HISTOPATHOLOGY OF HERNIATED LUMBAR INTERVERTEBRAL DISCS COMPARED WITH NON-HERNIATED LUMBAR INTERVERTEBRAL DISCS

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The histologic structure of 104 lumbar intervertebral discs from 21 cadaveric spines was compared with discographic (DG) and magnetic resonance imaging (MRI) findings to improve their interpretation. Furthermore the histology of herniated and non-herniated discs from elderly persons was studied. Using specific stains the annulus fibrosus and the nucleus pulposus were investigated for degenerative and regenerative alterations. DG revealed high sensitivity only for late and highly pathologic alterations. MRI's sensitivity for nuclear degenerative alterations was higher than DG's. None of the two radiographic medhods achieved satisfactory sensitivity for annular tears and dissociation. High specificity (1,0 with MRI; 0,8 with DG) was only achieved for the loss of acid mucopolysaccharides (MPS) in nucleus.

Herniated discs of the elderly revealed increased degeneration of the nucleus pulposus. Reduced collagen fibers and scars as well as increased tears and dissociation where found in the annulus fibrosus of herniated discs. A considerable increase of morphologically regenerative processes in the annulus and nucleus of herniated discs was seen.

Key Words: *Histologic disc pathology, magnetic resonance imaging, discography, lumbar disc herniation.*

INDRODUCTION

Diagnosis of intervertebral disc disease is to a great extent based on radiographic methods. This diagnostic information, however, is not always easy to interpret as the scructural composition cannot be seen directly and a correlation between radiographic abnormalities and objective clinical findings does not always exist. Pathologic radiographic findings of disc degeneration are present in both asymptomatic and symptomatic patients. Although pathoanatomic alterations of discs can be seen very clearly by means of microscopy, histology of the intervertebral disc has no influence on the diagnosis of intervertebral disc disease or preoperative surgical considerations. Thus histologic investigations of surgically removed specimens are not regularly performed and little is known about the relationship between histopathologic and radiographic abnormalities.

Herniated nucleus pulposus of the lumbar spine represents a common spinal disorder that especially affects patients less than 50 years of age. Disc disease in patients over 50 years is rather caused by disc degeneration than by herniation. This low incidence may be the reason why most of the literature refers to disc herniation of younger patients.

We compared histopathologic features of disc degeneration with radiographic findings to improve their interpretation. Furthermore we compared the histology of discs from elder persons with radiographic signs of herniation to those with non-herniated discs.

METHODS

104 Lumbar intervertebral discs (levels Th12/L1 to L5/S1) from 21 cadaver spines (>60y n = 16; 50 - 60y n = 4; 30 - 40y n = 1) without history of surgical treatment were investigated. magnetic resonance imaging (MRI) and lumbar discography (DG) were performed in order to examine the discs for severe degeneration and to differentiate between herniated and non-herniated discs.

Specimens were obtained as trephine discs by trepanation from ventral to dorsal. Media for preservation were formalin (2-10 days), aqua destillata (2 hours), ethanol 60%, 80%, 100% (2 hours each) and xylol (2x2 hours). Microtome sections (12 µm) were cut from paraffin blocks with a special disposable knife blade for bone. Using different stains (Hematoxylin-Eosin, Elastica van Gieson, Mowry[11], Prussian Blue, von Kossa) as well as polarizing microscopy for examination of birefringence the histomorphology of the annulus fibrosus and the nucleus pulposus was studied seperately (Tab. 1).

Degenerative alterations were characterized by annular tears, increase of tissue dissociation in the annu-

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Table 1: Methods: Stains or techniques conducted for histologic diagnosis

