

ACTA ORTHOPAEDICA SCANDINAVICA  
Supplementum no. 55

---

FROM THE UNIVERSITY CLINIC OF ORTHOPAEDICS AND TRAUMATOLOGY  
(CHIEF: PROFESSOR K. E. KALLIO) AND THE ROENTGEN DIAGNOSTIC  
DEPARTMENT OF THE UNIVERSITY SURGICAL CLINICS  
(CHIEF: DOCENT ROLF KÖHLER), HELSINKI, FINLAND

# CONTRAST EXAMINATION OF LUMBAR INTERSPINOUS LIGAMENTS

*(Ligamentographia interspinosa lumbalis)*

BY

ROLF KÖHLER

MUNKSGAARD  
Copenhagen 1962



PRINTED IN FINLAND BY TILGMANN,  
HELSINKI 1962

## CONTENTS

	Page
I. Introduction .....	7
II. Anatomic and histopathologic survey .....	9
III. Object of the examination .....	11
IV. Series and method .....	13
V. General survey of the presence of ligamentous changes in the series	18
— Age and sex .....	18
— Localization .....	19
— Posture of the lumbar spine .....	19
— Height of the spinous process .....	21
— The capacity of the lumbar spine for extension .....	22
— Displaced spinous processes .....	24
— Ligament thickness .....	25
VI. The different types of changes in the three lower interspinous ligaments, their incidence and roentgenologic diagnosis .....	28
— Normal ligaments .....	28
— Ligaments in displaced spinous processes .....	30
— Cavity formation .....	32
— Ruptures in ligaments .....	38
a. Partial ruptures .....	39
b. Complete ruptures .....	43
— Flaccid ligaments .....	46
VII. Disk degeneration, trauma of the lumbar spine and changes in the interspinous ligaments .....	49
— Disk degeneration .....	49
— Trauma .....	52
VIII. Changes in the three lower lumbar interspinous ligaments and low back pain .....	54
Discussion .....	59
IX. Summary and Conclusions .....	61
Acknowledgements .....	62
References .....	63



## I. INTRODUCTION

Ligamentous changes in the two lower interspinous spaces were often observed by KALLIO in connection with operations for prolapsed disk. The supraspinous ligament was thin and inelastic while the interspinous ligaments appeared relaxed, displayed an irregular surface, and appeared to be fat-infiltrated or fibrotic; some were almost transparent and extremely thin while others were completely flaccid whatever their macroscopic appearances. In numerous cases this author observed rents stretching half-way across the ligaments or total defects, rounded holes through which it was possible to pass a sound to the opposite side. The corresponding 'Bewegungssegment' showed in many cases increased mobility and the spinous processes sometimes displayed irregular contours or marginal deposits of cartilaginous or osseous consistency.

A search of the literature produced highly divergent, not to say conflicting or totally inadequate, accounts of the anatomic and function conditions of the lumbar interspinous ligaments. This was true, for example, of the course of the fibre bundles. Nor was any information found concerning the presence of congenital defects in these ligaments. Unequivocal facts relating to the supraspinous ligament were few.

The lower lumbar spine is of essential surgical-orthopedic significance, mostly because of the mixed pathology of the intervertebral disk. However, KALLIO considered from his operative experience, that the posterior ligaments in the lumbar spine which bind together the spinous processes merit greater clinical attention than they have hitherto received. He emphasized the necessity of detailed anatomic analysis of the supraspinous and interspinous ligaments and suggested to RISSANEN that he should investigate the anatomy and pathology of the interspinous ligaments of the lumbar spine in autopsy material. This author presented his results in 1960 as a doctoral thesis.

It was held by KALLIO that there was no satisfactory preoperative procedure for the establishment of changes in the interspinous ligaments although it might be of value in many cases. The present writer had to admit his inability to demonstrate these ligamentous changes roentgenologically. It was of no help basing the solution on the assumption that the differences

between the spinous distances in a flexed and extended spine in roentgenograms taken sagittally were significantly dissimilar in normal and pathologic ligaments. It proved necessary to resort to other expedients, and it appeared that a positive contrast medium might overcome the absence of contrast differences between the ligament and the surrounding soft parts and thus enable a roentgenologic diagnosis of the ligament to be made. A paraligamentous injection of contrast medium of this type produced a demonstration of the lumbar interspinous ligaments in the form of filling defects. A preliminary report of the investigation method applied to 100 clinical cases was published in 1959.

## II. ANATOMIC AND HISTOPATHOLOGIC SURVEY

Vertebral bodies, neural arches and processes constitute the inner, stable, basic structure of the lumbar spine which is joined into a whole by various kinds of softer tissue. The anatomist LUSCHKA (1858) took an interest in the functional conditions in the spinal column and regarded the intervertebral disks as the 'Halbgelenke' of the human body. The axis of rotation of the dorso-ventral movements of the lumbar spine lies within the area of the small joints.

