

The Relation Between Annular Disruption on Computed Tomography Scan and Pressure-Controlled Diskography

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ABSTRACT. Derby R, Kim BJ, Chen Y, Seo KS, Lee SH. The relation between annular disruption on computed tomography scan and pressure-controlled diskography. *Arch Phys Med Rehabil* 2005;86:1534-8.

Objective: To analyze the relation between annular disruption determined by computed tomography (CT) scan and diskographic findings using pressure-controlled manometric diskography.

Design: Cross-sectional using prospectively gathered data.

Setting: Ambulatory spine intervention unit.

Specimens: Two hundred seventy-nine disks from 86 patients (55 men, 31 women) who were referred for diskography of suspected chronic diskogenic low back pain.

Interventions: Not applicable.

Main Outcome Measures: The grade of annular disruption was rated using CT diskography and fluoroscopic imaging as follows: 0 (no disruption); 1 (extension into the inner third of the annulus); 2 (extension into the middle third of the annulus); 3 (extension into the outer third of the annulus); 4 (circumferential extension with a $>30^\circ$ arc at the disk center); and 5 (contrast media leakage into the outer space). Diskography was performed via a pressure-controlled manometric technique using an injection rate of .05mL/s and a restricted total volume of 3.5mL. Pain was rated on a 0 to 10 numeric rating scale (NRS). Criteria for symptomatic disks included provocation of patient concordant pain (NRS score, $\geq 6/10$) at 50psi or less above opening pressure, with 3.5mL or less of total volume. Symptomatic disks were classified as "low pressure sensitive" or "high pressure sensitive" based on the pressure level that evoked pain. Disks classified as low pressure sensitive required an NRS score of 6 out of 10 or higher at 15psi or less above opening pressure. Disks classified as high pressure sensitive required an NRS score of 6 out of 10 or higher at pressures within a range of 15 to 50psi.

Results: The numbers of disks at each annular disruption grade were 19 (6.8%) at grade 0, 29 (10.4%) at grade 1, 35 (12.5%) at grade 2, 42 (15.1%) at grade 3, 69 (24.7%) at grade 4, and 85 (30.5%) at grade 5. A total of 93 disks met the criteria for a symptomatic disk. The extent of annular disruption and the rate of symptomatic disks correlated significantly ($P < .001$). The highest symptomatic disk rate was observed in grade 4 disks. Of 93 symptomatic disks, 88 (94.6%) showed annular disruption of grade 3 or greater. Disks with grades 0 to

2 and grades 3 to 5 annular disruption differed significantly when the mean NRS relative to intradiskal pressure was compared ($P < .001$). Comparing the disk type of symptomatic disks at each annular disruption grade, there was a decreasing trend of low pressure sensitive disks relative to the extent of annular disruption (62.5% at grade 3, 39.4% at grade 4, 34.2% at grade 5).

Conclusions: Annular disruption reaching the outer annulus fibrosus is a key factor in pain generation. Disk morphology, including annular disruptions extending beyond the outer annulus, may permit increased diskography specificity.

Key Words: Intervertebral disk; Low back pain; Pain; Rehabilitation.

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THE INTERVERTEBRAL DISK is the primary pain source in the anterior column of the lumbar spine, and is a common source of chronic axial pain.¹⁻³ Diskogenic pain putatively arises from radial tears of the annulus fibrosus, extending from the nucleus to the outer one third of the annulus.^{4,5} In vivo animal studies have shown that annular tears lead to secondary degenerative changes and neo-innervation in the periannular and outer annular regions.^{6,7} Moneta et al⁸ reported that the elicitation of clinical pain during diskography is associated with leakage of contrast media to the outer part of the annulus fibrosus, and suggested that the presence of outer ruptures was the best predictor of concordant pain reproduction. Slipman et al⁹ suggested that the premise of diskography is stimulation of nerve endings through a fissure extending to the innervated outer third of the annulus that elicits a concordant pain response, identifying the tear as a nociceptive source.