Stains (techniques) conducted	Histologic parameter	Criteria for histologic diagnosis
Hematoxylin-eosin	Numbers of cells (chondrocytes and fibrocytes)	Highest and lowest number of cells in an area of 1mm^2 at a magnification of 100
	Chondrocytic halo	Widening
	Annular tears	Number and length
	Tissue dissociation (necrosis-like lytic alteration)	Number and extent
	Clusters (more than three cells aggregated)	Number of nuclei and frequency of occurence
	Scarring	Number and length
	Vascularisation	Positive
Elastica van Gieson	Collagen fibers	Density and intensity of red staind fibers
Mowry	Matrix-MPS	Extent of blue stained area
	Synthesis of MPS in clusters	Intensity and area of blue stained substances in clusters or in halo around chondrocytes and clusters
Prussian blue	Iron deposits (residues of prior bleeding)	Extracellular, blue stainded
Von Kossa	Calciumcarbonate, -phosphat	Positive, extracellular, brown stained
Polarizing microscopy	Calciumpyrophosphate dihydrate (chondrocalcinosis)	Positive birefringence

lus, vascularisation, iron deposits, calcification of the matrix, scarring, loss of acid mucopolysaccharides (MPS) in the matrix of the nucleus pulposus, and an increase of collogen fibers in the nucleus. Cluster formation, synthesis of MPS in the clusters, width of chondrocytic halo, and increased numbers of cells (fibrocytes and chondrocytes), were considered regenerative features.

RESULTS

Part I: Comparison of histopathologic features of degeneration and radiographic findings

66 discs (64%) were considered degenerated by DG and 55 discs (53%) by MRI (Tab. 2).

Table 2: Sensitivity and specificity achieved by MRI ad DG for histopathologic features of disc degeneration

Histopathologic feature (degeneration positive)		Sensitivity		Specificity	
		DG	MRI	DG	MRI
Annular tears	n = 31	0,61	0,52	0,38	0,45
Annular tissue Dissociation	n = 23	0,70	0,65	0,38	0,5
Vascularisation	n = 18	0,83	0,78	0,41	0,52
Iron deposits	n = 3	1,0	1,0	0,38	0,48
Chondrocalcinosis	n = 13	1,0	0,92	0,43	0,53
Calciumcarbonate, -phosphate	n = 13	0.77	0,92	0,39	0,53
Loss of MPS in nucleus	n = 65	0,65	0,80	0,80	1,0
Increase of collagen fibers in nucleus Scarring	n = 38	0,71	0,76	0,51	0,68
	n = 19	0,84	0,79	0,42	0,52

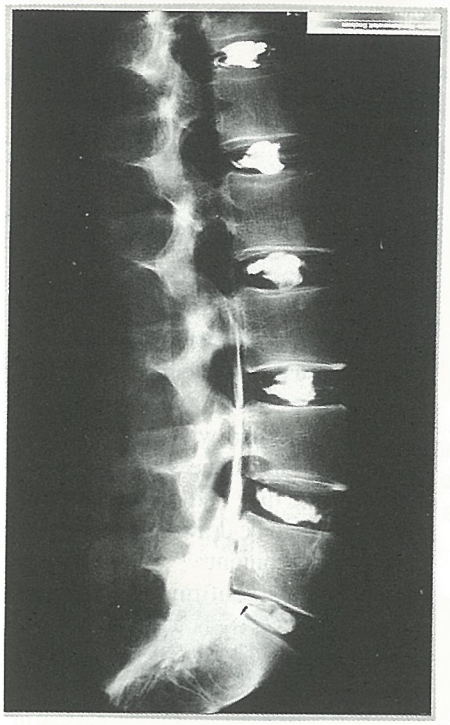

Figure 1.a. discography

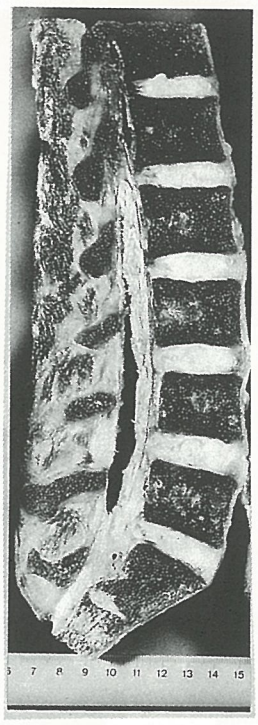

Figure 1.b. macroscopy

Figure 1: Morphology of lumbar discs without signs of degeneration

Both radiographic methods confirmed our histomorphologic diagnosis of degeneration with a high sensitivity for many, but not all criteria. With discography a sensitivity below 0.7 was achieved for annular tears and for the loss of MPS in the nucleus pulposus. All discs revealing iron deposits and chondrocalcinosis were considered degenerated by DG. MRI exhibited a lower sensitivity than DG, except for the following parameters: increase of collagen fibers in the nucleus, the loss of MPS in the nucleus and calcium deposits (calciumcarbonate, -phosphate). Lowest MRI sensitivity was found for solely annular criteria.

