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Orientation of the articular processes at L4, L5, and S1 Possible role in pathology of the intervertebral disc

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Summary. In the synergistic complex formed by the intervertebral disc and posterior articular processes, the latter play a significant role to protect the disc and block forward movement of the spine. This role is of special importance at the level of the lumbosacral interface whose inclination contributes to increase shearing forces acting on the disc. The orientation of the lumbosacral articular processes modifies the distribution of the mechanical stress acting at their level. The relationship between the orientation of the articular processes and the stress transmitted to the disc was studied by computerized tomography (31 subjects without disc prolapse, 35 subjects with disc prolapse, 110 operative reports). Sagittal orientation of the facet joints, which is consistently more pronounced on the right side, seems to promote the occurrence of disc prolapse at the lumbosacral level.

L'orientation des apophyses articulaires L4, L5 et S1. Leur rôle possible dans la pathologie discale

Résumé. Dans l'ensemble synergique disque intervertébral - apophyses articulaires postérieures, celles-ci jouent certainement un rôle important de protection du dique et de blocage des mouvements du rachis vers l'avant. Ce rôle est particulièrement sensible au niveau de l'interligne lombo-sacré dont l'inclinaison favorise les contraintes de cisaillement au niveau du disque. L'orientation des articulaires lombo-sacrées modifie la répartition des contraintes à leur niveau. C'est ce qui a été étudié ici sur des examens tomodensitométriques (31 sujets sans hernie discale, 35 sujets avec hernie discale, 110 comptes rendus opératoires). La « sagittalisation » des articulaires toujours plus importante à droite qu'à gauche semble favoriser la hernie discale à ce niveau.

Key words : Lumbosacral joint – Lumbar articular processes – Pathogenesis of intervertebral disc prolapse

The intervertebral disc and the system of articular processes form a veritable synergistic complex ensuring the stability and mobility of the spine in all spatial planes. Alteration of one component of this complex necessarily affects the other components. Although considerable work has been devoted to investigation of the composition, structure and mechanical properties of the intervertebral disc, few studies have dealt with the articular processes. According to classical anatomical descriptions, the articular processes can undergo movements of rotation and translation. However, the latter type of movement mainly occurs in the thoracic spine and in the course of extreme movement. In the lower lumbar spine, the articular processes mainly seem to undergo movements of rotation with an instantaneous center of rotation at the periphery of the intervertebral disc (Gonon and Dimnet, 1982).

Alteration of the intervertebral disc modifies this synergistic complex and leads to the occurrence of unwanted movements of translation. The articular processes are like tracks to guide the movement of one vertebra with respect to an adjacent one. Such movement is pronounced in the lower lumbar spine, i.e. 17° at L4-L5, 20° at L5-S1. Modification of the orientation of the articular processes or an alteration of the latter may lead to transfer of undue stress to certain elective points on the intervertebral disc or to unwanted shearing movements. Such shearing forces are most pronounced

