ANNULAR TEARS AND DISC DEGENERATION
IN THE LUMBAR SPINE
A POST-MORTEM STUDY OF 135 DISCS

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We studied 135 lumbar discs from 27 spines removed post-mortem from subjects of an average age of 31.5 years. Defects of the annulus fibrosus were classified as peripheral, circumferential or radiating; the nucleus pulposus as normal, moderately or severely degenerate.

Peripheral tears were more frequent in the anterior annulus, except in the L5-S1 disc. Circumferential tears were equally distributed between the anterior and the posterior annulus. Almost all the radiating tears were in the posterior annulus, and closely related to the presence of severe nuclear degeneration.

Histology suggested that peripheral tears were due to trauma rather than biochemical degradation, and that they developed independently of nuclear degeneration. The association of peripheral annular lesions with low back pain is uncertain but our study suggests that they may have a role in the pathogenesis of discogenic pain.

The degenerating human intervertebral disc shows dehydration and fraying of the nucleus pulposus, and also the formation of tears within the annulus fibrosus. Schmorl and Junghanns (1932) gave the first descriptions and many authors have since reported the morphological features of these tears (Friberg and Hirsch 1950; Hirsch and Schajowicz 1953; Vernon-Roberts and Pirie 1977; Vernon-Roberts 1987). Annular tears may be related to the pathogenesis of low back pain, but their relationship to the biochemical degradation of the intervertebral disc and their association with mechanical stress remain uncertain. Recent pathological observations and experimental studies have highlighted the possible role of discrete peripheral lesions of the annulus in accelerating the degenerative changes of the other components of the disc (Osti, Vernon-Roberts and Fraser 1990), but the incidence of the various types of annular defects is unknown.

We have analysed the characteristics and relative incidence of annular defects in a cadaver study of the human lumbar spine.

MATERIAL AND METHODS

Our prospective study examined all five lumbar discs from each of 27 spines collected, between 1987 and 1989, from an active adult population in Adelaide, excluding those affected with metabolic or skeletal disorders, or who had died as a result of trauma. The 135 discs were from subjects aged between 17 and 50 years (average 31.5).

Freshly excised lumbar spines were radiographed and then fixed in formal saline. Individual joint complexes including the intervertebral disc, its adjacent end-plates and the posterior arch with intact apophyseal joints were separated and decalcified. Decalcification was checked by daily radiographs and at its completion each intervertebral disc with its adjacent end-plates was cut into six parasagittal slices of uniform thickness. Each slice was examined under a dissecting microscope and photographed, then processed into wax for histology.

Morphological classification

Annular tears. Annular defects were classified into three types: peripheral or rim lesions, circumferential (concentric) and radial (Fig. 1).

Peripheral tears. Peripheral tears, or rim lesions, were defined as discrete tears of the outer layers of the annulus fibrosus, parallel and adjacent to one or both end-plates.
Classification of tears of the annulus fibrosus (see text).

The L2-L3 intervertebral disc of a 39-year-old woman. There is a rim lesion (arrow) at the anterior edge of the upper vertebra, with early osteophyte formation and bone marrow replacement by granulation tissue ($\times$ 5).

The L4-L5 intervertebral disc of a 46-year-old man. There is advanced osteophyte formation at the anterior edge of the upper vertebral body, related to disorganisation of the bony rim. This appearance is consistent with an old rim lesion (arrow) ($\times$ 5).

The L3-L4 intervertebral disc of a 50-year-old man. An area of cystic degeneration (arrow) associated with highly vascular granulation tissue separates the central portion of the disc from the posterior annulus fibrosus ($\times$ 6).

The L4-L5 intervertebral disc of a 50-year-old man, showing a radial cleft extending to the outer layers of the anterior annulus (arrow). This is associated with multiple concentric clefts and extends into a rim lesion. Marrow replacement with granulation tissue is seen in relation to the rim lesion ($\times$ 5).