The pathology of intervertebral disks has attracted considerable and sustained interest during the last few decades. Mention should be made especially of the intensive research on the spine which flourished in Germany during the latter half of the 1920s. The pathologist SCHMORL deserves mention in this respect before other investigators. He gave much new knowledge to which later workers were able to subscribe.

The study of the spine has been concerned almost exclusively with disease conditions in the vertebral bodies and intervertebral disks, and little attention has been paid to the posterior region of the lumbar spine; This applies not least to the interspinous ligaments and is somewhat surprising in view of the considerable degree of movement between the spinous process in extension and flexion which causes either a stretching or compression of the soft parts between the bony surfaces. Extreme movements would seem to contribute to producing changes in the ligaments which cannot be entirely immaterial for the function or clinical symptomatology of the spine. RISSANEN's detailed study of a large material threw new light on several problems relating to the supraspinous and interspinous ligaments of the lumbar spine. The essential points of his results are given in what follows.

This author considered that the supraspinous ligament attached to the tips of the spinous processes constituted the most effective limitation to excessive ventral flexion of the spine. He found that this ligament was, contrary to earlier opinion, absent in the lower parts of the lumbar spine. The dorsal and medial part of the lower interspinous ligaments assumed some of the duties of the supraspinous ligament in preventing excessive moving apart of the spinous processes. The supraspinous ligament undergoes considerable changes with age, the most characteristic of these being metaplasia

of the tendinous tissue into fibrocartilage, calcification and metaplastic ossification. No signs of rupture of the supraspinous ligament were evident in any of his cases, even on microscopic examination.

RISSANEN stated that the general course of the fibre bundles in the interspinous ligaments ran from behind downwards and forwards. Microscopically the ligament was seen to be composed chiefly of collagenous bundles with a very few elastic fibres. The ligament is thus capable of withstanding considerable traction but no notable stretching. By the twentieth year of life changes begin gradually to appear in the ligaments. Metaplasia of the tendinous tissue into fibrocartilage takes place and breaking of the fibre bundles, fragmentation and, finally, cavity formation occur in the middle of the ligament. In older subjects the cavities often ultimately become formations reminiscent of true joints.

Ruptures were established in the lower interspinous ligaments, mostly in the lowest two, in a total of 21 per cent of subjects over 20 years of age. Microscopic examination in all cases demonstrated various degenerative changes of which cyst-like degeneration was the most prominent. The degenerative changes appearing early in the interspinous ligaments and the cavity formations developing inside them, as well as the ligament ruptures, were all attributed to a heavy local mechanical strain caused by anatomic factors as well as to certain other more general conditions affecting the organism as a whole.

### III. OBJECT OF THE EXAMINATION

As already mentioned briefly in the introduction, the writer had elaborated a roentgenologic method of examining the lumbar interspinous ligaments and a preliminary report of the method appeared in 1959. The present study sums up the observations made and the results achieved with the aid of the method in examination of the three lower lumbar interspinous ligaments in a clinical series.

The examination was limited to the ligaments mentioned since the majority and the most extensive of the lumbar interspinous changes are situated in these interspaces. This was the case, e. g. with all the ligamentous ruptures in RISSANEN's material. The restriction of the examination site was also necessitated by the area of occurrence of lumbar disk prolapses; in the present series it was invariably in the three lower intervertebral spaces.

One hundred and ten cases of the total 229 cases of the series had undergone a lumbar spine operation. The interspinous ligaments were carefully examined and the findings were recorded in the operation report. The writer himself was often present at this phase of the operation and was able to compare the preoperative roentgenologic finding with the ligamentous morbidity which was exposed. In the other cases the roentgenologic finding was compared with the operation report. Conformity with the operation finding was very good in about 90 per cent of the cases.

The roentgenologic examination failed in 5 cases to demonstrate cavities or ruptures in an interspinous ligament, owing to the latter being imperfectly outlined by the contrast medium; the subjects were either obese or had very firm dorsal muscles. Relaxed ligaments escaped detection in 4 cases; again the reason can be placed upon a faulty injection technique. As will be pointed out later, the diagnosis of flaccid ligaments requires intimate contact between the contrast medium and the ligament, a desideratum that in these cases was not adequately achieved. Minor deviations from the operation findings were evident in 6 cases; these were of such a nature that it is not unlikely that the ligamentous changes were analysed more accurately and correctly by the roentgenologic examination.

It would appear in view of these figures that there is some justification in stating that a refined roentgenologic examination of the three lower lumbar

interspinous ligaments is capable of demonstrating any changes without necessarily resort to operation.

Neither of the methods approaches the exactitude obtained in RISSANEN'S meticulous dissection of the ligaments. On the other hand, both are satisfactorily reliable from the practical and clinical view points, which supports a review of the investigations and an analysis of the results.

The present investigation was undertaken with a view to determining: —

1) The kind of ligament changes that may be diagnosed roentgenologically and their roentgenologic characteristics.

2) The distribution of the changes by age and sex.

