FROM THE ORTHOPAEDIC CLINIC OF KAROLINSKA INSTITUTET, STOCKHOLM. CHIEF: PROFESSOR STEN FRIBERG

ANATOMICAL AND CLINICAL STUDIES ON LUMBAR DISC DEGENERATION

BY

STEN FRIBERG and CARL HIRSCH

ANATOMY

Abnormal mobility between two vertebrae had previously been observed both at autopsies and operations. In 1944 Knutsson showed that, in certain cases, hypermobility between two lumbar vertebrae could be demonstrated roentgenologically, that in bending forward there was anteposition and in bending backwards retroposition of the cranial to the caudal vertebra. This abnormal mobility which we have called instability of the vertebrae was observed both with other roentgenological signs of disc degeneration and as an isolated phenomenon. When it occurred alone, Knutsson regarded it as an early sign of degeneration of the intervening disc. Patho-anatomically this has not yet been confirmed.

We have made a patho-anatomical study of the lumbar discs with special regard to cases with radiographic signs of degeneration and to cases where instability occurred as an isolated phenomenon. The material consists of 100 spines i.e. 500 lumbar intervertebral discs from autopsy cases. The age variation is shown in fig. 1 below. The spines were taken from patients who had died from e.g. ulcer, trauma, circulatory disturbances etc.; those dying from infection or metastatic tumours were excluded.

The material was selected. We tried to have cases from all age classes but we were mainly interested in those between the ages of 21 and 50 years. The lumbar spine was dissected

1-10 years	9
11-20 „	4
21-30 „	21
31-40 „	17
41-50 „	21
51-60 „	12
61-70 „	12
71-80 „	3
81-90 „	1
	100 cases

Fig. 1.
The table shows the number of post mortem cases in each age group.

out with the sacrum and fixed in a vice, and as soon as possible after death, in most cases after a few hours, at room temperature, the preparation was flexed and extended without force and X-rayed in the different positions. After a short period of formalin fixation the intervertebral discs were removed by horizontal section and macrophotographed. Microscopical examinations were made on the material:

Radiographic changes	Number of spines	L1	L2	L3	L4	L5	Number of intervertebral discs
normal radiographs	46						
instability	15			1	12	4	17
disc degeneration	17	2	3	4	9	11	29
vacuum phenomenon	10		1	1	5	3	10
spondylosis deformans	20						
spondylolisthesis	2					2	2
osteoporosis	1						
Mb. Bechterew	1						

Fig. 2.
The frequency of the different changes seen on the radiographs.

Roentgenological signs of disc degeneration, i.e. reduced disc space, osteophytes and sclerosis, were observed in 29 spaces (17 cases), and instability in 17 spaces (15 cases); 12 of these were in the fourth disc.

The nucleus pulposus shows regressive changes quite early (Schmorl and others). With increasing age the fluid content decreases, the fibrous structure increases, and the delimitation from the annulus becomes less marked. It seems that these changes should be regarded as lying within the

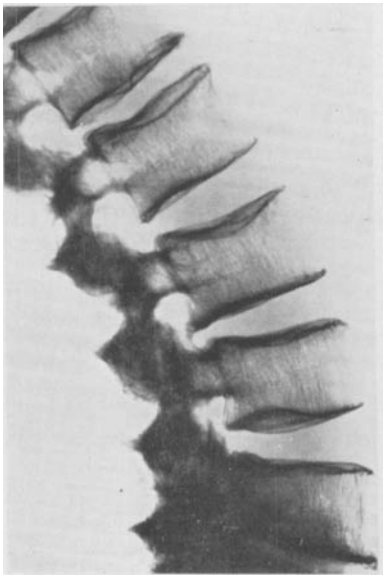


Fig. 3.

Radiograph of case 56. The disc space between L1 and L2 is rather narrower than is normal. Slight osteophyte formation on the lower anterior border of L1. The L2-L3 space is normal. L3 vertebra is slightly retroposed to L4, and there is a small osteophyte on the upper anterior border of L4. L4-5 space shows no abnormality. The lumbo-sacral space is narrow, and the edges of the vertebral bodies are sclerotic.

frame of normal physiological processes rather than as a pathological degeneration.

The difficulty is to decide when the condition is really of pathological significance. Our investigation has convinced us that definite degeneration must be presumed when ruptures are to be observed in the annulus.