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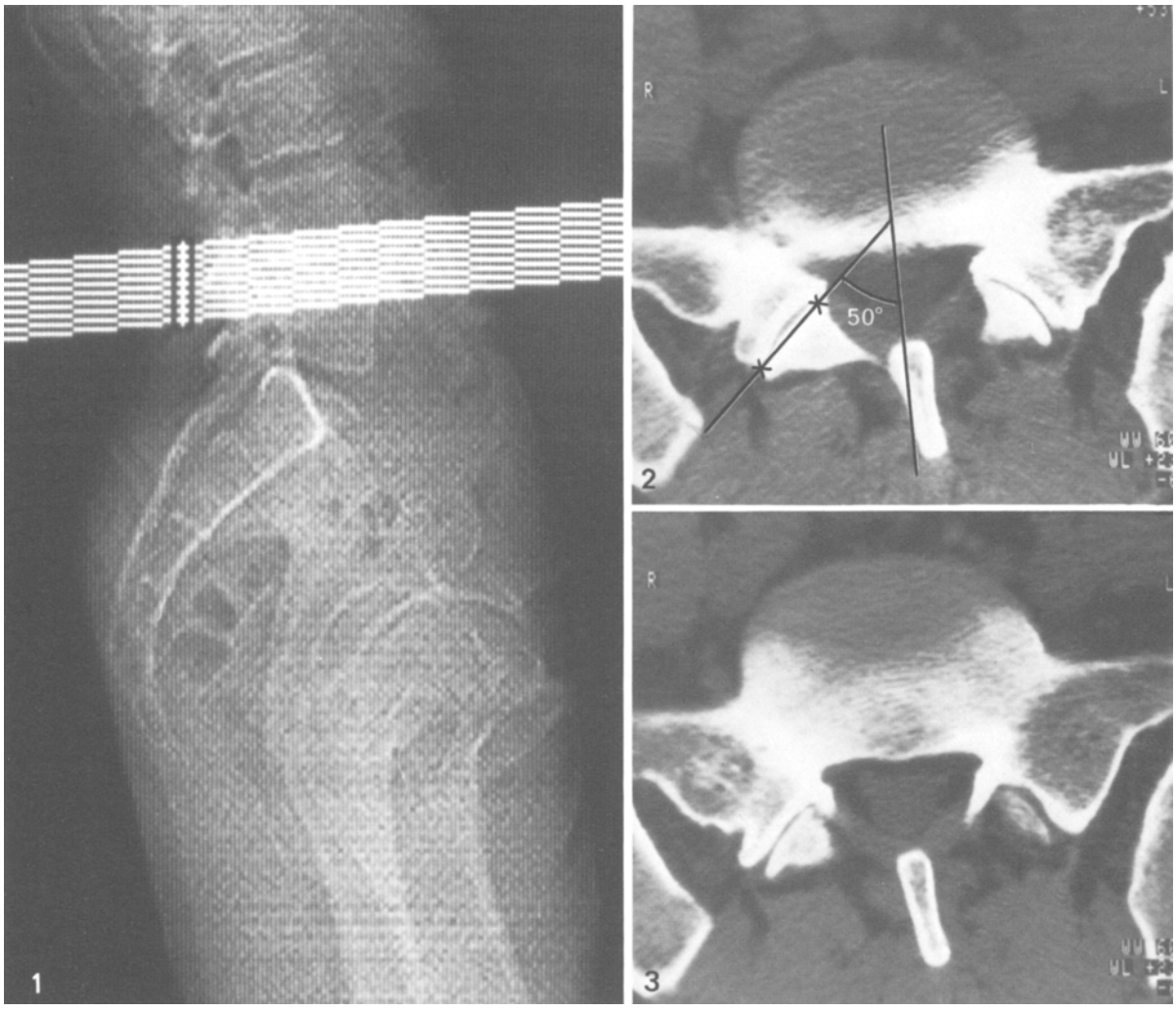

Figs. 1-3
1 Planes of CT cuts of the L4-L5 interface. **2** An example of measurement of the inclination of the facet joint interface. **3** Example of a case excluded from this study. Note that interpretration is impossible due to the pronounced degenerative lesions involving the facet joint

1 Plans de coupes tomodensitométriques pour l'interligne L4-L5. **2** Exemple de mesures d'un angle d'inclinaison de l'interligne articulaire. **3** Image récusée : ininterprétable du fait d'une forte arthrose inter-apophysaire postérieure

at the level of the lumbosacral interface in cases where the latter is tilted with respect to the horizontal plane (30°). These observations led us to measure the orientation of the articular processes at the lumbosacral level. Such measurement can now be easily obtained using computerized tomography (CT).

In this paper, the study method is first described followed by presentation of the numerical results of CT imaging and finally an attempt to correlate these results with the incidence of lateralization of intervertebral disc prolapse.

Methods

CT imaging of the L4-L5 and L5-S1 intervertebral spaces was done in 31 subjects without obvious alteration of the corresponding intervertebral discs, investigation in these cases was prompted by the existence of abdominal pathology or lumbago with clear absence of disc herniation. Patients with abnormal vertebral arches (malformation or obvious asymetry) or degenerative disease of the facet joints were excluded since in these conditions precise measurement of the inclination of the interface of the facet joint cannot be done (Fig. 3).

