MECHANISMS OF RETROLISTHESIS IN THE LOWER LUMBAR SPINE A RADIOGRAPHIC STUDY

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The study investigates lower lumbar segments with posterior vertebral shifts (retrolisthesis) with respect to the orientation of facet joints, disc height, lordosis of the lumbar spine, and orientation of vertebral endplates. Standing lumbar radiographs as well as CT and/or MRI investigations of 69 patients were analyzed. Data from patients with retrolisthesis (20 cases) were compared to data from patients with degenerative spondylolisthesis (DS, 23 cases), and from patients without signs of vertebral shifts (26 cases).

The orientation of facet joints in segments with retrolisthesis was not different from segments without shifts, whereas the facet joints in patients with DS were oriented more sagittally. The overall lordosis of the lumbar spine and the endplate inclination were considerably reduced in patients with retrolisthesis, especially compared to those with DS. Disc height was comparable in retrolisthesis and DS, but was reduced compared to segments without shifts.

The results support biomechanical considerations, that a retrolisthesis of a lower lumbar spine segment is correlated with a reduction of lumbar lordosis, endplate inclination, and segmental height.

Keywords : lumbar spine ; degeneration ; retrolisthesis ; lordosis ; disc height ; facet joints.

Mots-clés : rachis lombaire ; arthrose ; rétrolisthésis ; lordose ; hauteur discale ; articulations interfacettaires.

INTRODUCTION

Degenerative changes of the lumbar spine are frequently combined with translational malalignment of a vertebra in the sagittal plane. A dynamic shift, which is detectable on dynamic films, must be differentiated from a fixed deformity, which represents the last stage in the degenerative cascade (9). Such a deformity is characteristically visible on neutral standing views, and a translational shift of at least 3 mm is considered significant (5). Usually the shift is oriented forward as in segments with degenerative spondylolisthesis (DS). However, backward translational deformities may also occur (5) which may be termed "retrolisthesis".

Several studies have analyzed etiological factors for DS which frequently becomes clinically relevant with the symptoms of a spinal canal stenosis. Facet joints and particularly their orientation in the transverse plane seem to play an important role, and it could be shown that DS is correlated with a pronounced sagittal orientation of the joints (3, 6, 15). The reduction of resistance against anterior shear forces thereby seems to promote anterior gliding within the spinal segment. Also, in segments with DS, endplate inclination is more pronounced, which further increases anterior shear (2).

There is, however, a paucity of information on these factors in association with a retrolisthesis in a spinal segment which may be observed in up to 30% of extension films of patients with low back pain (14).

The present study investigates several radiological parameters in lower lumbar segments with

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posterior vertebral shifts. The findings are compared to data of two control groups, one with DS and the other without vertebral shifts in any direction.

MATERIALS AND METHODS

Patients fulfilling the following criteria were included in the study :

- Neutral standing films of the lumbar spine in anteroposterior and lateral directions, showing a five-segmental lumbar spine with a scoliotic lumbar curve of less than 10°,
- No signs of infection, tumor, fracture, or other bony destruction,
- No previous surgery on the lumbar spine,
- Axial MRI or CT image cuts which had to be aligned parallel (+/-5°) to the endplate at the level of the inferior margin of the intervertebral space.

Patients were assigned to one of three groups :

Group A : *Retrolisthesis of at least 3 mm in one of the three lower lumbar segments*

This group comprised 20 patients (9 female, 11 male) with an average age of 56.2 years (SD 8.4 years). In 14 cases the retrolisthesis was confined to one level, in 5 patients retrolisthesis occurred bisegmentally and in one case in all three lower lumbar levels. A shift of L3 over L4 was seen in 9 patients, of L4 over L5 in 11 (Group A2), and of L5 over S1 in 7. Group A2 comprised 5 females and 6 males with an average age of 54.6 years (SD 7.2 years).

Group B : *Degenerative Spondylolisthesis of at least 3 mm in the segment L4-5*

This group comprised 23 patients, 16 females and 7 males with an average age of 69.0 years (SD 10.2 years).

Group C : *No vertebral shift in any direction*

The patients of this group were randomly chosen from the files to form a sex- and age-matched cohort to group A. Group C comprised 26 patients, 13 female and 13 male, with an average age of 51.8 years (SD 7.3 years).

