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THE INSTABILITY ASSOCIATED WITH DISK DEGENERATION IN THE LUMBAR SPINE

by

Folke Knutsson

Examination of anatomic specimens of the lumbar spine has shown that disk degeneration (osteoichondrosis) causes abnormal movements between the vertebrae (Hildebrandt, Güntz) and it has been assumed that the clinical symptoms of disk degeneration are due to this instability. Putti aptly likened the condition to pseudarthrosis. This being the case, it is remarkable that no attempts have been made with roentgen examination of living subjects to determine whether the disk junction is stable or whether there are abnormal movements between the vertebrae and, if so, to register the degree of instability.

The ordinary roentgen examination of the lumbar spine is intended for study of the anatomic conditions and is generally done with the patient lying down. Since November of 1943 I have routinely complemented this examination with profile pictures taken with the patient standing and bending as far forward and backward as possible, in order to make a functional test of the stability of the disk junction. By this means I have often been able to demonstrate abnormal movements between the vertebrae, due to loss of stability. With these complementary pictures, the roentgen diagnosis of disk degeneration embraces the following features.

1) Narrowing of the intervertebral space. (It is difficult to determine whether the lumbosacral disk is narrowed, for it varies greatly in thickness normally. It is intermediate in form between the thick lumbar and rudimentary sacral disks, whence a biologic explanation for its great variability. If it is narrow but there are no changes in the vertebral body, it may be considered sacralized and thus an anatomic variation.)

1 Submitted for publication, July 13, 1944.
2) *Reactive changes in the vertebral bodies* consisting of sclerosis of their surfaces and lipping of their margins.

3) *Vacuum phenomenon.* Fissures occur in the degenerated disk substance which may be visualized in the roentgen pictures as airy spaces due to the vacuum which develops when the walls in the fissure gape apart, usually on backward bending of the spine (Magnusson, Knutsson). This vacuum phenomenon may be an early pathognomonic sign and occur in an otherwise intact intervertebral space (Knutsson).

4) *Abnormal situations of the vertebrae in relation to one another,* such as retroposition of the overlying vertebra, pseudospondylolisthesis and rotatory slipping in scoliosis, indicate that the stability is disturbed. Positional changes of this nature may be considered acquired, being due to reduced stability in the disk. In genuine spondylolisthesis, on the other hand, the abnormal position between the vertebral bodies is due to the deformity as such and not to acquired displacement.

5) *Abnormal motion* can often be demonstrated by films of the patient in extreme flexion, as will be shown presently. It can often be shown how retroposition of a vertebra or pseudospondylolisthesis is only one stage in a sequence of abnormal movements, and is due to the habitual posture. The displacement may be decreased or entirely corrected by extreme reducing movements and, again, it may be increased by forced movement in the opposite direction. The abnormal movements include both parallel displacement of the vertebrae and abnormal tilting movements (Knutsson).

**Technic**

My aim was to make a functional test of the stability of the disk junction. Consequently it was necessary to insert as much power as possible in the extreme movements. For this reason I abandoned my first attempts with films of the patient lying down in positions of induced lordosis and kyphosis and changed over to examining them in the upright position.

I routinely restricted my examination to profile pictures, because they permit a geometric survey of vertebrae and intervertebral spaces, except in the case of scoliosis. It is not possible to make a similar methodical study with frontal pictures with lateral flexion, for the lordosis, which usually cannot be entirely eliminated, causes the different intervertebral spaces to be projected differently. In some cases, however, examination of the lateral mobility should provide valuable information as regards separate disks.

I take one profile picture in maximal backward flexion and another in maximal forward flexion. In the former case the patient stands at
the edge of the photographing table, supports himself with his buttocks on the edge and bends backward as much as possible, grasping the table behind him with his hands. In the latter case, he sits on the table, puts his feet on a chair and then bends forward as much as he can. (Fig. 1.) Secondary rays were shut-tered off by means of Lys-holm’s grid. A distance of one meter was used between the focus and film. It would be advantageous, of course, if the distance could be increased so as to produce more uniform projection of large parts of the spinal column.

As far as I know, no such functional test for the stability of separate disk junctions has been used hitherto. Several authors have made exa-minations with the patient standing. Thus Güntz took roentgen photographs of erect subjects to register the habitual posture and to study the range of movement and fixation in different parts of the spine. BAK-KE took films in extreme positions of the spine in normal persons to study the range of motion in different sections. DUNCAN and HOEN tested the mobility in the intervertebral disks in clinically proved cases of disk prolapse by photographing the patients in the upright position, both bent to the sides and forward and backward. They found that the intervertebral space was not pressed together in the affected region, the movement being checked to prevent further protrusion of the herniation against the nerve root. They observed this condition in cases where the intervertebral space was of normal width, but not, as a rule, in cases of marked disk degeneration with narrowed intervertebral spaces. After operation on the herniation, the movements of the disk again became symmetric. Consequently, in such cases it is a question of muscular fixation which protects the affected part of the disk from compression, and their method does not test the anatomic stability of the disk junc-tion.

