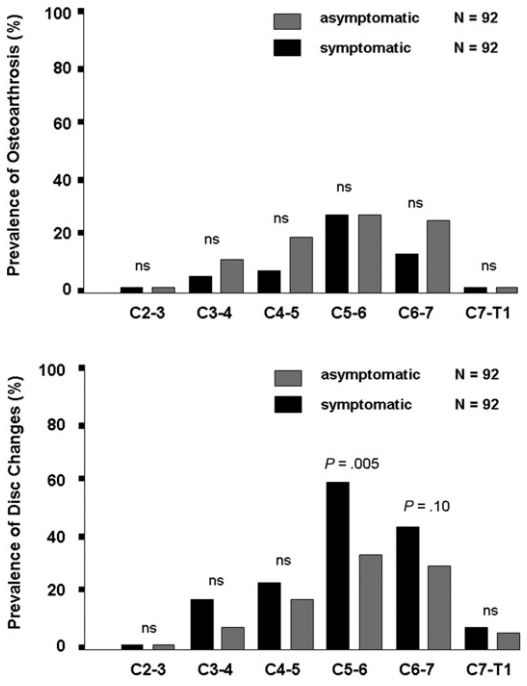

Fig. 2. Histograms showing the relative prevalence of degenerative changes in the cervical intervertebral disks and cervical zygapophysial joints in individuals with and without neck pain. (*Data from* Fridenberg ZB, Miller WT. Degenerative disc disease of the cervical spine. A comparative study of asymptomatic and symptomatic patients. J Bone Joint Surg Am 1963;45:1171–8.)

Table 6
A contingency table showing lack of association between various grades of osteoarthrosis of the lumbar spine and back pain in a large population study

	Osteoarthrosis		
	Grade 0–1	Grade 2	Grade 3
Pain	398	82	19
No pain	403	60	15

($\chi^2 = 3.46$, $P = .177$).

Data from Lawrence JS, Bremner JM, Bier F. Osteoarthrosis. Prevalence in the population and relationship between symptoms and x-ray changes. Ann Rheum Dis 1966;25:1–24.

of 0.56 means that 56% of the population with back pain have degenerative changes. Combining the 2 figures reveals that 42 of the 56% of patients with back pain and degenerative changes (ie, 75%; 42/56) have degenerative changes that are not symptomatic. Therefore, in a given patient, the odds are overwhelmingly in favor of the degenerative changes being not relevant to the pain. Under those conditions, the 25% whose pain might be caused by degeneration cannot be distinguished from the 75% in whom it is not.

Degenerative changes in the lumbar intervertebral disks or zygapophysial joints do not correlate with back pain.

Table 7
A contingency table showing lack of association between osteoarthrosis of the lumbar zygapophysial joints and back pain across various ages.[19] None of the proportions is significantly different from another, using a Fisher exact test

	Age Group (y)					
	<40	40–49	50–59	60–69	>70	All
Back pain	1	3	11	8	1	24
Proportion	0.25	0.75	0.61	1.00	0.50	0.65
No back pain	5	18	38	25	8	94
Proportion	0.25	0.42	0.83	0.89	0.70	0.64

Data from Kalichman L, Li L, Kim DH, et al. Facet joint osteoarthritis and low back pain in the community-based population. Spine 2008;33:2560–5.

Similar results arise from studies that used MR imaging.[17,41–43] Features such as reduced signal intensity, altered shape of the nucleus pulposus, reduced disk height, and anular tears are only marginally more common in individuals who report a history of back pain, with odds ratios only in the range between 1.5 and 2.6.[42] A systematic review[44] concluded that the evidence was insufficient to implicate degenerative changes as the cause of back pain.

INTERNAL DISK DISRUPTION

Internal disk disruption is a condition that affects lumbar intervertebral disks. It has been interpreted and misrepresented as representing degenerative changes, but it does not. Moreover, it is a condition that does correlate with pain.