CT sections were made at 3 mm intervals parallel to the intervertebral space under examination. A total of 5 measurements were made for each intervertebral space, the mean of which was taken

as the reference value (Fig. 1). The two ends of the articular interface were identified and a straight line made to join them together. Next the sagittal plane passing through the center of the vertebral canal was identified. This plane is perpendicular to a line connecting the two tangents to the lateral surfaces of the body of the vertebral (Fig. 2).

Similar measurements were made in 35 patients with radicular sciatic pain due to demonstrate prolapse of the intervertebral disc with compression of the 5th lumbar or 1st sacral nerve root. The criteria for measurement were the same as those described above. Furthermore, the incidence of lateralization of the disc prolapse was compared to the presence or absence of "sagittalization" of the facet joint interface on the side of the disc herniation.

Finally operative records of 110 cases of disc prolapse were examined. Here again, lateralization of the hernia was compared to the incidence of "sagittalization" of the facet joint interface.

Results

Study of the apparently normal L4-L5 and L5-S1 intervertebral spaces

The mean (±SD) angle of inclination of the right facet joint interface at L4-L5 (31 cases) (Fig. 4) was 45.7±11° (range 28-69°). On the left side the mean angle was 51.4±10° (range 30-74°). These results demonstrate that the facet joint interface occupies a more sagittal position on the right compared to the left side, the mean difference between the two joints being 5.7°. Donovan (1984) previously reported that the right facet joint at L4-L5 showed a more sagittal position compared to the left joint in two-thirds of cases. Our results confirmed these findings (22 out of 31 cases). Furthermore, there seems to be a correlation between the curved appearance of the facet interface (concave medially and posteriorly) and its degree of sagittalization, i.e. the lesser the degree of sagittalization the greater the curved appearance of the interface. However, since such curvature was not measured the above finding relates to our subjective impression only.

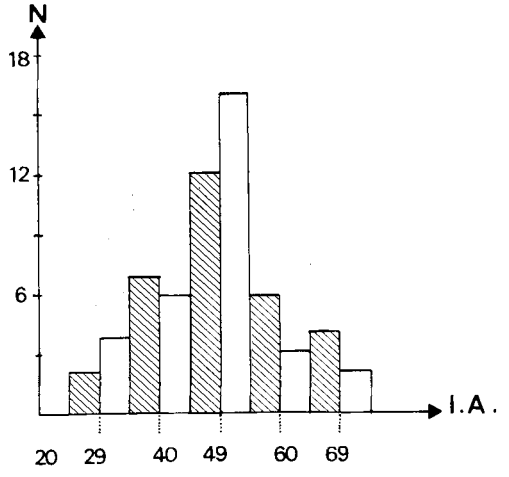

Fig. 4
Histogram showing facet joint inclination at the L4-L5 level (empty bars = left facet joints; shaded bars = right facet joints)

Histogramme de répartition des inclinaisons articulaires au niveau de l'interligne L4-L5 (les côtés gauches sont laissés en blanc, les côtés droits sont en grisé)

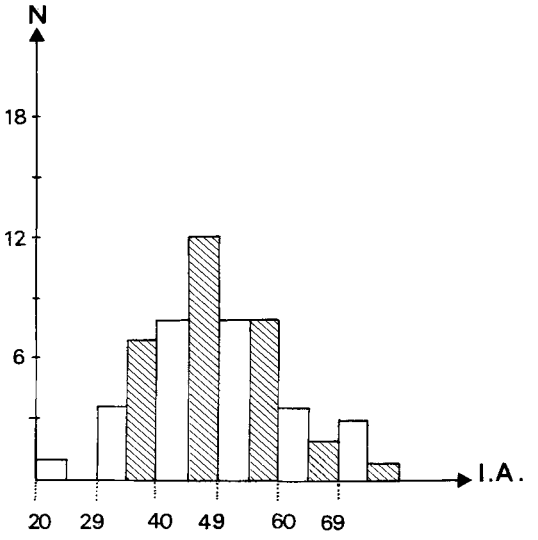

Fig. 5
Histogram showing facet joint inclination at the L5-S1 level (empty bars = left facet joints; shaded bars = right facet joints)