The following parameters were analyzed :

- *Orientation of facet joints in the horizontal plane.* Two points were identified to define the anteromedial and posterolateral margin of each facet. The angles were measured with respect to a coronal reference plane on the posterior wall of the vertebral body (fig. 1). Boden *et al.* (3) have shown that MRI and CT scans provide comparable data, and both image modalities were used in this study. The three lower lumbar segments were measured twice, and the average was used for further analysis. No attempt was made to assess intra- or interobserver variability, as these have been shown to be insignificant (7).
- *Intervertebral disc height of L3-4, L4-5 and L5-S1.* The sum of anterior and posterior disc height is expressed as a percentage of the disc width, thereby correcting for radiographic magnification (4) (fig. 2).

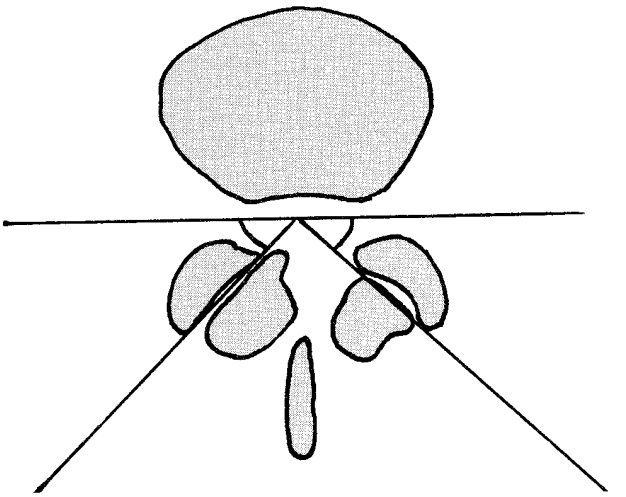

Fig. 1. — Measurement of facet joint angulation in the transverse plane. A line parallel to the posterior vertebral body wall serves as reference.

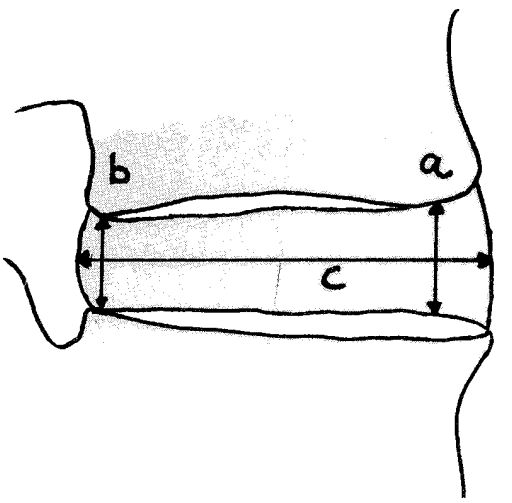

Fig. 2. — Measurement of disc height as Farfan Index. The sum of anterior disc height a and posterior height b is divided by the sagittal disc width c.

Fig. 3. — Sagittal profile of a lumbar spine with retrolisthesis at levels L3-4 (7 mm) and L4-5 (5 mm). Inclination of endplates is reduced to 25° at S1, -7° at L5 and -19° at L4 in relation to the horizontal plane.

- *Lordosis of the lumbar spine.* The angulation between the upper endplates of L1 and S1 was measured according to the Cobb technique.
- *Inclination of L4, L5, and S1 endplates.* Angulation of the upper vertebral endplates was measured with respect to a horizontal line as defined by the lateral margin of the standing radiograph (fig. 3).

Statistical comparison was performed using the nonparametric Mann-Whitney-U-Test. Groups A and B were different in their sex- and age-distribution; therefore two matched subgroups were tested. Thereby, all patients with a retrolisthesis at the level L4-5 (Group A2) were compared to a randomly selected subgroup of group B.

Resulting p-values of < 0.05 were accepted as significant, p-values of < 0.01 as highly significant.

RESULTS

The amount of retrolisthesis in 27 analyzed segments measured 4.8 mm on average (SD 1.6 mm) and ranged from 3 to 8 mm. There were no significant differences between the levels. The amount of the slip was not correlated with the disc height nor with the age of the patient.

Disc height

The average disc height in segments with retrolisthesis expressed in the Farfan Index was 32.9 (SD 14.1) for L3-4, 31.1 (SD 14.5) for L4-5, and 28.0 (SD 16.1) for L5-S1. These values were not significantly different from group B (Table I).