Definition

Internal disk disruption is characterized by the presence of isolated, radial fissures penetrating from the nucleus pulposus into the anulus fibrosus but without breaching the outer anulus. The presence of a fissure distinguishes an affected disk from a normal disk, and the presence of a single fissure distinguishes the disk from those affected by widespread degenerative changes.

Internal disk disruption is characterized by isolated radial fissures through the anulus fibrosus of lumbar intervertebral disks.

The fissures can be graded according to the extent to which they penetrate the anulus (**Fig. 3**). Grade I, II, and III fissures reach the inner, middle, and outer third of the anulus, respectively.[45] If a grade III fissure spreads circumferentially around the annulus, it is promoted to grade IV.[46]

Diagnosis

The conventional means of diagnosing internal disk disruption is postdiskography CT scanning. The diskography places contrast medium into the nucleus and into any fissures that may be present, whereas CT scanning shows the radial and circumferential nature of the fissure.

Cause

Internal disk disruption arises as a result of injury to the overlying vertebral end plate. This condition can occur as a result of a sudden, severe

Table 8
The validity of finding degenerative changes on plain radiographs as a diagnosis of low back pain

Source (Ref.)	Degenerative Changes	Back Pain		Sensitivity	Specificity
		Present	Absent		
[31,32]	Present	130	92	0.55	0.61
	Absent	106	142		
[31,32]	Present	170	135	0.72	0.44
	Absent	66	106		
[33]	Present	90	61	0.46	0.68
	Absent	105	127		
[34]	Present	45	19	0.23	0.80
	Absent	151	77		
[35]	Present	115	71	0.32	0.77
	Absent	243	237		
[36]	Present	39	42	0.58	0.70
	Absent	28	100		
[37]	Present	462	360	0.59	0.52
	Absent	320	390		
[38]	Present	55	77	0.75	0.37
	Absent	18	45		
[39]	Present	139	51	0.80	0.45
	Absent	35	41		
[40]	Present	177	35	0.81	0.36
	Absent	41	20		
Pooled	Present	1422	943	0.56	0.58
	Absent	1113	1285		

compression injury, or it can occur as a result of fatigue failure of the end plate.

Biomechanics studies have shown that vertebral end plates are susceptible to fatigue failure.[47] When subjected to repeated compression loads as small as 50% to 60% of the ultimate tensile strength of the end plate, the end plate can fracture after as few as 100 repetitions.[48,49]

The end-plate fracture constitutes an insult to the underlying disk, and precipitates degradation of the matrix. The mechanism remains uncertain. The injury might trigger an inflammatory response in the matrix, or the trigger might be more subtle: a reduction in pH in the region of the injury that increases the activity of metalloproteases that degrade the matrix. Nevertheless, it has now been shown in animal studies that deliberately fracturing the end plate results in chemical changes in the matrix akin to those of degeneration, namely changes in proteoglycans and glycosaminoglycans, and progressive dehydration of the nucleus.[50–52]

Biomechanics studies and animal studies implicate end-plate injury as the cause of internal disk disruption.

How radial fissures develop has not been established, but a possible explanation is that once the matrix is degraded it no longer braces the anulus from buckling inwards. Continued normal activities of daily living might then progressively tear elements of the unsupported anulus.

Once the nuclear matrix has been degraded, the ability of the nucleus to sustain compression loads is compromised. This situation is evident from the internal biomechanics of the affected disk.

Biomechanics

Internal stresses within a disk can be measured using stress profilometry.[47,53] If a transducer