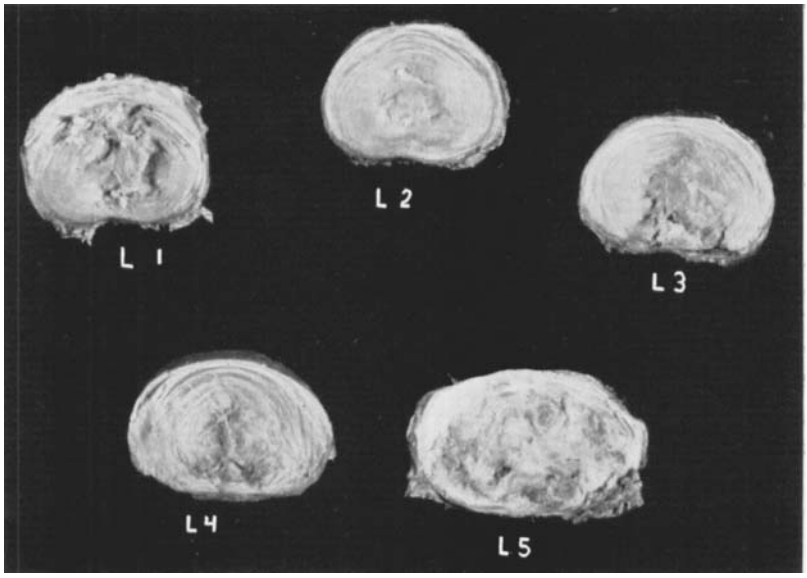
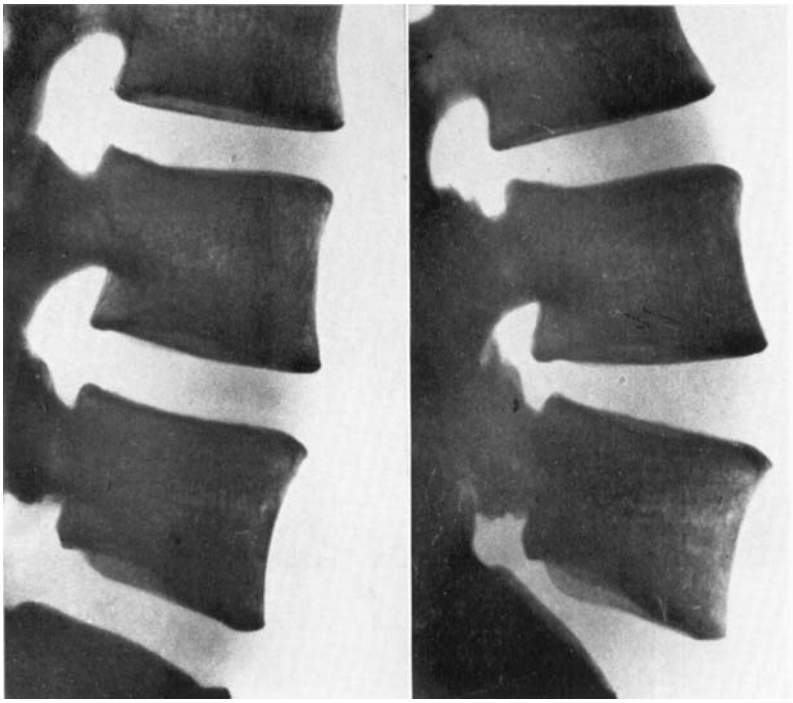


Fig. 4.
Sections of the 5 lumbar discs of Case 56. Cf. radiograph in fig. 3. There is degeneration of the 1st, 3rd, 4th, and 5th discs. L5 disc is completely destroyed. The changes are most marked anteriorly in L1, and posteriorly in L3, 4 and 5.

The following observations have been made on discs showing radiographic evidence of degeneration. The type and localisation of the ruptures in the annulus are different at different levels of the lumbar spine. In the upper part they are more or less concentric, and in severe cases they may be found all round the annulus, equally anteriorly and posteriorly. In the two lower discs the degenerative changes occur mainly posteriorly, and often show a characteristic configuration.

Fig. 3 shows a lateral radiograph of a lumbar spine which has examples of different degrees of disc changes, slight changes in the first disc, very advanced degeneration in the fifth. Fig. 4 shows the cross sections of the discs. In the first disc there are definite changes all round, especially anteriorly and centrally. The third and fourth discs have, in spite of very slight radiographic changes, definite ruptures poster-



a b

Fig. 5.