Table I. — Data from all patients in the three groups. Averages are given with standard deviations in parentheses. Statistical testing was performed with reference to the group with retrolisthesis. Significant differences ($p < 0.05$) are indicated *, highly significant ($p < 0.01$) **

	Group A Retrolisthesis	Group B DS	Group C No shift
N	20	23	30
Age	56.2 (8.4)	69.0 (10.2) **	53.6 (8.8)
Ratio f/m	9/11	17/7	15/15
DH L3-4	33.2 (13.3)	37.2 (8.7)	37.5 (11.0)
DH L4-5	32.2 (12.1)	30.2 (14.3)	39.4 (9.4) *
DH L5-S1	33.3 (15.6)	33.8 (19.4)	32.6 (14.8)
Fac L3-4	108.0 (18.4)	116.4 (15.2)	108.4 (14.3)
Fac L4-5	86.3 (18.4)	105.0 (22.6) **	88.3 (17.4)
Fac L5-S1	85.2 (21.9)	79.3 (18.0)	74.4 (16.2)*
Lord L1-S1	44.1 (11.1)	52.5 (14.0)	49.0 (11.1)
Incl L4	-0.9 (10.5)	7.0 (6.1) **	1.2 (7.1)
Incl L5	10.5 (9.8)	18.4 (7.0) **	15.2 (7.2)
Incl S1	32.6 (6.3)	36.6 (7.0)	33.2 (9.1)

DH = Disc height, expressed as Farfan Index

Fac = Sum of both facet joint angulations in the horizontal plane (in degrees)

Lord = Lumbar lordosis between endplates of L1 and S1 (in degrees)

Incl = Inclination of endplates with respect to the horizontal line (in degrees).

Patients without shifts (group C) showed larger disc heights. At the L4-5 level this difference was statistically significant.

Facet joint orientation

In all groups the facet joint orientation was more sagittal from the cranial to the caudal segments. At the L3-4 level there were no statistical differences. At L4-5 patients with DS showed joint orientations which were about 20° more sagittal than patients of groups A and C (Table I). This statistically highly significant difference could also be found in analyzing the matched subgroups (Table II). At L5-S1, facet joints in group A were oriented more sagittally, which was significant compared to group C.

Table II. — Comparison of data from two subgroups. All segmental shifts are at level L4-5 ; both subgroups are age- and sex-matched

	Retrolisthesis (L4-5)	DS Sex-age-matched
n	11	11
Age	54.6 (7.2)	60.7 (6.9)
Ratio f/m	5/6	6/5
DH L3-4	33.5 (12.2)	37.4 (8.9)
DH L4-5	31.1 (14.5)	28.4 (11.9)
DH L5-S1	39.1 (16.0)	32.5 (18.2)
Fac L3-4	111.5 (18.1)	118.4 (13.7)
Fac L4-5	87.0 (18.9)	110.0 (21.5) *
Fac L5-S1	89.3 (16.1)	80.3 (22.2)
Lord L1-S1	40.0 (8.4)	53.1 (12.2) *
Incl L4	-4.1 (8.3)	8.3 (4.9) **
Incl L5	6.3 (7.5)	20.8 (7.1) **
Incl S1	31.2 (5.0)	37.4 (5.4) *

Lordosis

The overall lordosis of the lumbar spine (upper endplate L1 to upper endplate S1) was very variable in all groups with values between 25° and 64°. On average lordosis was smallest in patients with retrolisthesis (fig. 3). In the comparison of the matched subgroups, this difference was also statistically significant (Table II).

Inclination of endplates

In patients with retrolisthesis, the endplates were less inclined at all levels compared to the other groups (fig. 3). This difference to patients with DS was highly significant for the levels L3-4 and L4-5 (Table I). In analyzing the two matched subgroups, the difference at the L5-S1 level also became significant (Table II).

DISCUSSION

Retrolisthesis may be observed in any spinal segment, but a specifically high incidence has been reported for the L5-S1 level (14). The present study was confined to the lower lumbar levels to permit a better comparison to findings in segments with a forward shift (DS), which occurs predominantly at the L4-5 level. Our data show no specific prevalence of one level for a retrolisthesis. However, in 6 of 20 patients, more than one level was involved, which indicates the importance of underlying factors influencing the entire lumbar spine.

Forces in the lower lumbar spine may be divided into two components : an axial force A which acts perpendicular to the endplates and an anterior shear force S which acts parallel to the discs (11). The facet joints usually provide a counterforce S', providing equilibrium and preventing a forward shift. A reduction in this counterforce S', however, may result in anterior translation. Patients with DS show facet joint angulations, which are significantly more sagittal compared to patients without vertebral slips (6, 8). This is also confirmed in the present study. In contrast, facet joint orientation in patients with retrolisthesis was more comparable to patients without vertebral slips.