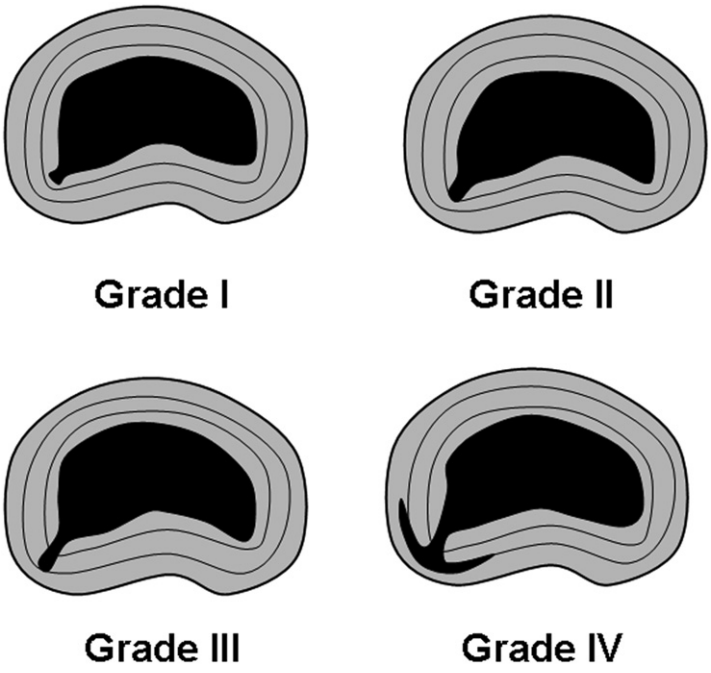

Fig. 3. The appearance of various grades of radial fissures in lumbar intervertebral disks.

probe is inserted into a disk and progressively withdrawn, it can be used to measure ambient stresses across the diameter (profile) of the disk.

In a normal disk, internal stresses are uniform. The outer, ligamentous anulus shows no compression stresses, but the inner anulus and the nucleus show compression stresses that are uniform across the nucleus but with a small peak in the posterior anulus (Fig. 4).[47,53]

> Internally disrupted disks show distinctly abnormal distributions of stress in the nucleus pulposus and posterior anulus.

In a disk with internal disruption, the internal stresses are irregular and reduced in magnitude, in some disks and in some regions reducing to zero.[47,53] This observation means that the nucleus is not bearing compression loads normally. As a result, the posterior anulus comes to bear more than its accustomed share of the axial load, and shows increased stresses (see Fig. 4). In laboratory experiments using cadaver disks, these biophysical features are precipitated immediately after the end plate fails.[47]

Correlations

Radial fissures are neither degenerative nor age changes. They occur independently of age or degenerative changes.[54] However, they are strongly associated with the affected disk being painful on diskography (Tables 9 and 10).

The biophysical features of internal disk disruption also correlate with the disk being painful. Decreased nuclear stress and increased stress in the posterior anulus each, independently, correlate with reproduction of pain (Table 11).[58]

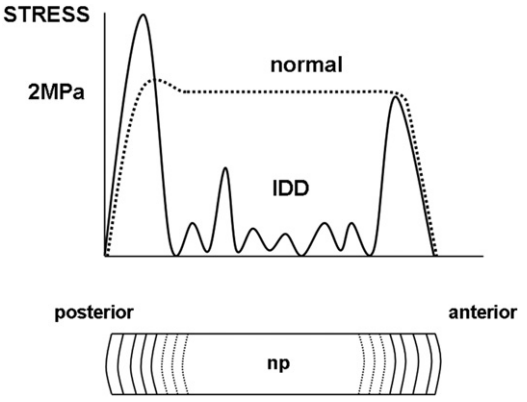

Fig. 4. The features of a normal disk and one affected by internal disk disruption (IDD) under stress profilometry. The graph shows the magnitude of the stresses within the disk across a diameter that pass from the anterior anulus to the posterior anulus. In a normal disk, the stresses are uniform. In a disk with IDD, the stresses in the nucleus pulposus (np) are irregular, decreased, and may be zero, but the stress in the posterior anulus is increased substantially more than normal.

Table 9
The association between the grade of anular disruption and reproduction of pain by disk stimulation. The numbers refer to the number of patients showing the features tabulated

	Anulus Disruption			
Pain Reproduction	Grade III	Grade II	Grade I	Grade 0
Exact	43	29	6	4
Similar	32	36	21	8
Dissimilar	9	11	6	2
None	16	24	67	86

$\chi^2 = 148$; $P<.001$.