(Fig. 2). These were frequently accompanied by ingrowth of vascular granulation tissue, sometimes extending into the middle layers of the annulus. Rim lesions generally gave origin to circumferential tears, seen as separation of the individual annular lamellae. The adjacent bony rim sometimes showed replacement of the marrow by granulation tissue, and osteophytes were often associated with these lesions (Fig. 3).

Circumferential tears. These were the most common annular defects in both the anterior and the posterior
annulus (Fig. 4). Especially in the outer layers of the annulus, they were sometimes associated with vascular ingrowth and cystic degeneration, and were commonly seen in relation to rim lesions.

**Radial tears.** These appeared to be a typical expression of more advanced degeneration, forming clefts which radiated from the nucleus pulposus to the outer lamellae of the annulus in a plane parallel or oblique to the end-plate (Fig. 5). In discs in which there was still some demarcation between annulus and nucleus, radiating ruptures were associated with nuclear displacement.

This displacement was accompanied by outward bowing of the annular lamellae where these were separated by the cleft, and by inward folding of the contralateral inner annulus, towards the site of displacement (Fig. 6). Some radiating ruptures ran into the mid-substance of the outer annulus (Fig. 7), and extended into rim lesions close to the end-plate. The outer peripheral
portion of such a tear may become vascularised with granulation tissue at various stages of maturity.

**Nucleus pulposus degeneration.** We also classified the morphological appearance of the nucleus pulposus into three grades according to its macroscopic appearance (Fig. 8):

*Grade I: normal.* There was clear demarcation between the nucleus pulposus and the concentric lamellar structure of the annulus fibrosus. The cut surface of the nucleus was bulging, with a gel or watery consistency and a milky creamy colour. There were no clefts extending from the nucleus into the annular substance.

*Grade II: moderate degeneration.* The distinction between nucleus and annulus was less well defined, and the cut surface of the nucleus was flatter and more solid. Its colour was slightly darker, and early clefts were seen to extend towards the outer areas of the disc.

*Grade III: severe degeneration.* There was no distinction between nucleus and annulus fibrosus. The cut surface was flattened and of friable consistency. Yellow-brown pigmentation was common and extensive clefts reached to the outer annulus.

**RESULTS**

Our results are summarised in Tables I and II.

*Peripheral tears* were more frequent in the anterior disc, except at the L5-S1 level where there were four anterior and five posterior rim lesions.

*Circumferential tears* were seen equally in the anterior and posterior parts of the annulus at the four upper levels, but at the L5-S1 level there were 18 circumferential tears posteriorly and only seven anteriorly.

*Radial tears* were almost exclusively seen in the posterior annulus and in almost half of the L5-S1 discs.

*Nuclear degeneration* was seen in eight L1-L2 discs as against 18 L5-S1 discs.

We compared the findings in 18 subjects under 35 years of age with those in nine over 35 years. There was no significant difference in the incidence of peripheral and circumferential tears, but the incidence of radiating ruptures in the posterior annulus was much greater in the older age group, correlating with the presence of degeneration of the nucleus pulposus. Seven of 45 discs (15.6%) from the older group showed severe nuclear degeneration as against two of 90 discs (2.2%) from subjects under 35 years of age.

No annular defects were seen in about half of the discs from the younger age group, but definite annular pathology was found in 33 of the 45 discs from subjects over 35 years old (Table II).

Seven of the nine discs with severe nuclear degeneration had radial tears, and four showed evidence of circumferential defects. By contrast, only two of all the discs which showed peripheral tears had grade III nuclear degeneration.

**DISCUSSION**

Schmorl and Junghanns (1971) considered that the appearance of clefts extending from the nucleus pulposus into the annulus was related to the desiccation and fraying of the central part of the disc. They recognised that clefts within the annulus could occur independently of the nucleus as concentric defects in the anterior and posterior regions. They also described, in relation to osteophyte formation, separation of the annulus fibrosus from the rim of the vertebral body along a plane parallel and adjacent to the end-plates. This was seen specifically at the very periphery of the disc. Coventry, Ghormley and Kernohan (1945a,b) considered that during the third decade of life the typical appearance of concentric fissuring of the annulus preceded the more important changes in the nucleus pulposus.