Radial annular tears can be found by diskography, but only post diskography computed tomography (CT) clearly defines fissures extending to the outer third of the annulus and extending circumferentially within the annulus fibrosus. Vanharanta et al^{10,11} have shown that the CT diskography can elucidate the morphologic features of intervertebral disk disruption. In addition, they reported that more than 70% of painful disks confirmed by provocative diskography exhibit the grade 3 annular fissures as defined by the Dallas discogram description (DDD).¹² More recently, Aprill and Bogduk⁵ described a modified DDD including grade 4 for circumferential annular tearing.

Diskography is a diagnostic tool for detecting pathologic disks in chronic low back pain (LBP) patients. Although some physicians debate the clinical value of diskography, it has demonstrated a theoretical relation between diskogenic pain pathophysiology and annular tears. To develop greater objectivity for detecting pathologic disks, Derby et al¹³ proposed precise diskographic criteria for symptomatic disks. Criteria, including reproducible concordant pain on a numeric rating scale (NRS) score of 6 out of 10 or higher at 50psi or less above opening intradiskal pressure, and 3.5mL or less total volume for pressure-controlled manometric diskography afforded high

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specificity in diagnosing diskogenic LBP in patients with normal psychometrics, and in asymptomatic volunteers.¹⁴

We used CT diskography and fluoroscopy to determine the effect of annular disruption on pain generation, the relation between the grade of annular disruption and pressure-controlled manometric diskography findings in chronic LBP patients.

METHODS

Subject Recruitment

We obtained approval from our institutional review board and human subjects review committee before the study. We outlined the potential risks of diskography to the subjects before obtaining their informed consent. Eighty-six patients with chronic LBP were recruited (55 men, 31 women; age range, 20–70y; mean, 44.5y). Patients were not eligible for the study if they were allergic to contrast media, iodine, or cephalosporin antibiotics.

Diskogram

Before the study, patients were instructed in the use of the NRS (range, 0 [no pain] to 10 [worst pain that could ever be experienced]) for pain intensity responses. Intravenous prophylactic antibiotics were administered 20 minutes before the procedure. Patients were premedicated with .025mg/kg of midazolam. We did fluoroscopic examinations of the subjects' spines to confirm segmentation and to determine the appropriate level for needle placement. Using a posterolateral approach, a 25-gauge, 6-in needle was placed into each disk via a 20-gauge, 3.5-in introducer needle. The 25-gauge needle was then advanced into the center of the disk. Needle position was confirmed by anteroposterior (AP) and lateral fluoroscopic imaging. Nonionic contrast mixed with antibiotics was injected into each disk at .05mL/s with a controlled injection syringe with digital pressure readout (Intellisystem^a). An opening pressure was recorded when contrast was first seen entering the disk. At an injection speed of .05mL/s (1 revolution of the Intellisystem manometer), pain responses and any contrast leakage or fissures were recorded. Contrast injection was continued until subjects reported significant pain/pressure (NRS score, $\geq 6/10$). If they did not report pain or pressure, intradiscal pressure of 100psi above opening pressure was the end point of the diskogram. In cases of failure to reach 100psi above opening pressure due to contrast leak, a total volume of 3.5mL was used as an indication of the study end point. After the injections, we obtained and interpreted AP and lateral spot films were obtained and interpreted. Using a standardized technique, we did separate injections in at least 3 levels of the L1-2 to L5-S1 disks. Each diskogram was done by an expert diskographer with a mean of 20 years of experience. Participants tolerated the procedure well and there were no complications.

Before and during the procedure, patients were monitored with pulse oximetry and a blood pressure cuff. Supplemental oxygen was administered by nasal cannula. During the injections, subjects were awake, alert, and responding appropriately. CT was performed immediately after the diskography and patients were asked to mark on a pain drawing the type and location of the most severe pain felt during and after the procedure.

Pain Evaluation

Pain intensity was scored via NRS and the pressure associated with a pain response was noted. The NRS scores were determined at 15, 30, and 50psi above opening pressures. The

NRS was then monitored over a 30-second period. Patients were asked to describe any discomfort during the procedure as "familiar" or "unfamiliar." Prediskography and postdiskography pain drawings were used to compare and confirm concordance assessments made during the injections.