3) The effect of posture, height of the spinous processes, range of extension of the lumbar spine and displaced spinous processes on the changes in the interspinous ligaments.

4) The relationship between the thickness and any changes in the ligaments.

5) The origin of the changes in ligaments a) in connection with degeneration and prolapse of a disk b) after spinal trauma.

6) Whether any correlation exists between the changes in the lumbar interspinous ligaments and low back pain.

#### IV. SERIES AND METHOD

The series consisted of 229 cases on which ligamentography was performed in the period between January 1958 and May 1960. One hundred and eighty nine cases had low back pain or sciatica, while the remaining 40 had never been so afflicted, had been admitted to hospital for other reasons and had volunteered to act as controls.

The age distribution is seen in the following table.

	Controls			Cases with back pain		
	Male	Female	Total	Male	Female	Total
11—20 years .....	2	1	3	3	3	6
21—30 » .....	10	3	13	24	5	29
31—40 » .....	11	4	15	48	14	62
41—50 » .....	5	3	8	41	22	63
51—60 » .....	1	0	1	20	6	26
61—70 » .....	0	0	0	1	2	3
	29	11	40	137	52	189

*Table 1.* Age distribution of the investigation series of 229 cases.

The male: female ratio in both the principal groups was almost 3 : 1. The youngest and the oldest age categories as well as the other groups of the control material are unusable for statistical purposes when separated; the control material, on the other hand, should be usable in its entirety for a statistical analysis.

The age distribution of the two principal groups of the total series shows a distinctly lower age trend among the cases without back symptoms. This was as to be expected; degenerative changes, which are the main cause of low back pain, increase with advancing age. Indeed, the author was surprised that it was difficult to find subjects over 40 years of age who had never felt pain referable to the lumbar spine. This was one reason for the somewhat unsatisfactorily large number of controls. The other reason was that quite a number of those approached were not inclined to submit voluntarily without any benefit to themselves to an examination involving a number of pricks with a pin and thus not completely painless.

*The method of investigation* was based on the fact that the space which lies between two adjacent spinous processes is filled completely by the interspinous ligaments located in the spinous plane, i. e. sagittal plane, as shown in Fig. 1.

The ligaments in children form a continuous tendinous membrane and in the study carried out by RISSANEN (101 subjects aged 0—10 years) they were completely intact. The ligaments showed no perforation or other defects in this age group if the sacral and lumbar skeleton of the child was normal. It is possible on the other hand to demonstrate a variety of changes in the lumbar spinous ligaments from the 20th year of age onwards.

There is no likelihood of eliciting these changes in conventional roentgenograms, the evaluation of which requires, as was pointed out in the introduction, a change in the contrast conditions in the interspinous region. When positive contrast medium was injected along the ligamentous wall between the spinous processes the interspinous ligaments appeared in the antero-posterior roentgenograms of the lumbar spine as sharply demarcated, usually slightly spindle-shaped filling defects between the contrast medium deposits which the ligament prevented from spreading right up to the median line. The contrast medium usually spread irregularly in the lateral direction and

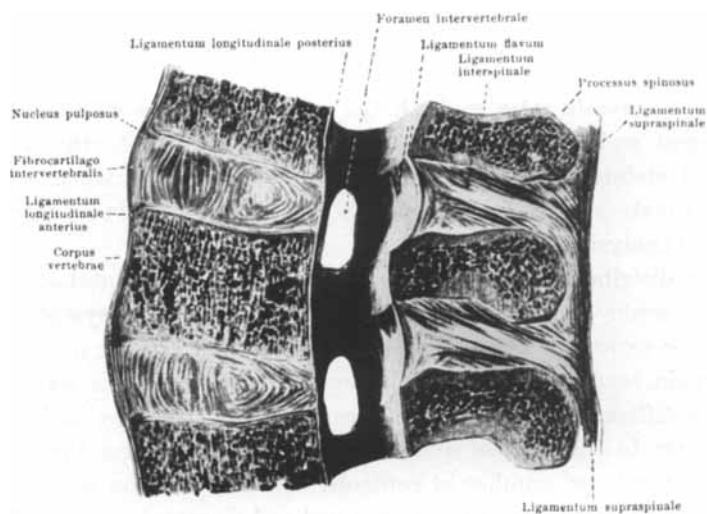
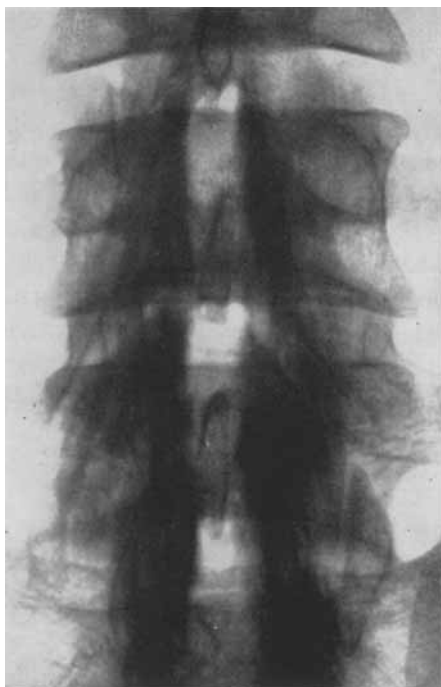


Fig. 1. Median section through the lumbar spine showing the supraspinous and interspinous ligaments (after SPALTEHOLZ).