Compared with the mainly high sensitivity for pathologic histology, high specificity was only achieved for the loss of MPS in the nucleus. For that criterium MRI demonstrated a higher specificity than DG. For increase of collagen fibers in the nucleus only MRI showed a slight specificity of 0.68. Despite higher specificity of MRI than that of DG for all criteria no satisfactory results were obtained for any other parameters with either MRI or DG. With MRI high sensitivity as well as high specificity was observed only for the nuclear parameter of loss of MPS.

Part II: Comparison of the histopathology of radiographically diagnosed herniated discs with non- herniated discs from elder persons

Protrusion or nuclear herniation was found in eight discs of six different spines (levels L2/3 n = 1, L3/4 n = 5; age: 50-60a n = 2; >60a n = 6). In the control group without herniation 49% were considered degenerated with MRI and 58% with DG.

Within the degenerative features both the annulus fibrosus and the nucleus pulposus of herniated discs showed a considerable loss of MPS. An increase in calcification was seen more frequently in the nucleus than in the annulus of herniated discs. The percentage of discs with high collagen fiber density in the nucleus was increased in herniated discs, whereas the annuli of herniated discs exhibited high collagen fiber density in a lower percentage than non-herniated discs. Scarring, vascularisation and tissue dissociation revealed opposite changes in the annulus and nucleus. Compared to non-herniated discs there was a decrease in scarring and vascularisation in the annulus and an increase in the nucleus. Tissue dissociation however was increased in the annulus and decreased in the nucleus.

Regenerative processes were increased in herniated discs in the annulus as well as the nucleus. Herniated discs showed a significant increase in cluster formation, especially in the nucleus. Synthesis of MPS in clusters, aggregation of MPS in halo surrounding clusters and widening of the chondrocytic halo could be seen in all of our herniated annuli and nuclei. None of the herniated discs showed reduced numbers of cells in the annulus. In the nucleus reduced cell numbers were also less frequent than in non-herniated discs.

DISCUSSION

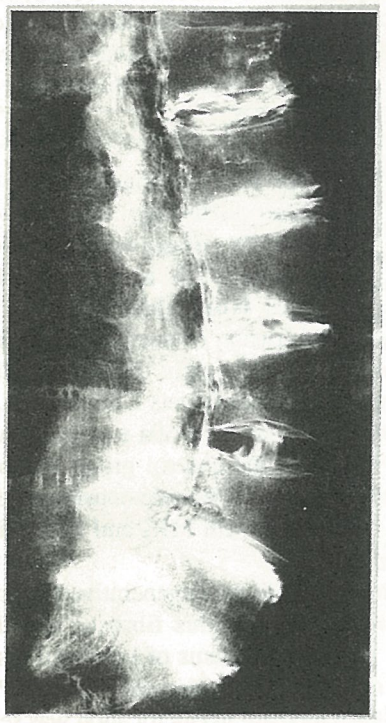

Figure 2.a. discography

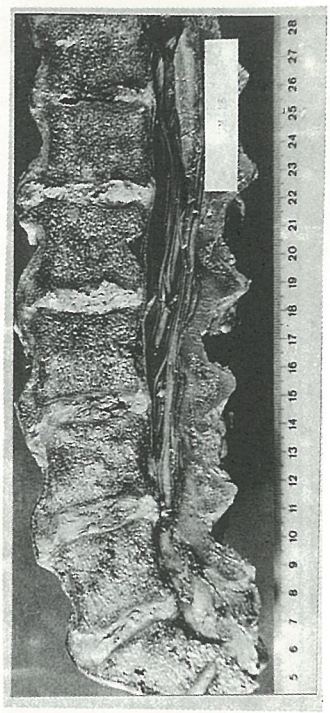

Figure 2.b. macroscopy

Figure 2: Morphology of lumbar discs with severe degeneration

Radiographic and histologic diagnosis basically differ in their means of asessing the state of vertebral disc degeneration. Thus a single histologic parameter cannot be correlated directly with the complex radiographic findings. The influence of specific histomorphologic alterations on diagnosis using DG and MRI, however, can be assessed by gaining sensitivity and specificity for that structural alterations. Our histologic criteria chosen for evaluating disc degeneration are commonly accepted indicators of disc degeneration in pathology [2,3,9,12].