Histogramme de répartition des interlignes articulaires au niveau de l'interligne L5-S1 (les côtés gauches sont laissés en blanc, les côtés droits sont en grisé)

At the level of L5-S1 (Fig. 5) (30 cases) the mean angle of inclination of the right facet joint interface was 47.2±9° (range 35-71°). On the left side this mean angle was 51.5±13° (range 30-78°). Once again, sagittalization of the facet joint interface was slightly more pronounced on the right side, the mean difference between the two joints being 4.3°. As described above at the L4-L5 level, the curved appearance of the articular interface seemed to be related to its degree of sagittalization. Finally, sagittal orientation of the facet joint predominated on the right side (20 out of 30 cases).

Study of the articular interface on the side of disc prolapse

Of the 35 patients studied, 15 showed disc prolapse at L4-L5 and 20 at L5-S1. At the L4-L5 level, disc prolapse was on the right side in 9 cases. In 7 of these cases, the right facet joint interface lay in a more sagittal position compared to the mean value. In the two other cases the articular interface lay closer to the coronal plane. In the 6 cases of left-sided prolapse at L4-L5, the left facet joint interface displayed sagittalization in only two cases. In sum, of the 15 patients with disc prolapse at L4-L5, the facet interface on the side of the hernia lay in a more sagittal plane in 9 cases and a more coronal plane in 6 cases. It follows from these results that at the

L4-L5 level there is no significant relationship between the angle of the facet joint interface and the side of disc prolapse.

In the 20 cases of disc prolapse at L5-S1, 9 out of the 11 hernias on the right side corresponded to the presence of a sagittal facet joint interface on the same side. In 6 of the 9 cases with left-sided disc prolapse a sagittalized left face joint interface was seen. These results indicate that at the L5-S1 level, herniation is on the side of the more sagittal facet joint interface in three-quarters of cases. Statistical analysis by the χ^2 test ($\chi^2=2.23$) showed that this result was statistically significant ($P=0.03$).

Study of operative reports

Operative reports were studied in 110 consecutive cases having undergone surgery in the Department of Neurosurgery (Pr Lepoire), at the hospital Saint-Julien in Nancy. In the 58 patients with hernia at L4-L5, the prolapse was on the left side in 36 cases and on the right in 22, i.e. in two-thirds of the cases on the side showing theoretically less sagittalization of the facet joint. This finding confirms the absence of correlation between the orientation of the articular interface and the side of disc prolapse at L4-L5, as pointed out above.

In the 52 cases involving the L5-S1 disc, prolapse was on the right side in 31 cases and on the left in 21. In these cases, the ration of right compared of left-sided hernia was proportional to the right-left predominance of sagittalization of the facet joint interface.

Discussion and conclusion

The results of this study do not lead to definite conclusions since a small series of patients studied and CT imaging was not done in strictly normal subjects.

As a general rule, the lower lumbar spine shows asymmetry, i.e. only three out of 61 posterior arches examined in our study were strictly symmetrical on CT imaging. In two-thirds of cases, the facet joint on the right side lies in a more sagittal position at both the L4-L5 and L5-S1 levels.

The correlation between sagittalization of the articular process and the mechanism leading to disc prolapse merits further comment. A study published by Farfan and Sullivan in 1967 showed a strong correlation between the side of the more sagittal facet joint interface and the side of disc prolapse. Our results are also in favor of this correlation at the L5-S1 level, but not at L4-L5. Indeed, the L4-L5 interface lies in a practically horizontal position and is submitted to very little shearing force.