Diskogram Criteria for Symptomatic Disk

To be designated as a symptomatic disk by diskography required an abnormal disk, pain response on the NRS of 6 out of 10 or higher, above opening pressure level of 50psi or less, pain described by the participant as "familiar," and a negative control disk. Each symptomatic disk was categorized as "low pressure sensitive" or "high pressure sensitive." Disks classified as low pressure sensitive required an NRS score of 6 out of 10 or higher at 15psi or less above opening pressure. Disks classified as "high pressure sensitive" required an NRS score of 6 out of 10 at pressures within a range of 15 to 50psi.

Determination of Annular Disruption Grade

Annular disruption grade was classified via modified DDD,¹² in which the scale was extended to include instances where contrast medium spread circumferentially through the annulus fibrosus. This was defined as grade 4 disruption by Aprill and Bogduk⁵ and was distinguished from grade 3 by the spread of contrast medium circumferentially within the substance of the annulus fibrosus, subtending a greater than 30° arc at the disk center. We used grade 5 to describe contrast medium leaking from a disk confirmed during diskography by fluoroscopy. In the grading, we used both CT diskogram results and fluoroscope images. Two observers performed grade ratings independently at different times. In addition, each observer rated annular disruption grade twice, with at least a 1 day interval to analyze intraobserver repeatability. Both observers then discussed and decided the final grade of annular disruption.

Data Analysis

Statistical analyses were performed with SPSS/PC+ software.^b Inter- and intraobserver reliability for annular disruption grade were analyzed using κ statistic. Kappa values greater than .75 represent excellent agreement beyond chance, and values between 0.4 and .75 represent fair to good agreement.¹⁵ We used a chi-square test to compare symptomatic disk rate and symptomatic disk categorization related to annular disruption grade. Mean NRS at each pressure level as a function of annular disruption grade were compared using the analysis of variance.

RESULTS

Sample Characteristics

A total of 279 disks from 86 patients (55 men, 31 women; age range, 20–70y; mean, 44.5y) were examined. Disks included 17 at the L1-2 level, 41 at L2-3, 68 at L3-4, 77 at L4-5, and 76 at L5-S1. The number of disks at each annular disruption grade were as follows: 19 (6.8%) at grade 0, 29 (10.4%) at grade 1, 35 (12.5%) at grade 2, 42 (15.1%) at grade 3, 69 (24.7%) at grade 4, and 85 (30.5%) at grade 5 (table 1).

Inter- and Intraobserver Reproducibility

The reproducibility of grading by 2 physicians at different times showed that the annular disruption grade was consistent with a κ value of .762. Fifty-one disks were graded differently by the 2 physicians. The most common occurrences of discrepancy were grading between grades 1 and 2. There were no

Table 1: Number of Disks as a Function of Annular Disruption Grade at Each Disk Level

Level	Annular Disruption Grade						Total
	0	1	2	3	4	5	
L1-2	1	4	2	1	5	4	17
L2-3	7	7	6	6	5	10	41
L3-4	5	10	13	8	19	13	68
L4-5	5	7	3	12	20	30	77
L5-S1	1	1	11	15	20	28	76
Total	19	29	35	42	69	85	279

grading differences of more than 1 grade level. Intraobserver agreement of each observer also showed excellent agreement at κ values of .794 and .812, respectively.

Comparison of Imaging Modalities

Eighty-five disks with leakage of contrast medium from the disk during diskographic study were rated as grade 5. Of that number, 2 and 10 disks were rated as grade 3 and 4 via CT diskogram, respectively; however, leakage of contrast medium was observed using fluoroscopic imaging, resulting in their categorization as grade 5. The grading of 4 disks was changed after fluoroscope imaging. These changes involved increasing 2 disks from grade 1 to grade 3, 1 disk increased from grade 0 to grade 1, and 1 disk from grade 2 to grade 3.

Correlation of Diskographic Findings With Annular Disruption

Ninety-three of 279 disks (33.3%) met the criteria for symptomatic disks. There was a significant correlation ($P < .001$) between the extent of annular disruption and the rate of symptomatic disk. Grade 4 had the highest rate (fig 1). Eighty-eight of the 93 symptomatic disks (94.6%) showed annular disruption greater than grade 3 (16 of grade 3, 34 of grade 4, 38 of grade 5). Of 196 disks with more than grade 3 annular disruption, a 44.5% met the criteria for a symptomatic disk.