Normal mechanics

The normal movements between the vertebrae and function of the intervertebral disk have been studied in anatomic specimens and de-scribed in detail, especially by FICK and STRASSER. The anatomic con-struction of the disk with a capsule-like annulus fibrosus enveloping
Fig. 2. (1134/37) Normal case.

Fig. 3. (6980/43) Normal case.

Fig. 4. On bending of the spine the nucleus pulposus is moved to the convex side, with the result that the increase in pressure is distributed evenly over the whole surface of the vertebral body. (From STRASSER).

1 In similar figs the left picture is taken in flexion backward and the right in flexion forward.
Fig. 5, 6, 7.

Cases of degeneration with slightly narrowed intervertebral spaces and marginal lipping of the vertebral bodies. Signs of instability in the form of parallel displacement in the direction of flexion are seen, the upper vertebra being retroposed on backward bending.

Fig. 5 (5090/41)

Fig. 6 (1146/43)

Fig. 7 (7142/43)

The elastic nucleus pulposus is of great importance to normal function. The nucleus may be likened to a fluid-filled vesicle which, being incompressible, may be deformed but not altered in volume. If two vertebral bodies are pressed against one another from above downward, the nucleus is flattened and pressed out to the sides. The annulus fibrosus is then exposed to greater pressure in the peripheral direction and its cir-
Fig. 8 (1252/44). Degeneration of the disk between the fifth lumbar and first sacral vertebrae, manifested by narrowed intervertebral space, marginal lipping of the vertebral bodies and the vacuum phenomenon. The fifth lumbar vertebra is retroposed, and the retro-position increases on forward bending. Thus there is parallel displacement in the direction opposite to flexion, signifying instability.

Fig. 9 (1828/36). Degeneration of the disk between the fifth lumbar and first sacral vertebrae. In 1932 slight retroposition and narrowing of the intervertebral space were manifested. In 1943 the intervertebral space was still narrower, the retroposition had increased, and the vacuum phenomenon, indicating fissuring of the disk substance, had appeared. On forward bending the retro-position of the fifth lumbar segment increased, instability being thus manifested by parallel displacement in the direction opposite to flexion.

cumference bulges out slightly. Thus the disk acts as a resilient shock absorber.

Flexion of the spine causes unilateral compression of the disk on the concave side and the nucleus pulposus is displaced over to the opposite side (STRASER). Because of the incompressibility of the nucleus the increased pressure is then transmitted fairly uniformly over the whole cross section of the disk. If the disk were composed entirely of the same material, the pressure would be confined to half its cross section. On flexion the annulus bulges out on the concave side and is stretched and slightly drawn in on the convex side.

Thus the normal disk junction is characterized by great mobility, allowing varying angles between the vertebrae, but also by great sta-
Instability associated with disk degeneration

Instability, hindering parallel displacement. The spinal column is bent like an elastic rod and, according to Fick and Strasser, parallel displacement between the vertebrae does not take place. Movements between two adjacent vertebrae take place through axes which go through the nucleus pulposus and are accompanied by comprising movements in the joints of the transverse processes (Fick). The mobility is dependent upon the thickness of the cartilaginous disk.

Pathologic mechanics

Knowing the fundamental importance to normal mobility of the normal construction of the disk with the nucleus pulposus and annulus fibrosus, it is easy to understand how pathologic changes in the disk influence the mechanics. Thus if the nucleus loses its normal turgor through fluid loss and degenerative processes, the disk loses its functional character entirely. Naturally the disability so produced is proportional to the degree of change in the disk. When the disk loses its expansile resiliency, the pressure is no longer evenly distributed over the surfaces of the vertebral bodies. On forward and lateral flexion, abnormal tilting movements take place and the increased pressure is confined to the anterior and lateral regions, respectively, of the vertebral surfaces (Strasser, Keyes and Compere). Furthermore, parallel displacement occurs between the vertebrae (Hildebrandt, Güntz, Putti and others). The abnormal movements result in reactive changes in the vertebrae in the form of sclerosis of the surfaces and lipping of the edges.

If abnormal movements of this kind between two vertebrae are seen, it is justifiable to conclude that the anatomy of the disk is impaired and the clinical term for such impairment is disk degeneration. It is true that other kinds of changes in the disk (as in tuberculous or septic spondylitis or trauma) may cause abnormal movements, but as a rule the form of disk degeneration described by Schmorl, Junghans, Putti, Güntz and others is present.

Fig. 10 (1440/44).