Data from Moneta GB, Videman T, Kaivanto K, et al. Reported pain during lumbar discography as a function of anular ruptures and disc degeneration. A re-analysis of 833 discograms. Spine 1994;17:1968–74.

Radial fissures correlate strongly with the disk being painful.

Decreased nucleus stress and increased posterior anulus stress each correlate with the disk being painful.

Two features evident on MR imaging are signs of internal disk disruption. Modic changes reflect current or past inflammatory responses around the end plate, whereas high-intensity zones reflect circumferential tears. Each of these MR imaging features independently correlates with the affected disk being painful. Not all studies agree on this conclusion but most are consistent (Tables 12 and 13). Studies have differed on the sensitivity of these signs (ie, how well and how often they can be detected), but all studies agree that the signs are highly specific (ie, when present, they are unlikely to be false-positive signs that the affected disk is painful).

High-intensity zones and Modic changes correlate with the disk being painful.

Mechanisms of Pain

For understandable reasons, the mechanisms by which internal disk disruption evokes pain have not been directly studied. Patients have not volunteered to have their disks explored with microelectrodes to sample or deliver potentially noxious chemicals, or with probes that might mechanically stress selected zones of the disk. Nevertheless, the circumstantial evidence allows for 2 models or a combination thereof.

Two features of internal disk disruption are pivotal to explaining how it becomes painful. First, the clinical data indicate that grade III and IV fissures are most likely to be painful. This finding suggests that nuclear material must have access to the outer third of the anulus, which is where the nociceptive apparatus of the disk is located. In turn, this finding suggests that noxious chemicals, such as nitric oxide, might stimulate nociceptors to produce chemical nociception.

The second feature is the increased stress in the posterior anulus seen on stress profilometry. This finding suggests that the posterior anulus is being excessively stressed mechanically, which allows for mechanical nociception from the nociceptors in the posterior anulus.

Table 10
The association between grades of anulus disruption and reproduction of pain on disk stimulation, as found in 4 studies. A, Aprill and Bogduk[46]; B, Smith et al[55]; C, Lim et al[56]; D, Kokkonen et al.[57]

	Anulus Disruption			Anulus Disruption	
A	Grade III, IV	Grade 0–II	B	Grade III, IV	Grade 0–II
Pain	38	0	Pain	39	5
Not pain	37	31	Not pain	67	51
$P = .000$			$P = .000$		
	Anulus Disruption			Anulus Disruption	
C	Grade III, IV	Grade 0–II	D	Grade III, IV	Grade 0–II
Pain	33	27	Pain	16	31
Not pain	1	36	Not pain	11	54
$P = .000$			$P = .003$		

Table 11
The correlation between abnormal stress profiles and pain on stimulation of a lumbar intervertebral disk

Biophysical Properties	Disk	
	Painful	Not Painful
Nuclear Stress		
Depressurized	11	0
Normal	7	13
	Fisher exact test; $P = .017$	
Anular Stress		
Stressed	17	2
Normal	1	11
	Fisher exact test; $P = .001$	

Data from McNally DS, Shackleford IM, Goodship AE, et al. In vivo stress measurement can predict pain on discography. Spine 1996;21:2500–87.

Table 12
The sensitivity, specificity, and likelihood ratio of Modic changes as predictors of the affected disk being painful, as reported by 12 studies

Sample	Sensitivity	Specificity	Likelihood Ratio	95% Confidence Interval	Source (Ref.)
2457	0.25	0.94	4.2	3.3–5.2	59
152	0.23	0.97	7.7	1.9–31.6	60
101	0.22	0.95	4.4	1.3–15.0	61
255	0.18	0.90	1.8	0.9–3.5	62
178	0.14	0.87	1.1	0.5–2.6	63
97	0.09	0.83	0.52	0.2–1.8	56
3240	0.24	0.83	3.4	2.8–4.1	All

Table 13
The sensitivity, specificity, and likelihood ratio of the high-intensity zone as a predictor of the affected disk being painful, as reported by 12 studies