Interestingly, the mean NRS according to intradiskal pressure during diskography showed significant differences between grade 0 and 2 and grade 3 and 5 ($P < .001$, fig 2). Grades 3, 4, and 5 showed no significant differences.

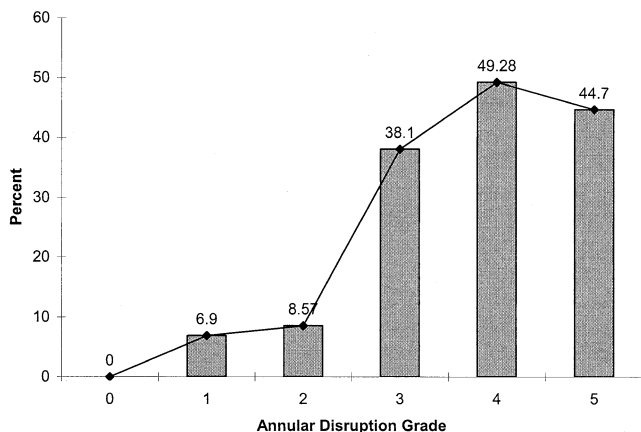


Fig 1. Percentage of symptomatic disks as a function of annular disruption grade. Grade 4 disks showed the highest symptomatic disk rate. The symptomatic disk rate and the annular disruption grade were significantly correlated ($P < .001$).

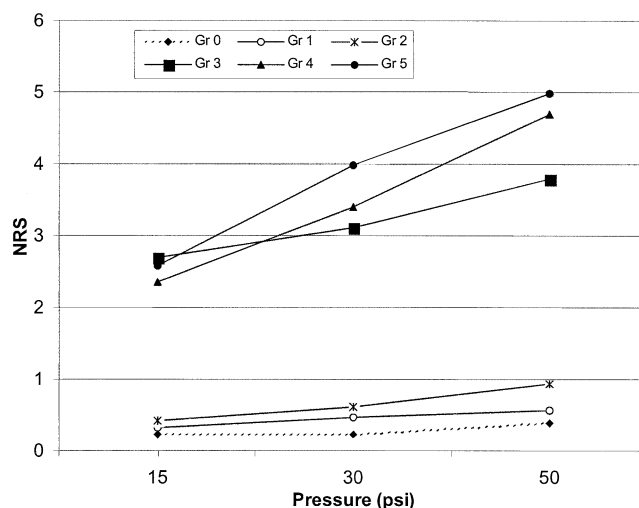


Fig 2. Mean disk NRS for each annular disruption grade at 3 pressure levels. Pressure means above opening pressure.

Disks classified as low pressure sensitive and high pressure sensitive showed no significant differences at each annular disruption grade. However, there was a decreasing rate of low pressure sensitive disks with increasing annular disruption from grade 3 to grade 5 (62.5% at grade 3, 39.4% at grade 4, 34.2% at grade 5; fig 3).

DISCUSSION

The nucleus pulposus contains no nerve supply, however, the outer annulus contains nerve endings derived from the sinovertebral nerve branch, the gray rami communicants, and the lumbar ventral rami. Korkala et al¹⁶ showed that these nerve endings do not contain substance P and are therefore not nociceptors, but nociceptors are located in the posterior longitudinal ligament adjacent to the disk. Some investigators^{17,18} have shown that nerves in disks contain peptides such as calcitonin gene-related peptide, vasoactive intestinal peptide, and substance P, which characterize nociceptive nerve fibers. Various types of disk injury may cause neo-innervation via nociceptive nerve fibers, transforming the healthy disk into a pain generator. Freeman et al⁶ reported a healing response following

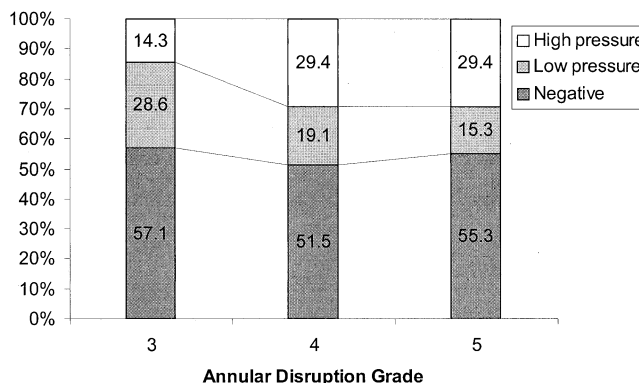


Fig 3. Distribution of high pressure sensitive, low pressure sensitive, and negative disks as a function of annular disruption grade. Grade 3 disks were more frequently chemically sensitive and grade 5 disks were more frequently mechanically sensitive.

posterolateral annulus fibrosus incision in 20 sheep. Neo-innervation in the periannular and outer annular region was observed using immunohistochemical techniques.