There is a small vacuum vesicle on the upper anterior edge of the second lumbar segment, and some marginal lipping. This vesicle indicates incipient spondylosis deformans, differing from the vacuum phenomenon in disk degeneration which is seen in the center of the disk (cf. fig. 8, 9, 20).
Fig. 11, 12. Disk degeneration with extremely slight osteophytic formation on the edges of the vertebral bodies but with marked instability, consisting of parallel displacement in the direction of flexion (retroposition).
Fig. 13 (1748/44). Disk degeneration with narrowed intervertebral space and considerable instability consisting of parallel displacement in the direction of flexion (retroposition). The surfaces and margins of the vertebral bodies are intact.

Present Series

Routine examination with the aforedescribed method was made in altogether 140 cases during the period Nov. 1, 1943 to March 31, 1944. In 71 cases the results were negative, signifying that the vertebrae and intervertebral spaces were free of changes and that there was no instability. In 16 of the 69 cases with disk degeneration, two disks were affected and in one case three disks. Only one disk was involved in the rest of the cases. The total number of degenerated disks was thus 87. In 58 of them there were anatomic signs of disk degeneration. Eighteen of the disks were anatomically normal but showed instability. Spondyloolisthesis was present in 11 cases.

Parallel Displacement

A. The series comprises 58 sure instances of disk degeneration with anatomic changes.

1) Displacement in the direction of flexion. (Fig. 5, 6, 7, 11, 12, 13.) In the great majority of cases the parallel displacement was such that
Fig. 14 (20/44)  

Signs of instability consisting of parallel displacement in the direction of flexion (retroposition). The instability is the only sign of disk degeneration, the intervertebral space being of normal height and the surfaces and margins of the vertebral bodies intact.

Fig. 15 (58/44)  

the overlying vertebra was retroposed on backward bending of the spine and returned entirely or partially to its normal position on forward bending (18 cases). Only in 8 cases was the relative position of the vertebrae normal on backward bending, while on forward bending the upper vertebra shifted forward in relation to the other (anteposition, pseudospondylolisthesis).

Fig. 16 (6820/43)
Fig. 17 (6285/43). Signs of instability consisting of parallel displacement in the direction of flexion (anteposition). The instability is the only sign of disk degeneration, the intervertebral space being of normal height, and the surfaces and margins of the vertebral bodies intact.

Retroposition thus constituted only a temporary position, one phase in the range of movement of the spine, not a fixed anatomic position. It is obviously the lordosis in the lumbar spine which created the mechanical conditions for the retroposition.

Severin showed in a large series of disk degeneration that retroposition occurred in about 50 per cent. The frequency is different for different situations.

Retroposition is thus a manifestation of instability with parallel displacement. Hitherto it has been thought that when there was disk degeneration causing narrowing of the intervertebral space, the upper vertebra was directed slightly backward only because of the slanting of the articular plane in the joints of the transverse processes, but this is incorrect. Accordingly, as the retroposition is a manifestation of instability, it is a sign of disk degeneration.

2) Displacement in the direction opposite to flexion. (Fig. 8 and 9.) The lumbosacral disk was an exception. On degeneration there, the parallel displacement took another direction. The vertebra was generally retroposed in the midposition, moved backward on flexion forward and forward on flexion backward. This was the case in the 4 instances of degeneration in the lumbosacral disk. This difference is probably due to the fact that the fifth lumbar segment is moved against the whole pelvic block and that other factors enter into play than in movements between two free vertebrae.

3) No displacement occurred in 28 cases.

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Fig. 18 (6192/42). Space between fourth and fifth lumbar vertebrae slightly narrowed but no changes in the surfaces or edges of the vertebral bodies. There are abnormal tilting movements between the vertebrae, signifying severe degeneration of the disk. Operation disclosed degeneration and prolapse of the disk.

**Disk Degeneration With Anatomic Changes**

<table>
<thead>
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<th>Displacement in direction of flexion</th>
<th>Displacement in direction opposite to flexion</th>
</tr>
</thead>
<tbody>
<tr>
<td>L. 1—L. 2</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>L. 2—L. 3</td>
<td>1</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>L. 3—L. 4</td>
<td>5</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>L. 4—L. 5</td>
<td>13</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>L. 5—S. 1</td>
<td>9</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>28</td>
<td>26</td>
<td>4</td>
</tr>
</tbody>
</table>

Thus instability could be demonstrated in approximately half the cases of disk degeneration. In the other half the disk junction appeared to be stable despite signs of degeneration. The fact that no displacement could be demonstrated in these cases may be due to several reasons. In some cases the degeneration may not be far enough advanced to cause abnor-
Fig. 19 (4510/43). Abnormal tilting movements between the fourth and fifth lumbar vertebrae, but normal intervertebral space and no changes in the surfaces or edges of the vertebral bodies. The abnormal movements are the only sign of disk degeneration. On operation a greatly protruding disk was found and on incision a probe could be inserted 4 cm. into fissures in the degenerated substance of the disk.