Prior studies have demonstrated that changes in the discographic pattern seen on discography parallel morphologic changes of disc degeneration . This was confirmed by our results only for late, highly pathomorphologic changes[1, 8].

Loss of MPS in the nucleus and annular tears are pathophysiologically important features of disc degeneration. The sensitivity achieved for these criteria was clearly lower than for later and more severe alterations such as residues of prior hemorrhage (iron deposits), vascularisation and calcification.

Based on the fact that high specificity was achieved only for the loss of MPS in the nucleus it must be concluded that within our investigated criteria, the presence of high amounts of MPS is the only parameter that has influence on a disc being considered normal by DG.

The MRI has proved an adequate diagnostic tool to recognize degenerative processes at an early stage[4, 5, 10].Changes seen with MRI give information as to the state of hydration of the disc and therefore allow inferences to be drawn regarding proteoglycan content[4, 10].

This was confirmed by the high specificity (1, 0) as well as the high sensitivity (0, 8) for the loss of MPS in the nucleus. The association of increased collagen fibers in the nucleus and reduced hydration was expressed by a sensitivity of 0.76 and a specificity of 0.68. As low specificity shows, none of our other criteria seem to have any influence on a disc being considered normal by MRI.

Discs with histological signs of degeneration were found to be pathologic to a high degree, with exception of annular tears and annular dissociation. Microscopically even very small tears and slight tissue dissociation can be seen, which might be too discrete to change the signal intensity. We also agree with Kornberg[7], who explained the low sensitivity of MRI for annular disruption with the interval of time necessary between the development of disruption and the loss of sufficient water content to be reflected on MRI as decreased signal intensity.

Lumbar disc herniation is thought to be rare in elderly people since the nucleus already shows dehydration and therefore reduced internal pressure. Disc herniation was found in only 8% of the discs we investigated. None of our herniated discs showed normal MPS in the matrix either in the annulus or in the nucleus, so that pathogenetic factors other than the high hydrostatic pressure in the nucleus must be of

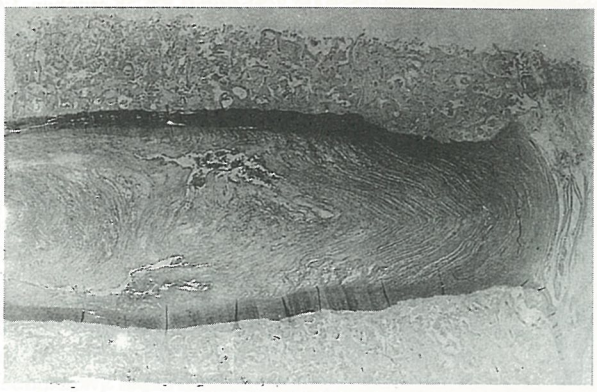

Figure 3.a. without degeneration (see Fig. 1) regular structure of the annulus fibrouss; tissue dissociation in and arround the nucleus (lacunae)

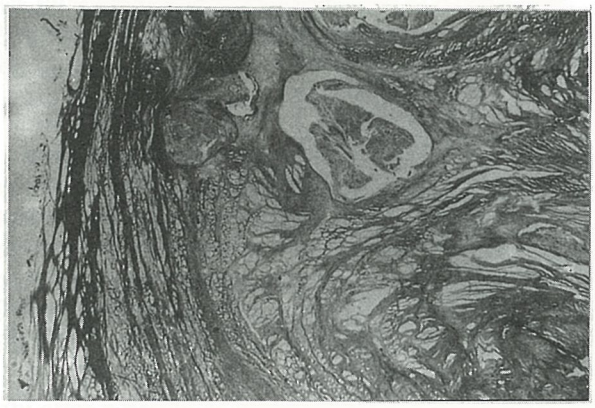

Figure 3.b. severe annular degeneration (see Fig. 2) excessive tissue dissociation, annular tears and protrusion of nuclear tissue in the outer annulus fibrosus

Figure 3: Histology of lumbar discs (nuceus pulposus and dorsal annulus fibrosus)

importance. Hirsch[6] hypothesized that disc herniation is a manifestation of disc degeneration. No ruptures occur in an annulus without the nucleus showing advanced structural changes.