The relation between disk morphology and clinically significant diskogenic pain remains controversial. The frequency of morphologic abnormalities revealed via diskography in the back pain population is high and increases with age,^{19,20} putatively from painless degenerative changes.²⁰ Discrepancies between morphologic appearance and pain provocation have also been described.²¹ Milette and Melanson²² reported retrospectively that concordant pain was evoked by injection in only 37% of patients with a morphologic abnormality documented by diskography. Antti-Poika et al⁴ reported only a 52.8% concordant pain provocation rate in disks with abnormal morphologic changes, as shown by diskography. Although it is clear that such abnormal morphologic structures are nonspecific, it does not follow from studies such as these that annular tears and diskogenic pain are unrelated.

While degenerative morphologic changes are not necessarily associated with pain response, there have been reports that annular tears may be associated with pain provocation.^{23,24} Vanharanta et al¹⁰ found that pain reproduction during diskography correlated with the extent of annular disruption. Grades 0 and 1 disruptions were rarely painful, but 75% of grade 3 disruptions were associated with exact or similar pain reproduction. Conversely, 77% of disks with exact or similar pain reproduction exhibited grade 3 annular disruptions. Grade 2 disruptions were less regularly associated with pain reproduction. Our result, showing relatively high rates of annular disruption at grades 3 or higher among symptomatic disks (94.6%, 88/93 symptomatic disks) corroborates these reports. These results also suggest that annular disruption involving the inner-outer annulus fibrosus is a key factor in pain generation.

In this study, we combined strict criteria with pressure-controlled manometric diskography to increase the specificity of symptomatic disk detection. The new criteria and technique have afforded relatively low false positive rates,¹⁴ which may explain the substantial correlation between symptomatic disks and annular disruption grades relative to that reported in previous studies. Additionally, fluoroscopic findings were combined with CT diskographic findings to assess disruption grade more accurately. Although disruption grades derived from CT diskography alone were only infrequently changed by fluoroscopic findings, use of both imaging techniques was more accurate than CT diskography alone.

Symptomatic disk rates in grades 1 and 2 disks were extremely low (2/93 and 3/93, respectively). Higher pain intensities were observed in grade 3–5 disks relative to grade 0–2 disks at the same pressure (fig 2), supporting the importance of annular disruption reaching the outer annulus for pain generation. There was more severe pain intensity with increasing pressure in disks with circumferential extension of tearing (grade 4) and contrast media leakage through the outer annulus (grade 5) than in disks with only radial tearing until outer annulus (grade 3). However, these differences were not statistically significant. More nociceptive structures would be exposed in grades 4 and 5 disks than in grade 3 disks, and over the course of contrast media injection, more nociceptive neural endings could be stimulated. Grade 5 disks showed higher rates of high pressure sensitive disks. The extension of contrast media leakage and direct pressure due to annular disruption may irritate other structures (eg, posterior longitudinal ligament and dorsal root ganglion). As a result, other pain origins should be carefully excluded and disks with a contrast leak in the annulus fibrosus should be evaluated with caution.

CONCLUSIONS

Annular disruption directly correlates with diskography findings for a symptomatic disk when pressure-controlled manometric techniques with strict criteria are used. A significant percentage of symptomatic disks showed annular disruption extending into the outer third of the annulus or beyond the outer annulus. These results support that annular disruption reaching the outer third of the annulus fibrosus is a key factor in pain generation. Morphologic findings such as annular disruptions extending into or beyond the outer annulus may increase diskography specificity.

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Suppliers

- a. Merit Medical Systems, 1600 W Merit Pkwy, South Jordan, UT 84095.
- b. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.