Radiograph of case 80. Post-mortem case.
a. spine in flexion. Normal height of disc spaces.
b. spine in extension without forcing. The L4 vertebra is displaced backwards. The intervertebral foramen is considerably reduced between L4 and L5, compared with the upper foramina.

iorly, though they are intact anteriorly. The fifth disc is completely destroyed.

When instability was present alone, without other radiographic sign of degeneration, the changes in the discs were the same as in those with narrowed interspace. The anatomical changes may be considerable, even though the radiograph shows only hyper-mobility.

Fig. 5 is a radiograph of a lumbar spine with instability of the fourth vertebra, and fig. 6 shows the fourth disc in

cross section: a sagittal, irregular, perforating rupture runs right through it posteriorly, and by a T-shaped division undermines a fairly large part of the annulus towards the intervertebral foramen. This is a common picture.

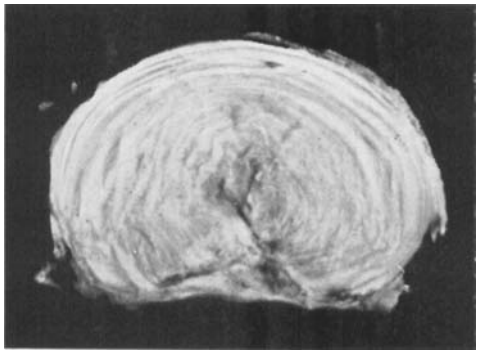


Fig. 6.

The unstable L4 disc from post-mortem case no. 80. Cf. radiograph in fig. 5. T-shaped ruptures in the posterior part of the disc running towards the intervertebral foramina on both sides and undermining the whole posterior border of the annulus fibrosus.

Fig. 7.

Intervertebral disc with partial ruptures within the postero-lateral borders of the annulus fibrosus. The nucleus pulposus flows out in the area of the rupture.

A total or subtotal interruption of the continuity of the fibrous structure of the annulus was noted in 16 out of the 17 cases with instability.

A common feature of degeneration of the two lower discs seems to be the presence of ruptures, radiating from the centre posteriorly and postero-laterally, and surrounded by smaller ruptures. The larger, main ruptures usually extend

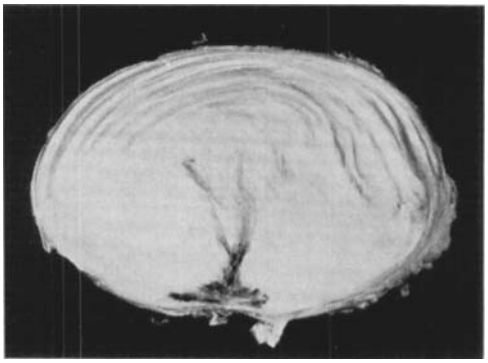


Fig. 8 a.
Intervertebral disc with ruptures running through the posterior part of the annulus fibrosus in the midline.

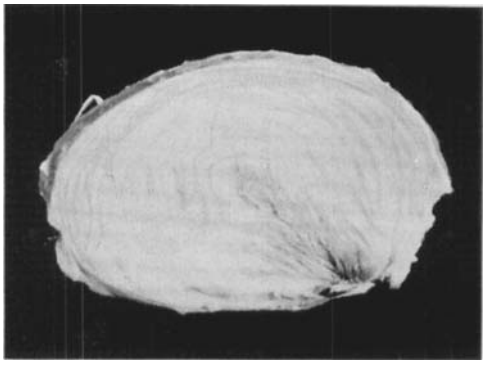


Fig. 8 b.
Intervertebral disc with perforating ruptures through the postero-lateral part of the annulus fibrosus out towards the intervertebral foramen.

either sagitally or towards the intervertebral foramen. See figs. 7 and 8.

The sagittal ruptures very often divide, as in fig. 6, the lateral ruptures running more or less concentrically towards

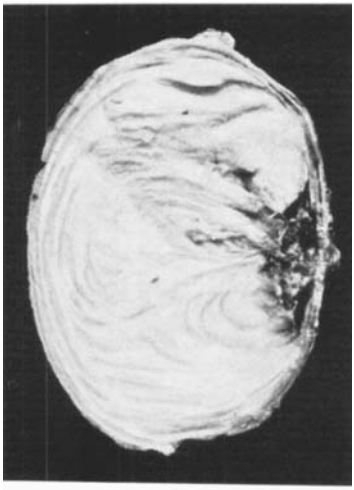


Fig. 9 b.
Degenerated intervertebral disc.