**Fig. 2.** Normal finding. Bilateral paraligamentous injections of contrast medium. Interspinous ligaments appear as filling defects located between the spinous processes and medially sharply demarcated. Lateral contour of the contrast medium shows moderate streakiness.

was often streaky (Fig. 2). The writer expected that the penetration of contrast medium into or through the ligament and the irregular contour of its medial border might reveal a pathologic ligament.

In the first 60 cases the contrast medium was injected unilaterally and on the side of the patient's main symptoms. It was believed that in this way a defect would be best revealed by a flow of contrast medium to the side uninjected. Bilateral injection, however, eventually proved to give a more complete result without loss of the advantage gained by the earlier method; the bilateral injection technique was consequently employed exclusively and is as follows.

The patient is placed in a lateral position on the Bucky table, with the lumbar spine flexed. The three lowermost interspinous spaces are palpated and marked and the skin is cleansed. A 20 ml syringe fitted with a No 12 needle and filled with 1 % xylocaine-exadrine is employed for the first

injections. A small quantity of the anaesthetic is injected subcutaneously in the midline over the L 5 — S 1 interspinous space. The needle is then introduced to its entire length at right angles to the skin but 0.5 to 1 cm lateral to the midline in the sagittal plane along the interspinous ligament.

The needle first encounters a certain amount of resistance which, after the point has penetrated a distance of about 1 cm, is reduced, provided the ligament has not been penetrated. Five to seven ml of the anaesthetic are then injected and the procedure is repeated on the opposite side. The two nearest ligaments above are similarly treated. By placing the tip of the index finger on the adjacent spinous process it is easy to locate the ligament, provided the subject is not too obese. Satisfactory examination of obese persons is difficult as the exact deposition of contrast medium is a basic condition for a reliable investigation result and cannot be achieved when the tips of the processes are impossible to palpate through the covering layer of fat.

After the administration of anaesthesia, 1 to 2 ml of the contrast medium were injected at the first site of insertion. A test dose of this kind may be useful in disclosing sensitivity to the drug. Only one of the author's cases developed urticaria during the examination and none of them reacted to the test dose.

The series of injections is repeated 10 to 15 minutes later with a contrast medium substituted for the anaesthetic, 4 to 5 ml of the medium being introduced in the same way as close as possible to the ligamentous wall. At first we used a 20 % monoiodized water-soluble preparation (Conturex, Lundbeck, Kontrast -U, Leo), chiefly in order to prevent injury in the event of its accidental introduction into the lumbar canal. (We employ the same preparations for lumbar myelography). The density obtained was fairly satisfactory, but since accidents need hardly be feared a slightly more concentrated preparation such as Urografin 30 % seemed to be preferable; this considerably improved the quality of the films and is now used exclusively.

After the injection of the contrast medium a roentgenogram is obtained in the anteroposterior projection with the patient supine and with the lordosis reduced as much as possible. All the ligament measurements given below were obtained from this film. An exposure with the lordosis accentuated as much as possible may also be indicated in order to show the degree to which a long and narrow, slightly stretched ligament may increase in thickness when the spinous processes approach one another. In pathologic cases, tomography (2 to 5 cm sections) was performed with the patient in the same position. This complementary examination will probably demonstrate liga-

mentous details which have been obscured in the routine roentgenogram through summation. A tomographic examination also helps in locating the pathologic ligament section in the anteroposterior direction and determining its dimension in depth.

The contrast medium is for the most part absorbed within an hour. The patient usually tolerates the examination fairly well. Repeated injections for the induction of anaesthesia, however, inconvenience sensitive individuals quite considerably. Injections of contrast medium are painless if the anaesthesia has been performed *lege artis*. On the other hand, the lower part of the back may be rather tender the day after the injection once the anaesthesia has worn off. The great majority of the patients preferred the examination to lumbar myelography.

## V. GENERAL SURVEY OF THE PRESENCE OF LIGAMENOUS CHANGES IN THE SERIES

### AGE AND SEX

It was established by RISSANEN that changes in the lower interspinous ligaments increase with advancing age. The percentage of tendinous tissue begins to decrease and that of loose connective tissue to increase immediately after the 20th year of life. The formation of cavities in the lower lumbar spaces of the interspinous ligaments with advancing age is also a common phenomenon. This author found, on the other hand, that ruptures in the interspinous ligaments are fairly evenly distributed between the different age classes from the ages 30 to 39 upwards. The relative incidence among women was slightly greater than among men.