...nal movements. In others anatomic healing may have taken place. The lipping at the margins of the vertebrae helps to create stability, and fibrous healing in the disk has the same effect. HILDEBRANDT has shown that the degenerated disk substance may be transformed by the ingrowth of connective tissue.

B. In 18 cases parallel displacement was observed without anatomic signs of disk degeneration. I considered these cases pathologic and classed them under "incipient disk degeneration". (Fig. 14, 15, 16, 17.)

**Incipient Disk Degeneration (No Anatomic Changes)**

<table>
<thead>
<tr>
<th></th>
<th>Displacement in direction of flexion</th>
<th>Displacement in direction opposite to flexion</th>
</tr>
</thead>
<tbody>
<tr>
<td>L. 1—L. 2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>L. 2—L. 3</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>L. 3—L. 4</td>
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<tr>
<td>L. 4—L. 5</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>L. 5—S. 1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>2</td>
</tr>
</tbody>
</table>

= 18

My method has led to early diagnosis in these cases, in my opinion, insufficiency in the disk junction having been demonstrated before the appearance of anatomic lesions. It may be objected that the cases may only
show normal variation in stability, the displacement being not necessarily due to a pathologic process in the substance of the disk. In order to meet this objection conclusively, it is necessary to examine a large series of normal cases. But it may be remembered that Fick and Strasser reported that parallel displacement between the vertebrae does not take place normally, and that my series contains 71 cases of a roentgenologically normal spine in which no parallel displacement was observed.
Abnormal Tilting Movements Between the Vertebrae

As a rule the movements of the spine are characterized by great harmony, the vertebrae tilting away from one another in a fairly uniform manner. On backward bending the intervertebral spaces show a slight wedge-shaped narrowing in their posterior parts and on forward bending a similar narrowing in the anterior parts or parallel disposition of the vertebral surfaces.

Occasionally I observed hypermobility in a single disk junction with much greater tilting movements than in the other intervertebral spaces. Whether this difference should be considered definitely pathologic or not is difficult to decide.

When the disk is degenerated, the normal mechanism for movement between the vertebrae is abolished, and abnormal tilting movements occur. Thus one can often see how on forward flexion, the anterior part of the affected disk becomes much more compressed than in the adjacent disks. On backward bending, on the other hand, the anterior part or the intervertebral space does not open as widely as the other spaces, if it does so at all. (Fig. 18, 19.) When the lordosis is produced, it can
often be seen how a streaked vacuum phenomenon occurs on the gaping apart of the vertebral surfaces.

**Spondylolisthesis**

The series includes 11 cases of spondylolisthesis. In 7 of them there were no signs of disk degeneration and no instability could be demonstrated (L. 5—S. 1 in 6 cases, L. 4—L. 5 in one case). In 3 of the 4 cases (L. 3—L. 4 in 2 cases, L. 4—L. 5 in one case) where the spondylolisthesis was combined with disk degeneration, parallel displacement was demonstrated and in the fourth (L. 5—S. 1) no displacement. The instability in spondylolisthesis seems to be entirely dependent upon whether or not the disk is degenerated and follows the laws for disk degeneration elsewhere. (Fig. 20, 21, 22.)

**SUMMARY**

The lumbar spine was examined with profile roentgen pictures of the patient in upright position and bending as much as possible backward and forward. By this means the author attempted to produce a *functional test of the stability of the disk junction*. In normal cases parallel displacement does not take place between the vertebral bodies and the tilting between the vertebrae is harmonious and similar all over. When the disk is degenerated, there often appear signs of instability in the form of parallel displacement and abnormal tilting movements between the vertebrae. In a large number of cases these signs of instability were the only manifestation of disk degeneration, the intervertebral space and surfaces of the vertebral bodies being intact. Thus the author's method often permits early diagnosis.

**ZUSAMMENFASSUNG**


**RÉSUMÉ**

La colonne vertébrale lombaire a été étudiée sur les images de profil de sujets debout tant en flexion antérieure qu’en lordose extrêmes. Le but de l’auteur était d’établir une *épreuve fonctionnelle de la stabilité de la connexion constituée par les disques*. Dans les cas normaux il ne se produit aucun déplacement selon les surfaces parallèles des corps
vertebrae, and the movements between the vertebrae are harmonious and similar in the various interspaces. When disc degeneration occurs, one often observes signs of instability consisting in parallel displacements and abnormal movements of the vertebrae relative to each other. In a series of cases, instability alone was evident as the only sign of disc degeneration, given that the interspace and the surfaces of the vertebral bodies were intact (early diagnosis).

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