Fig. 10.
'Concealed' disc lesion.

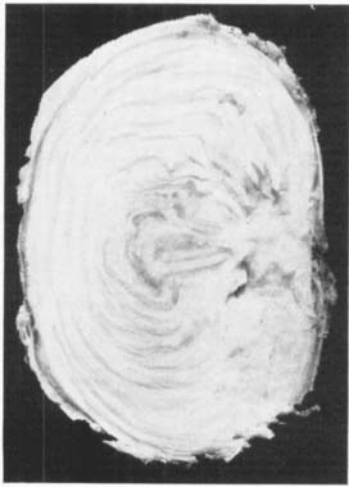


Fig. 9 a.
Degenerated intervertebral disc.

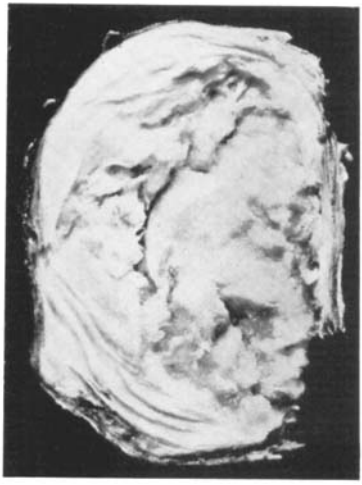


Fig. 9 c.
Disc with advanced degeneration.

the foramen. The whole posterior part of the disc may be affected in this way, although as a rule there is no prolapse.

In connection with the annulus ruptures, a special arrangement of the fibrous structure, apparently dependent on the localisation of the rupture, has sometimes been observed.

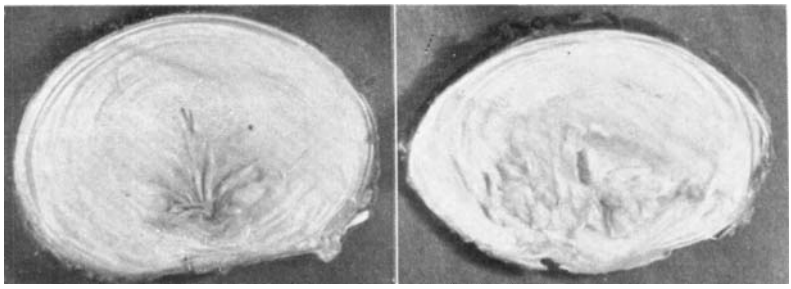
Fig. 11.
Case 59. Normal radiograph of the lumbar spine.

On the surface section the fibrous tissue appears to be "flowing out" towards the outer layers of the disc through the fissure. See figs. 7 and 8b. This may well be the case. With more pronounced ruptures in the annulus there is some retraction of its fibres, and tissue begins to be squeezed out through the ruptures because of the pressure within the disc.

In the fourth and fifth discs the anterior parts are generally intact, even with very advanced changes posteriorly. Fig 9a, b.

Among 500 discs, were found 11 prolapses, all backwards and all in the two lower interspaces. In all there were pro-

nounced ruptures of the annulus, and a more or less fibrous structure of the nucleus. Fig. 10 shows a L4 disc. Posterolaterally run two large ruptures, which mark a concealed prolapse in statu nascendi. This is a not uncommon picture. In all 11 prolapse cases there were, in addition to the transverse ruptures in the annulus, structural changes of the same kind as in the cases of disc degeneration described above.



a b

Fig. 12.

a. The disc between L4 and L5 in Case 59. Cf. the radiograph in fig. 11. The disc shows early degenerative changes in the central posterior area, though no changes are seen on the radiograph.

b. The lumbo-sacral disc of Case 59. Cf. radiograph in fig. 11. Necroses and collapse in the whole posterior part of the disc. There are numerous ruptures in the annulus fibrosus. No changes are seen on the radiograph.

The prolapse is a part phenomenon in a general degeneration of the disc.

Above, we have been discussing the appearance of discs which radiographically showed narrowed interspace, sclerosis and osteophytes, or instability. However, ruptures in the annulus, and fibrosis and necrosis of the nucleus have been observed macroscopically in many cases over 30 years of age. Instability may seem to be an early roentgenological sign of disc degeneration, but it presupposes advanced changes in the structure of the disc, and when narrowed interspace, sclerosis, etc. occur, the changes are marked. On the other hand, it must be pointed out that negative radiographic findings are no proof that the disc is intact. A normal radio-

graph may conceal not inconsiderable degenerative changes (see figs. 11 and 12).