The table below shows the distribution by age groups of the roentgenologically verified ligament changes. The number of men and women has been combined to make the groups as large as possible.

Age	Controls				Cases with back pain			
	Total	Cases with ligament changes	Number of ligament changes	Incidence %	Total	Cases with ligament changes	Number of ligament changes	Incidence %
11—20	3	0	0	0	6	6	8	100
21—30	13	7	10	54	29	20	26	69
31—40	15	9	11	60	62	42	61	68
41—50	8	5	6	63	63	41	60	65
51—60	1	1	1	100	26	22	28	85
61—70	0	0	0	—	3	1	1	33
Total	40	22	28	55	189	132	184	70

*Table 2.* Distribution of pathologic interspinous ligaments in the L 3—5 interspinous space according to the patient's age and the presence or absence of back pain.

The cases with back pain thus seem to have almost throughout a slightly higher incidence of ligamentous changes than the controls. A distinct increase related to age in the number of cases with pathologic ligaments cannot

be demonstrated until the 51—60 year group. Subjects aged from 11 to 20 are an exception, but the group is small and includes special cases with a past history of considerable traumata.

An increase in the number of pathologic ligaments in relation to the number of the cases appears earlier, from the year 31—40 period onwards. This would seem to indicate that there is perhaps a certain individual disposition to ligament changes. Subjects who show a ligamentous lesion in one of the interspinous spaces at a rather early age also develop changes with age in one of the adjacent ligaments.

If the cases with back pain are distributed by sex, 27 out of 52 women are found to have changed ligaments. The corresponding percentage is 52, comparing with 77 per cent for men, i. e. 105 cases with ligament changes out of 137. *There is thus a distinct difference between the sexes.*

#### LOCALIZATION

The ligamentous changes are distributed between the three lower interspinous spaces in the following table.

Interspinous ligament	Controls	Cases with back pain
L 3—4	2	36
L 4—5	6	85
L 5—S 1	20	63
Total	28	184

*Table 3.* Distribution of ligament changes in the three lower interspinous spaces.

In the controls, the frequency of changes in the lumbo-sacral interspace is considerable, and percentually higher than in the cases with back pain. There is no question of a special type of change, any more than with the dominance of changes in L 4—5 in the cases with back pain. The interspace L 3—4 lodges the smallest number of changes in both categories.

#### POSTURE OF THE LUMBAR SPINE

As was pointed out earlier, very little interest appears to have been shown in the pathology and roentgen diagnosis of the spinous process region. BRAILSFORD was perhaps the first to discuss the latter aspect. This was in

1929 in an extensive study based on a back material of 3.000 cases. He stated e. g. that «if for any reason the lordosis of the lumbar spine is increased, or the lumbosacral angle is diminished, the spinous processes are approximated to one another until in some cases they touch and their opposing surfaces may be moulded or faceted. Obviously, with such a spine, extension is checked by the locked-home position of the spinous processes, which are subjected to an abnormal strain and bursa and arthritic changes readily develop».

It was probably BAASTRUP more than anyone else who gave his attention to roentgenologic studies of the posterior region of the lumbar spine, which he discussed in several works. The first of them appeared in 1933 and in it he drew attention to the great force with which the spinous processes could be driven against one another by reason of the fact that they were the short arm of the system of levers formed by the vertebrae. The result of this as seen in the roentgenograms was that the bone edges of two contiguous processes showed pathologic changes due to pressure, marginal sclerosis, faceting and osteophytes. But when the bone edges of two contiguous spinous processes showed pathologic changes due to pressure it was necessary to suppose that the interspinous soft-tissue pad had first been injured and then destroyed to a greater or lesser extent. BAASTRUP considered that such changes occurred frequently when lordosis of the lumbar column was increased. The literature has several names for these changes. A common term is interspinous osteoarthritis; synonyms for it are Baastrup's disease and 'kissing spine', the latter being the usual term encountered in the Anglo-Saxon literature.

Very far-reaching conclusions were drawn by BAASTRUP concerning the association between low back pain and spinous changes diagnosed only roentgenologically or macro-anatomically. This was done also by later investigators such as KOPSTEIN, STEHR (1937), REINHARDT (1951), SCHUMANN & TRAUTMANN (1952), JOSENHANS (1954). The first three authors and the last author also emphasized the significance of marked lordosis in the production of the changes and clinical signs. RISSANEN, on the other hand was able to show that cavities in interspinous ligaments emerged earlier and more actively in the event of marked lordosis.

The present series appeared to provide a means of demonstrating a possible correlation between ligamentous changes and posture. To this end, the lumbar lordosis in all the cases was classified as marked, moderate or slight. The assessment was made from roentgenograms of the lumbar region taken with the beam directed vertically with the patient lying on his side in as natural a posture as possible. The following table gives the findings.

	Number of cases	Number of changed ligaments	%
Slight lordosis .....	80	63	79
Moderate lordosis .....	96	84	88
Marked lordosis .....	53	65	123
Total	229	212	93

*Table 4.* Incidence of changes in the three lower lumbar interspinous ligaments in the presence of different degrees of lordosis.