Sample	Sensitivity	Specificity	Likelihood Ratio	95% Confidence Intervals	Source (Ref.)
142	0.37	1.00	∞		64
120	0.82	0.89	7.5	4.0–14.1	46
256	0.45	0.94	7.5	3.7–15.1	65
152	0.27	0.95	5.4	1.7–17.1	66
101	0.52	0.90	5.2	2.4–11.2	61
155	0.81	0.79	3.9	2.5–6.0	67
178	0.57	0.84	3.6	2.2–5.7	63
109	0.45	0.84	2.8	1.4–5.5	68
152	0.26	0.90	2.6	1.2–5.8	55
97	0.56	0.70	1.9	1.2–3.0	56
116	0.27	0.85	1.8	0.9–3.8	69
80	0.09	0.93	1.3	0.3–5.4	70
1658	0.45	0.88	3.8	3.1–4.5	All

Both chemical nociception and mechanical nociception might be combined. Chemical factors might sensitize the nociceptors, rendering them more susceptible to mechanical nociception.

This model can be elaborated by adding the ingrowth of nerve fibers along radial fissures.[71–76] This neoinnervation increases the susceptibility of the anulus to nociception beyond that of which it is capable from its normal innervation.

Prevalence

Internal disk disruption is common amongst patients with chronic back pain who undergo invasive investigations. The original study found a prevalence of 39% (29%–49%) in 92 consecutive patients.[77] Two subsequent studies reported prevalences of 26% (18%–34%)[78] and 42% (34%–49%).[79] Although the estimates are not the same, their 95% confidence intervals overlap and are, therefore, compatible.

> Internal disk disruption is a common cause of pain in patients with chronic back pain.

Summary

Internal disk disruption is the most thoroughly studied, putative source of chronic back pain. The condition has a cause, and has been produced in biomechanics studies and induced in experimental animals. Its morphologic features can be clearly defined and can be detected on postdiskography CT. The condition has internal biophysical features. The morphologic features and the biophysical features each correlate with the disk being painful. The condition is strongly associated with characteristic signs on MR imaging. The condition is common.

DISCUSSION

As conventionally understood, so-called degenerative changes are irrelevant to spinal pain. They might become relevant if osteophytes compromise nerve roots and cause radicular pain, but they are not relevant for neck pain or back pain.

The causes of degenerative changes remain elusive, but the available evidence indicates that they amount to no more than normal age changes. Only exceptionally do degenerative changes reflect systemic metabolic disorders.

Clinically, degenerative changes have no correlation with neck pain, and no useful correlation with back pain. Therefore, they do not constitute valid diagnoses of the cause of pain.

Whereas radiologists have a legitimate responsibility to report what they see, they also have a responsibility to use appropriate terminology. The term degenerative is unnecessarily emotive and compromises the management of patients with pain. It is unnecessary and counterproductive. For that reason, it can be expunged from the radiologic lexicon. A simpler and accurate term is normal age changes.

Entirely different is the entity internal disk disruption. This entity is a genuine and well-studied cause of back pain, but it is not synonymous with degeneration. It shares some of the processes and features of degenerative changes in the disk, but is a response to injury. It cannot be seen and diagnosed on plain radiographs or conventional CT scans, because it shows no external features. For diagnosis in full form, internal disk disruption requires postdiskography CT scanning. However, some patients with this condition show Modic changes or high-intensity zones on MR imaging, each of which strongly, but not absolutely, implicates the affected disk as the source of pain.

Zygapophysial joints in any spine segment may also be a source of axial pain, but there is no correlation between radiologically observed zygapophysial joint osteoarthrosis and pain. Diagnosis of zygapophysial joint pain demands relief of the index pain with controlled anesthetic blocks of the joint innervation. There are suggestions in the literature that physiologic imaging parameters (T2 hyperintensity, gadolinium enhancement) may reveal painful zygapophysial joint synovitis, but definitive studies have yet to be performed.

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