CLINICAL OBSERVATIONS

The anatomical study just described impelled us to seek to establish on a clinical material how far disc degeneration could be observed roentgenologically. Therefore, to supplement the anatomical study we have investigated the cases examined and treated for "back trouble" at the Clinic during the years 1936-1946. Cases with tumours and T.B. have been excluded from the material, which comprises the diagnoses lumbago, lumbago-sciatica, disc degeneration, insufficientia dorsi, spondylosis deformans, spondylolysis, spondylolisthesis, sacralisations, hemi-vertebrae and other congenital abnormalities. During these 11 years 15,160 cases were seen, and 9419 patients were radiographed. Only the latter will be discussed. Some were not radiographed during the war because of shortage of films, and some simple cases of dorsal in-

Year of investigation	Number of cases examined	Number of cases examined		Number of cases with disc degeneration	Disc degeneration in % of number of cases radiographed
		Total	%		
1936	491	350	71	53	15
37	663	480	73	78	16
38	800	506	64	123	24
39	794	467	67	153	33
40	1140	625	55	194	31
41	1374	700	51	230	33
42	1678	907	54	285	31
43	1958	1117	53	452	41
44	1869	1217	64	586	49
45	2033	1361	67	680	50
46	2360	1689	76	838	50
Total	15160	9419		3672	39

Fig. 13.

sufficiency were treated without radiography; some brought radiographs from other clinics, and afterwards it was not possible to form a definite opinion about them. Roentgenological signs of disc degeneration were found in 3,672 (39 %), see fig. 13.

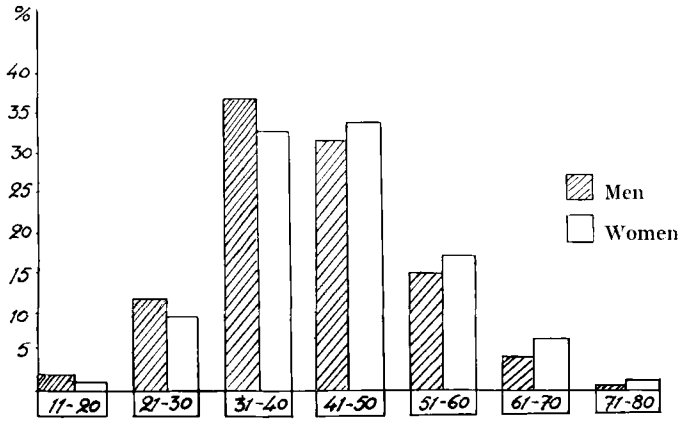


Fig. 14.
Age and sex distribution of the cases with disc degeneration.

In the table are included only cases where a diagnosis of disc degeneration was made the first time the patient was radiographed. A patient who, for instance, visited the Clinic in 1936, but was not examined radiographically until 1938, was registered in 1936. In this way the percentages for the first few years have come to be somewhat higher. During the earlier years of the table our attention was not so closely directed to disc degeneration, and this may to a certain extent explain the comparatively low proportion of diagnosed disc degenerations. During the years 1939-1942 the percentage of disc degenerations diagnosed on the bases of narrowed interspace, sclerosis and osteophytes, was comparatively constant. But since 1943 when our radiologist, Knutsson, began to use his instability tests, i.e. bending tests, the curve for diagnosed disc degeneration showed a definite rise. During the later years, roughly half of all the patients seen in the Clinic

because of low back pain have shown radiographic signs of disc degeneration.

Out of the 3,672 cases with disc degenerations, 2,081, or 57 %, were men, and 1,591, or 43 %, women. 1,530, or 74 % of the men were labourers. We have classed as labourers persons who, in the course of their work, have to lift and carry heavy objects. This classification is necessarily subjective, and its limits are mostly rather vague. The figures we have found scarcely support the belief that heavy manual labour plays an important part in the causation of lumbar disc degeneration. The percentages 74 % and 26 %—respectively — roughly represent the proportions of manual labourers and others in the community at large, and, in addition, the sex distribution does not show the preponderance of men which would be expected if heavy manual labour were of decisive importance.

Disc	%
Th 12-L 1	0,3
L 1-L 2	2,7
L 2-L 3	6,7
L 3-L 4	15,1
L 4-L 5	47,6
L 5-S-1	27,6

Fig. 15.
The site of the degeneration in 2104 cases with degeneration of an intervertebral disc. Radiographed 1944-6.