All changes in the three lower interspinous ligaments roentgenologically diagnosed are included in the table and, apart from cavities include rents and ruptures as well as flaccidity of the ligaments which latter may have another mechanical etiology than those mentioned earlier. Excluding flaccid ligaments, the percentages show even more marked statistical differences, viz. 50, 64 and 111 for slight, moderate and marked lordosis, respectively. The results conform fully with the observations reported in the literature. It was thus possible to prove that *the incidence of pathologic interspinous ligaments in the three lower interspinous spaces is essentially higher in the presence of marked lordosis than in moderate or slight lordosis.*

#### HEIGHT OF THE SPINOUS PROCESS

In addition to increased lumbar lordosis, BAASTRUP considered high (a large cranio-caudal dimension) spinous processes to be one of the primary causes of bone formation at the margins of the processes. The same point was emphasized by STEHR, REINHARDT and JOSENHANS. The present author also considered this point to merit closer examination in his series. The maximum height of all five lumbar spinous processes was measured in the lateral roentgenograms. Their combined height was then divided by the distance from the upper margin of the spinous process of L 1 to the upper margin of the spinous process S 1. In backs with low spinous processes this index of the spinous height was low, in the neighbourhood of 0.5, while in backs with high spinous processes it approached the value of 1.

The comparison would have been easier to perform for the combined height of the spinous processes or their mean height, but it was felt that this was not the correct procedure. It would have been necessary to employ the patient's body length as a factor of correction, but longitudinal measurements

were not made. As a substitute for this procedure the author measured the spinous process distance L 1—S 1.

The table below shows the distribution of ligamentous changes in backs with different indices.

Index	Number of backs	Number of ligamentous changes	% of changed ligaments
0.50—0.55	2	0	91.8 %
0.56—0.60	11	8	
0.61—0.65	25	26	
0.66—0.70	59	56	
0.71—0.75	56	58	92.4 %
0.76—0.80	41	31	
0.81—0.85	22	22	
0.86—0.90	13	11	

Table 5. The relationship between the mean height of the spinous processes in the lumbar spine and the changes in the interspinous ligaments L 3—5.

The number of ligament changes in all the groups is close to the number of backs. Calculation of the percentage frequency of the changes for the low and the high half of the table respectively gives surprisingly uniform values. The final conclusion drawn can be no other than that *the height of the spinous process does not appear to be correlated with the incidence of changes in the three lumbar interspinous ligaments.*

THE CAPACITY FOR EXTENSION OF THE LUMBAR SPINE

All the earlier workers mentioned in the foregoing stressed the significance of narrowing of the interspinous space as the cause of compression lesions in the corresponding ligament. This is presumably how the ligamentous changes originated in the presence of increased lumbar lordosis.

The assessment of the degree of lordosis was doubtless subjective. Before beginning the contrast medium examination, a lateral projection was made of the lumbar spine in maximal extension in all the cases in order to view this question from another and more exact standpoint. The minimum distance between the spinous process pairs L 3—4, L 4—5 and L 5—S 1 was measured, and the millimeter values were grouped in the ranges 0—5, 6—10 and 11—15 mm. The following table gives a general idea of the total number of cavities, rents and ruptures in the interspinous spaces in question compared with the distance in maximal extension.

Interspinous spaces	Distance mm	Number of changed ligaments	Number of interspinous spaces
L 3—4	0—5	20	118
	6—10	12	88
	11—15	2	23
L 4—5	0—5	54	137
	6—10	22	62
	11—15	7	30
L 5—S 1	0—5	29	101
	6—10	17	79
	11—15	10	49

*Table 6.* The number of cavities, rents and ruptures in interspinous ligaments L 3—5 classified according to the distance between the spinous processes in maximal extension.

To make the comparison as lucid and reliable as possible, the spinous process distance in maximal extension for all the three interspaces together was adopted as the point of departure for the following table.

Interspinous spaces	Distance mm	Number of changed ligaments	Number of interspinous spaces	%
L 3—4 + L 4—5 + L 5—S 1	0—5	103	356	29.5
	6—10	51	229	22.3
	11—15	19	102	18.6

*Table 7.* The relationship between the three different spinous process distances in the three lower lumbar interspaces in maximal extension and the presence of cavities, rents and ruptures in the corresponding ligaments.

The corresponding percentages when only the most severe changes, the ruptures, are taken into consideration, for the smallest (0—5 mm) interspinous process distance was 13.5, for the 6—10 mm distance 8.3 and for the 11—15 mm distance 5.9.