Conversely, the lumbosacral interface slants at 30° with respect to the horizontal plane. Most of the weight bearing force is transfered to the L5-S1 interface and a

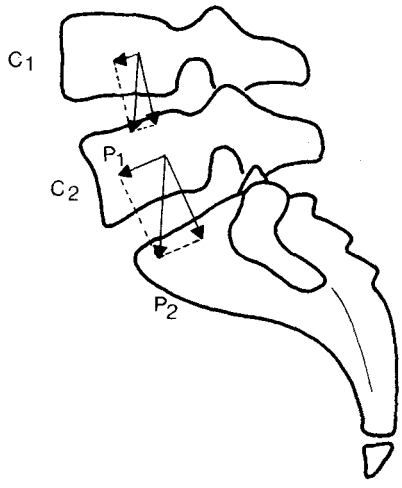

Fig. 6
The weight of the body (P_1 or P_2) can be broken down into a component of compression perpendicular to the intervertebral disc and a component of shearing (C_1 or C_2). The shearing force is small at the L4-L5 level and much greater at L5-S1.

Le poids du corps P_1 ou P_2 se décompose en une composante de compression perpendiculaire au disque et une composante de cisaillement C_1 ou C_2 minime au niveau de l'interligne L4-L5, beaucoup plus importante au niveau de l'interligne L5-S1

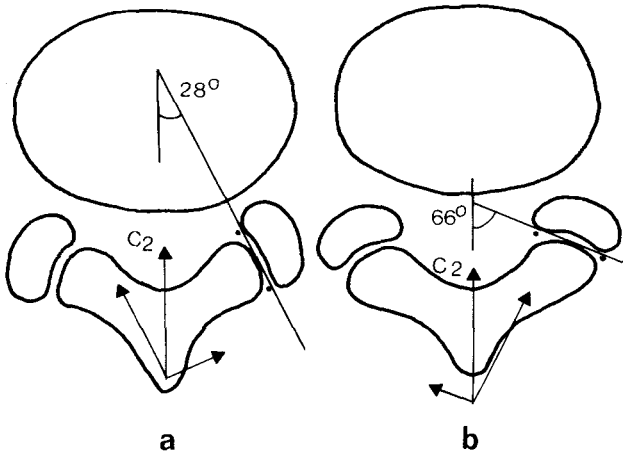

Fig. 7
a The facet joint interface is in a highly sagittal position (28°). Two-thirds of the shearing force (C_2) act to slide the vertebra anteriorly. **b** The facet joint interface is in a more coronal position (66°). Almost all of the shearing force (C_2) is blocked by the articular process

a Interligne articulaire très sagittalisé (28°). Les 2/3 de la composante de cisaillement C_2 ont tendance à faire glisser la vertèbre vers l'avant. **b** Interligne très frontalisé (66°). La quasi-totalité de la composante de cisaillement C_2 est bloquée par l'apophyse articulaire

significant part of this force exerts a shearing effect on the intervertebral disc (Fig. 6). A similar mechanism apparently leads to spondylolisthesis which involves the lumbosacral interface in 80% of case (Louis, 1971). The anterior shearing force acts on facet joints whose resistance to this force is greatest when the articular processes lie in a position close to the coronal plane. In other words, the sliding force yields a components of compression acting on the articular surfaces of the facet joint which is greatest when the joints lie close to the coronal plane. Conversely, an articular process lying in a more sagittal position offers little resistance to anteroposterior sliding. In these conditions, the intervertebral disc is no longer "protected" and it is conceivable that increased mechanical stress will act upon the disc (Fig. 7).

The posterior fibers of the anulus fibrosus are submitted to considerable traction during anterior flexion of the spine, especially when flexion is accompanied by the lifting of a weight. Furthermore, the nucleus pulposus, acting like a pressure distributor, transfers body weight into a force of posterior compression. Finally, rotation of L5 with respect to the sacrum is approximately 5° on each side. For the sake of simplicity, this phenomenon was not investigated in our study.

In the normal subject, forces of compression, traction and torsion act upon the intervertebral disc. In cases where the buttress effect of the articular process is lacking or insufficient, additional shearing forces will act upon the disc which is already submitted to considerable mechanical stress. Such shearing may then give rise to degenerative lesions, fissures or ruptures of the intervertebral disc. Although it is only a hypothesis, this conclusion is based on purely morphological data, mechanical studies and pathological and operative observations.

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