The majority of the patients with disc degenerations diagnosed radiographically were found in the age group 31-50 years, see fig. 14. The men show the highest frequency in the ages 31-40 years, the women in 41-50 years. It should be mentioned here that the great majority of cases coming to the Clinic have long-standing symptoms, usually resistant to therapy elsewhere.

The table does not show the age incidence of disc degeneration, but the age at which the patients have come to the Clinic, i.e. at the time when the symptoms were most pronounced. Patho-anatomically the degenerative changes in the discs are

progressive, and if there was full conformity between the degree of degenerative change and the symptoms, this would mean that the frequency would increase with the age. The curve seems to justify the assumption that the symptoms are to a certain extent transient, though healing, used in a patho-

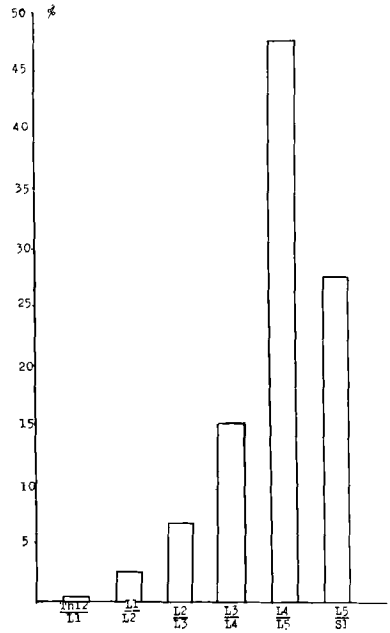


Fig. 16.
The same shown diagramatically. Cf. fig. 15.

anatomical sense, does not occur. In principle, the disc degeneration is an osteoarthritis, and it seems that in a similar manner the reactive changes in and around the disc may finally lead to a loss of its function with a consequent reduction of the symptoms.

The first part of this paper shows that instability is connected with disc changes, which conform in principle with those which are to be observed in radiographic disc degeneration. After the publication of Knutsson's observations in 1944,

cases with instability without other radiographic abnormality, or with only slight signs of disc degeneration were studied. During the years 1944-1946, instability without other signs of disc degeneration was observed in 303 (15 %) out of 2,104 cases of disc degeneration. The distribution of the different degenerated discs in these 2,104 cases is shown in fig. 15.

Almost half, or 47.6 % of the degenerations were localised to the fourth disc, and in 75.2 % to the fourth and fifth discs. It should be noted that 27.6 % for the fifth disc is probably a minimum figure in view of the difficulty of detecting changes in this often physiologically thinner disc.

Site	%
Th 12-L 1	0
L 1-L 2	0,7
L 2-L 3	4,2
L 3-L 4	18,5
L 4-L 5	70,3
L 5-S 1	6,3

Fig. 17.
The site of the instability in 303 cases with no other sign of disc degeneration.

Site	%
Th 12-L 1	0
L 1-L 2	1,8
L 2-L 3	8,0
L 3-L 4	20,3
L 4-L 5	60,1
L 5-S 1	9,8

Fig. 18.
The site of the instability in 275 cases with other signs of disc degeneration.

Scrutiny of the 303 discs with instability alone shows, that in 70.3 % the changes were localised to the fourth disc (see fig. 17). This is in conformity with the anatomical findings, where in 12 out of 17 intervertebral discs with instability, i.e. 70.6 %, the changes were in the fourth disc.

Instability was combined with other radiographic signs of degeneration in 275 cases (see fig. 18). In this group instability of the fourth disc was observed in 60.1 % of the cases.

SUMMARY

100 lumbar spines taken out from post mortem specimens have been studied. They were radiographed in various positions of flexion and extension, and the stability of the spines, i.e. of the discs, was assessed. Other radiographic changes were also recorded. The intervertebral discs were sectioned horizontally, and the changes observed in the nucleus pulposus and annulus fibrosus were recorded. Particular attention was paid to ruptures in the annulus fibrosus.

The records of 15,160 patients seen in the Clinic for lumbar pain, excluding those with tuberculosis and tumours, during the period 1936-1946, have been collected; and the incidence of radiographic signs of disc degeneration in the lumbar spine has been studied.