According to the above-mentioned biomechanical considerations retrolisthesis requires a reduction of the anterior shear force S or even its reversal. Posterior shear forces are balanced by resistance through ligaments and the facet joint capsule (16). The disc annulus provides a further stabilizing element. This, however, may be considerably reduced in cases of degenerative changes with loss of disc height and internal nucleus pres-

sure (10). Experimental studies have indeed confirmed increased posterior segmental instability after removal of the nucleus and parts of the posterior annulus (17). Our data confirm these biomechanical considerations. Patients with retrolisthesis showed less lumbar lordosis and less endplate inclination (fig. 3). Both factors lead to a reduction of anterior shear within the segment. Consequently, in contrast, if endplate inclination is more pronounced, anterior vertebral shift may be observed as in patients with DS (2). Also, the disc height was significantly reduced in segments with retrolisthesis, which underscores the importance of the disc for segmental stability ("flat tire syndrome").

Other clinical and radiological studies confirm these results. Lack *et al.* (12) report an increased incidence of retrolisthesis distal to segments ankylosed in kyphosis following infection. This is explained by reduced inclination of the adjacent endplate and therefore a reversal of the anterior shear force S. Instability investigations of segments above lumbar fusions have shown a posterior translation in 15% of cases (1).

Our data indicate the importance of a proper balance between lordosis, endplate inclination, and disc height for correct sagittal alignment of the lower lumbar spine. For segments with retrolisthesis, facet joint orientation does not seem to play a major role. However, further studies should also consider overall spinal sagittal alignment and pelvic orientation (13).

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SAMENVATTING

U. BERLEMANN, D. J. JESZENSZKY, D. W. BÜHLER, J. HARMS. Mechanisme van retrolisthesis in de laag lumbale streek.

Deze studie onderzoekt de laag lumbale segmenten met posterieure verplaatsing (retrolisthese) in functie van de oriëntatie van de facetgewrichten, de vertebrale hoogte, de lumbale lordose en de oriëntatie van de vertebrale eindplaten. Staande radiografieën en CT-scan en/of

MRI onderzoeken werden uitgevoerd bij 69 patiënten. De gegevens van 20 gevallen met retrolisthesis werden vergeleken met die van 23 gevallen met degeneratieve spondylolisthese (DS) en met 26 gevallen zonder shift. De oriëntatie van de facetgewrichten in de segmenten met retrolisthesis was niet verschillend met die zonder verplaatsing, doch de facetgewrichten bij de DS patiënten was meer sagitaal georiënteerd. De lordose en de oriëntatie van de vertebrale eindplaten was sterk gereduceerd vnl. t.o.v. de DS patiënten. De discushoogte was vergelijkbaar in de groep met retrolisthese en de DS groep, doch gereduceerd in de segmenten zonder shift.
Deze resultaten ondersteunen de biomechanische beschouwingen dat retrolisthesis is gecorreleerd met verminderde lumbale lordose, eindplaat inclinatie en segmentaire hoogte.

RÉSUMÉ

U. BERLEMANN, D. J. JESZENSZKY, D. W. BÜHLER, J. HARMS. Mécanismes du retrolisthésis au niveau du rachis lombaire bas : étude radiographique.

Les auteurs ont étudié, sur des segments du rachis lombaire bas présentant un glissement vertébral postérieur (retrolisthésis), l'orientation des facettes articulaires, la hauteur discale, la lordose lombaire et l'orientation des plateaux vertébraux. Cette étude a porté sur des radiographies du rachis lombaire en position debout et aussi sur des coupes au CT scan ou en RMN, chez 69 patients. Les résultats obtenus ont été comparés aux résultats des mêmes mesures effectuées chez 23 patients présentant un spondylolisthésis dégénératif et chez 26 autres sans signe de glissement vertébral. L'orientation des facettes articulaires au niveau des segments présentant un retrolisthésis ne différait pas de leur orientation au niveau des segments sans glissement, tandis que les articulations inter-facettaires étaient orientées plus sagittalement chez les patients qui présentaient un spondylolisthésis dégénératif. La lordose globale du rachis lombaire et l'inclinaison des plateaux étaient considérablement réduites chez les patients présentant un retrolisthésis, surtout par comparaison aux patients présentant un spondylolisthésis. La hauteur discale était comparable dans le retrolisthésis et le spondylolisthésis mais elle était diminuée par rapport aux segments sans glissement vertébral.
Ces constations viennent à l'appui d'une hypothèse biomécanique selon laquelle un retrolisthésis au niveau d'un segment lombaire bas serait corrélé à une réduction de la lordose lombaire, de l'inclinaison des plateaux et de la hauteur discale.