**Table II.** Incidence of discs showing annular tears by age of subject

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<th>Under 35 years (n = 90)</th>
<th>35 to 50 years (n = 45)</th>
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<tr>
<td>L1 to L2</td>
<td>9</td>
<td>6</td>
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<tr>
<td>L2 to L3</td>
<td>7</td>
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<td>L3 to L4</td>
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<td>7</td>
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<tr>
<td>L4 to L5</td>
<td>12</td>
<td>7</td>
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<tr>
<td>L5 to S1</td>
<td>10</td>
<td>7</td>
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<td>Total</td>
<td>45 (50%)</td>
<td>33 (73%)</td>
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*Morgan and King (1957) drew attention to the association between annular tears, radiographic instability and low back pain, observing the presence of "incomplete radial posterior tears" in the lower lumbar segments and of "anterior concentric fissures or slits" in the upper lumbar spine. Vernon-Roberts and Pirie (1977), reviewing over 300 lumbar spine post-mortems, confirmed that radiating annular tears were extensions of clefts from the nucleus pulposus, and also observed circumferential tears within the layers of the annulus and rim lesions near the attachment of the annulus to the*
peripheral vertebral body. The frequency, distribution and histological characteristics of vertebral rim lesions from 117 spines were reported by Hilton and Ball (1984), but they studied only central sagittal slabs of the T11-T12 and L4-L5 discs. They found rim lesions more frequently in the anterior disc, sometimes associated with major tears of the annulus. Most rim lesions showed evidence of attempted repair with fibrovascular and fibrocartilaginous tissue. On the histological appearances they considered that a traumatic aetiology was likely, and that these lesions could be related to low back pain.

Our study suggests that radiating annular defects are closely associated with degeneration of the nucleus pulposus and are most frequent in the lower lumbar spine and in the posterior annulus. Discrete tears of the annulus fibrosus can, however, occur in otherwise normal discs; these tears may precede degenerative changes in other parts of the intervertebral joint complex. The histological characteristics of rim lesions make it likely that they are due to trauma, rather than the biochemical degradation of disc tissue.

Friberg and Hirsch (1950) suggested that annular ruptures started in the inner layers and were directed outwards, either sagittally or laterally towards the periphery. The outward radiation of such ruptures was considered by Galante (1967) to be due to a combination of internal disc pressure and early degenerative failure of the inner annulus. By contrast, Kirkaldy-Willis (1983) proposed that annular lesions started in the outer lamellae, subsequently coalescing to extend inwards towards the nucleus pulposus.

Our observations indicate that tears of the peripheral annulus may develop independently. They should be regarded as separate entities from the radiating clefts that extend from a degenerating inner zone of the intervertebral disc. The formation of these discrete peripheral tears in relatively young discs has been demonstrated experimentally by Nachemson (1963, 1965). High intradiscal pressures would produce the greatest tensile strain in the outer layers of the annulus.

The relevance of peripheral annular lesions to the development of low back pain remains uncertain, but the common observation of vascular ingrowth and granulation tissue formation in association with peripheral defects of the annulus (Hirsch and Schajowicz 1953) suggests that these tears may produce symptoms. This is more likely since Yoshizawa et al (1980) and Bogduk (1988) showed that the outer annulus is the only part of the intervertebral disc with a demonstrable nerve supply. More confirmation comes from the observation that pain provocation at discography is closely related to the presence of tears extending to the outer lamellae of the annulus fibrosus (Adams, Dolan and Hutton 1986).

Conclusions. We suggest that defects of the peripheral annulus fibrosus precede the dehydration and fraying of the nucleus pulposus and are likely to be due to mechanical stress. These outer annular tears may influence and accelerate the degeneration of the intervertebral disc, and play a part in producing discogenic pain.

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REFERENCES