The post mortem material showed:

1) Disc degeneration acquires patho-anatomical importance when the annulus fibrosus begins to rupture.
2) In the lower lumbar discs the ruptures in the annulus were mostly localised to the posterior part of the disc. From the centre they were directed either sagittally or laterally backwards to the intervertebral foramen. In the upper discs the ruptures were frequently also anterior.
3) Marked degeneration may be present without any radiographic changes. Thus a normal radiograph does not exclude an important degeneration in a disc.
4) In 16 out of 17 cases with instability there were severe changes in the disc and ruptures in the posterior part of the annulus fibrosus.
5) When the radiograph showed reduced disc space, sclerosis or osteophytes, the corresponding disc was severely damaged.

6) In cases with prolapse of the disc the structure had the same patho-anatomical characteristics as in cases of simple degeneration. Disc prolapse is a part phenomenon of degeneration of the disc.

The clinical material showed:

1) Radiographic disc degeneration was found in 39 % of all the patients that came to the Clinic for "back trouble", and in 50 % of the material covering the last 2 years of the investigation.
2) 43 % of the cases with disc degeneration were women, and 57 % men.
3) 74 % of the men were engaged in physical work of some kind or other. This proportion agrees roughly with the country's proportion of labourers.
4) The authors found no evidence that heavy physical work is the direct cause of the disc changes.
5) Disc degeneration occurs most frequently (in 47.6 %) in the 4th lumbar disc, and in 75.2 % in the 4th and 5th discs together.
6) In 15 % instability was the only radiographic change. In 70.3 % [of these] it occurred at the 4th disc.
7) The investigation shows that radiography does not give satisfactory information on the condition of the disc in cases of lumbar pain. The instability test is a valuable contribution to diagnosis.

RESUME

Les auteurs ont examiné 100 colonnes lombaires provenant d'autopsies. Après la dissection, ces colonnes ont été radiographiées dans différentes flexions ventrales et dorsales afin de pouvoir apprécier la stabilité des vertèbres. Des modifications radiologiques ordinaires ont été enregistrées. Des disques étaient transpercés horizontalement et il y avait des altérations dans le nucleus pulposus et l'annulus fibrosus. Les ruptures de l'annulus fibrosus notamment ont été étudiées.

Les auteurs ont rapproché d'autre part tous les cas cliniques soignés à l'hôpital pour des douleurs lombaires entre 1936 et 1946, soit en tout 15,160 cas, en éliminant tous ceux atteints de tuberculose ou de tumeurs. Ils ont étudié la fréquence radiographique des dégénérations des disques dans la colonne lombaire.

En ce qui concerne le matériel provenant des autopsies, cet *examen a fait ressortir ce qui suit:*

1. Quand il y a rupture de l'annulus fibrosus, il semble qu'il y ait une dégénération certaine du disque.
2. Les ruptures de l'annulus observées dans les disques lombaires inférieurs ont été localisées dans la partie dorsale des disques, allant soit du centre en arrière, soit en arrière latéralement, en direction du trou intervertébral. Dans les disques lombaires supérieurs, les ruptures sont plus fréquemment ventrales.
3. Il pouvait y avoir des modifications dégénératives prononcées sans qu'elles apparaissent sur la radiographie. Une radiographie normale n'exclut donc pas la présence de modifications dans les disques.
4. Lorsqu'il y avait instabilité, on a trouvé dans 16 cas sur 17 des modifications sensibles et l'on a trouvé des ruptures dans la partie postérieure de l'annulus fibrosus.
5. Lorsque la radiographie a décelé une diminution dans l'épaisseur du disque, des scléroses ou des ostéophytes, les disques cartilagineux correspondants montraient des modifications extrêmement nécrotiques.
6. Dans les cas où il y avait prolapsus du disque, les modifications anatomo-pathologiques présentaient le même caractère que les cas de simple dégénération du disque. Le prolapsus du disque fait partie du phénomène de la dégénération du disque.

Dans le matériel clinique, les observations suivantes ont été faites:

1. Sur l'ensemble de ce matériel, on a constaté des dégénéra-

tions radiographiques de disque dans 39 %, pour les deux dernières années dans 50 % des cas.

2. Sur tous les cas de dégénération du disque, il y avait 43 % de femmes et 57 % d'hommes.
3. Parmi les hommes, 74 % étaient des travailleurs. Ceci correspond à peu près au pourcentage des travailleurs dans la population masculine.
4. Les auteurs n'ont pas trouvé la preuve qu'un dur travail corporel est la cause directe de la fréquence des modifications dégénératives des disques.
5. La fréquence de la dégénération des disques dans les différents intervalles lombaires établit que le plus grand nombre est localisé dans le disque de la 4ème vertèbre lombaire, à savoir 47,6 %. Dans 75,2 % des cas, les modifications du disque se trouvaient dans les deux disques lombaires inférieurs.
6. On a constaté de l'instabilité dans 15 %, sans autres modifications radiologiques. Dans 70,3 % des cas, celle-ci était localisée au 4ème disque.
7. Cette enquête semble prouver que l'examen radiographique ne donne pas à lui seul des renseignements satisfaisants sur l'état des disques dans les cas de douleurs lombaires. L'épreuve de l'instabilité constitue un précieux apport diagnostique.