Our results underline these opinions, as degenerative alterations were found more frequently in the nuclei of herniated discs than in non-herniated discs. We also regard reduction of -to our opinion- physiological dissociation in a nucleus as a pathologic expression, referring to insuffient nutritional supply. In a normal nucleus, dissociation improves the distribution of nutritional influx and guarantees quick metabolic efflux.

The annuli of herniated discs exhibited increased tears and dissociation and reduced collagen fiber density and scarring, these being features of an annulus with low mechanical stability. This structural composition of a dehydrated, fibrotic, scarred and calcified nucleus and a torn, dissociated annulus fibrosus with reduced collagen fibers and scars creates a situation where compressive load might extrude nuclear tissue more easily.

Morphologically reparative processes must be distinguished from degenerative alterations. Increased cellular turnover with widening of the chondrocytic halo, chondrocytic proliferation in clusters, and increased synthesis of mucopolysaccharides in clusters must be considered futile regenerative processes. Compared with non-herniated discs, these alterations were increased in the annulus and the nucleus as well. It is still not clear whether these processes are only determined by the pathogenesis of disc herniation. So far, however, we could show that these regenerative processes do not stop with increasing age, but also occur in discs of old people.

CONCLUSIONS

1. Severe pathomorphologic degenerative alterations were detected with high sensitivity by both radiographic methods.

2. Pathologically important degenerative alterations in the nucleus are better detected by MRI than by DG.

3. Despite higher sensitivity for annular tears and dissociation in DG than in MRI, none of the radiographic methods detected these changes with satisfactory sensitivity. It must be considered, however, that even very discrete discontinuities can be recognized by microscopy.

4. High amounts of MPS is the main criterion for a disc being considered normal. Absence of all the other degenerative features we investigated seems to have no influence on a disc being judged normal.

5. The structure of herniated discs from ederly persons can be characterized by advanced degeneration in the nucleus, reduced mechanical stability in the an-

Figure 4: Cluster formation with increased synthesis of MPHS, widening of halo surrounding clusters

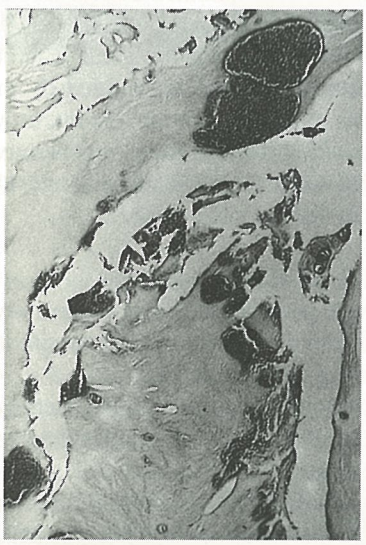

Figure 5.a. chondrocalcinosis (hematoxyline-eosin)

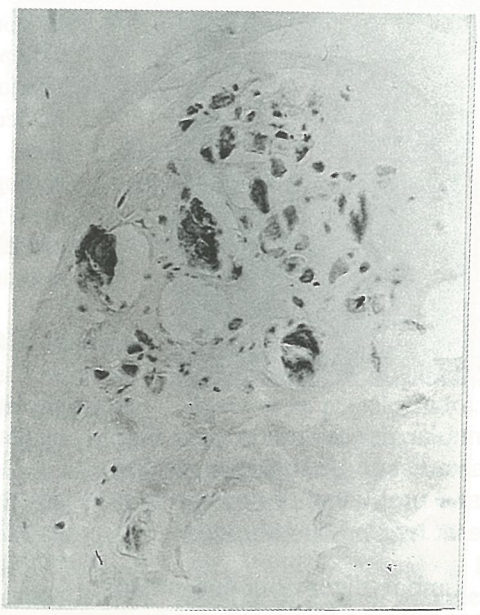

Figure 5.b. calciumcarbonate, -phosphate (von Kossa)

Figure 5: Calcification of the matrix

nulus and extensive regenerative processes in the annulus as well as in the nucleus.

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