The results of these calculations thus show the same trend as obtained for the posture of the lumbar spine and its effect on the changes in interspinous ligaments L 3—5. *The incidence of cavities, rents, and especially ruptures, was increased in the cases with a high degree of capacity for extension, to which the 0—5 mm distance between the interspinous processes corresponded.*

## DISPLACED SPINOUS PROCESSES

It was held by BURCKHARDT (1934) that whenever individual spinous processes appeared from examination of the lumbar spine to be displaced laterally, there was reason to suspect a high degree of spondylosis deformans. BAASTRUP wrote in 1940 that laterally displaced spinous processes reminded one of teeth that were badly set owing to insufficient space in the jaw. Such positioning of the processes would undoubtedly as a rule have been acquired in early childhood, and may be considered as a physiologic variant which, however, disposed to pathologic conditions. The monograph by SCHMORL & JUNGHANNS (1957) mentioned that under-developed and displaced spinous processes cause back ache probably because of incorrect loading of the faultily working muscles. LEWIT (1957) found that the deviation of the spinous processes was of very frequent occurrence and proof of a strain at a certain level, evidence of altered dynamics of the spine and a sign of asymmetrical muscular pull. The coincidence of the level of deviation and pain in 198 cases was 78 per cent.

This deviation or lateral displacement of lumbar spinous processes is quite a common roentgenologic finding. In the present series of 229 cases, 17 displaced spinous processes were demonstrated of L 3, 40 of L 4 and 23 of L 5. A striking frequency of cavity- and rupture-like changes was disclosed already during the roentgenologic examination in these cases, which suggested that a more detailed analysis of this observation was indicated. The table below gives a ready idea of the magnitude of this frequency compared with the corresponding incidence in the rest of the series.

Interspinous ligament	Cavities		Ruptures		Pathologic ligaments %	
	Normal spinous processes	Displaced spinous processes	Normal spinous processes	Displaced spinous processes	Normal spinous processes	Displaced spinous processes
L 3—4	10	6	18	1	17	41
L 4—5	10	9	53	11	33	50
L 5—S 1	12	4	35	9	23	53

Table 8. The ratio between cavities and ruptures in cases with displaced spinous processes and the rest of the series.

The table shows convincingly *the great frequency and preponderance of cavities and ruptures in interspinous ligaments that are attached to displaced spinous processes* compared with those in the sagittal plane. This is probably due to uneven loading within the ligament.

## LIGAMENT THICKNESS

It was established by RISSANEN that the structural principle of the interspinous ligaments was the same throughout the lumbar region, but that there were nevertheless differences between the two lowest ligaments on the one hand and the more cranially situated ligaments on the other hand. One reason for this was that the supraspinous ligament ended in L 4 or L 3. This author noted further that the thickness of the interspinous ligaments of the L 1—2 space and often also the L 2—3 space usually did not change with age and that their thickness in a man of about 20 was about 1 to 2 mm and about 2 to 3 mm in the two lowest spaces respectively. This was when the measurement was taken from the centre of the ligament, usually the thinnest place. The thickness increased considerably on moving ventrally towards the ligamentum flavum and dorsally towards the supraspinous ligament or the aponeurosis of the back. A thickening of the ligament with age was in contrast almost a rule in the two lowest ligaments and was most marked in the L 4—5 space in which thicknesses of 8 to 12 mm were fairly common. This thickening was considered by RISSANEN to be associated with the formation of cavities in the ligaments.

The present author's roentgenologic method makes it possible to determine the thickness of the ligament simply by taking the transverse measurement in the roentgenograms. Interspinous ligament L 3—4 represented the cranial group. It is unfortunately not the most suitable ligament, but it is the most cranial of those covered by the examination; ligament L 4—5 represented the caudal group. The measurement was made at the level at which the ligament was thickest, approximately halfway between the adjacent spinous processes.

The result obtained is seen in the following table.

Interspinous ligaments	Thickness mm	11—20 years	21—30 years	31—40 years	41—50 years	51—60 years	61—70 years	Total
L 3—4	4—7	5	19	32	32	9	0	97
	8—11	4	15	34	21	8	2	84
	≥ 12	0	8	11	18	10	1	38
L 4—5	4—7	5	16	22	19	10	0	72
	8—11	4	17	34	29	6	1	91
	≥ 12	0	9	21	23	11	2	66

Table 9. Thickness of interspinous ligaments L 3—4 and L 4—5 at different ages.

A superficial examination of the table is sufficient to show that interspinous ligament L 3—4 is thinner on an average than the more caudal ligament. Moreover, thick ligaments tend to be more common at the higher age. Ligaments thinner than 4 mm were not encountered. The values reported by RISSANEN were on the whole lower than those for the present series. At least a partial explanation for the difference may be the roentgenologic magnification which is about 10 per cent. The difference in tonus between living and dead tissue may also be of significance in this connection.

These differences are easiest to see in the following figure which compares the percentual occurrence of the two extreme thicknesses for both interspaces. The difference is not overwhelmingly great, but it is apparent.