ZUSAMMENFASSUNG

100 Lendenwirbelsäulen die der Leiche entnommen wurden, sind untersucht worden. Sie wurden in verschiedenen Flexions- und Extensionsstellungen Röntgenuntersucht und die Stabilität der Wirbel wurde festgestellt. Ondre röntgenologische Veränderungen wurden ebenfalls notiert. Die Zwischenwirbelscheiben wurden durch horizontale Schnitte zerlegt und die im nucleus pulposus und annulus fibrosus wahrgenommenen Veränderungen wurden aufgezeichnet. Besondere Aufmerksamkeit wurde den Rupturen im annulus fibrosus gewidmet. Ausserdem wurden insgesamt 15,160 Fälle ge-

sammelt, die im Krankenhaus wegen Schmerzen in der Lumbalregion während der Jahre 1936—1946 untersucht wurden. Ausgenommen waren Fälle mit Tuberkulose oder Tumoren. Das Vorkommen von röntgenologischen Zeichen von Diskusdegeneration in der Lendenwirbelsäule wurde studiert.

Das von der Leiche gewonnene Material zeigte:

1) Eine sichere Scheibendegeneration ist vorhanden, wenn der annulus fibrosus geborsten ist.
2) In den kaudalen Lendenzwischenwirbelscheiden waren die Rupturen im annulus in den rückwärtigen Partien der Scheibe gelegen und entweder zentral nach hinten oder lateral nach hinten gegen das foramen intervertebrale gerichtet. In den oberen Scheiben waren die Rupturen auch oft im vorderen Anteil zu sehen.
3) Ausgeprägte degenerative Veränderungen mögen vorhanden sein ohne dass es zu röntgenologischen Veränderungen kommt. Daher schliesst ein normales Röntgenbild Veränderungen in der Scheibe nicht aus.
4) In 16 von 17 Fällen mit Zeichen für Instabilität fand man schwere Veränderungen der Scheibe und Rupturen im rückwärtigen Teil des annulus fibrosus.
5) Wenn das Röntgenbild einen verminderten Wirbelzwischenraum, Sklerose oder Osteophytbildung zeigte, waren die entsprechenden Knorpelplatten ausgesprochen nekrotisch verändert.
6) Fälle mit Scheibenprolaps zeigten dieselben Charakteristika wie Fälle mit einfacher Degeneration. Der Scheibenprolaps ist Teilerscheinung einer Scheibendegeneration.

Das klinische Material zeigte:

1) Röntgenologisch wurde Scheibendegeneration in 39 % des gesammten Materiales und in 50 % des Materiales der letzten zwei Jahre gefunden.
2) 43 % der Fälle mit Scheibendegeneration waren Frauen und 47 % waren Männer.

3) 74 % der Männer hatten körperliche Arbeit zu verrichten. Diese Anzahl stimmt ungefähr überein mit der Anzahl der Arbeiter des Landes.
4) Die Verfasser fanden keinen Beweis dass schwere körperliche Arbeit die direkte Ursache der Scheibenveränderungen ist.
5) Das Vorkommen von Scheibendegeneration in verschiedenen lumbalen Zwischenwirbelräumen zeigt dass sie oftest, d. i. in 47,6 % in der 4. Lumbalscheibe und in 75,2 % in der 4. und 5. Scheibe auftritt.
6) Mangelhafte Stabilität war die einzige röntgenologische Veränderung in 15 % der Fälle. In 70,3 % trat diese in der 4. Scheibe auf.
7) Die Untersuchung zeigt dass man keine zufriedenstellende Auskunft über den Zustand der Scheibe durch Röntgenuntersuchung in Fällen von Schmerzen in der Lumbalregion erhalten kann. Die Instabilitätsprobe ist ein wertvoller Beitrag zur Stellung der Diagnose.

LITERATURE

Knutsson, F.: The instability associated with disc degeneration in the lumbar spine. Acta Radiologica Vol. XXV, 1944.