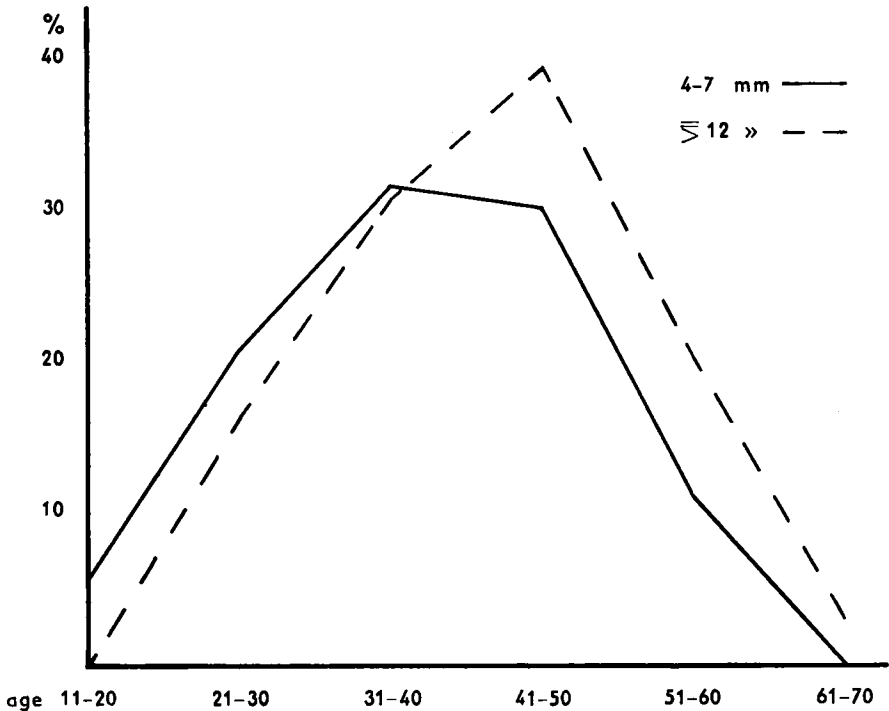


Fig. 3. The percentual age distribution of 4-7 mm and  $\geq 12$  mm thick ligaments belonging to interspinous spaces L 3-4 and L 4-5.

The following table shows the distribution by ligament thickness of the total of cavities and ruptures. Ruptures, as was also observed by RISSANEN, always display a minor or major cavity in the middle of the ligament.

Ligament thickness	L 3—4			L 4—5		
	Number of ligaments	Number of cavities	%	Number of ligaments	Number of cavities	%
4—7 mm	83	23	27.7	64	29	45.3
8—11 »	69	10	14.5	73	32	43.8
≤ 12 »	37	3	8.1	52	22	43.1

Table 10. The ratio between the incidence of cavities and the thickness of interspinous ligaments L 3—4 and L 4—5.

*The two adjacent interspinous ligaments behave completely differently. In the interspace L 3—4 cavities are most numerous in the thinnest ligaments and rare if the thickness is  $\leq 12$  mm. The cavity distribution in space L 4—5 again is remarkably uniform as regards ligaments of different thickness. RISSANEN'S observation that the ligaments thickened considerably, as shown by measurements taken on the outside when cavities originated, is contrary to the present author's findings as regards the L 3—4 ligament, nor does it altogether agree with the finding concerning the L 4—5 ligament. It is possible that the differences in the composition of the two materials have a role in this finding.*

## VI. THE DIFFERENT TYPES OF CHANGES IN THE THREE LOWEST INTERSPINOUS LIGAMENTS, THEIR INCIDENCE AND ROENTGENOLOGIC DIAGNOSIS

Mention has already been made in passing of the types of ligamentous changes that may be revealed by roentgenologic contrast medium examination. The roentgen findings in normal ligaments were also described in brief. In the following each group is discussed separately with special reference to the roentgen diagnosis in the examination of the ligaments.

### NORMAL LIGAMENTS

Normal interspinous ligaments were encountered in the three lower lumbar interspaces in 21 control cases (53 per cent) and in 69 of the cases with lumbar pain (36 per cent). The difference was distinct, but the materials are not fully comparable as the mean age of the controls was lower than of the group with back pain. This point will be considered again in discussing analysis of the correlation between back pain and interspinous ligament changes. *After a paraligamentous contrast medium injection, normal interspinous ligaments appear in the anteroposterior view as medially sharply defined, but sometimes slightly irregular, equally broad or somewhat spindle-shaped, contrast medium defects which are cranially and caudally delimited by two adjacent spinous processes.*

With thin spinous processes the upper, pointed, long and narrow margin of the process often appears to 'dip' into the ligament and the contrast medium consequently does not reach halfway up the height of the lateral boundary (Fig. 4). The lower margin of the spinous process is often considerably broader and arched and the contrast medium reaches the lateral contour of the process low down and caudally. The same is true cranially if the transverse section of the process is piriform and the maximum transverse measurement in the frontal plane is consequently large (Fig. 5). The interspinous ligaments are probably attached to their spinous processes at levels which appear to vary with the different forms of the fixed surface of attachment; it is possible that mechanical tenacity conditions have some

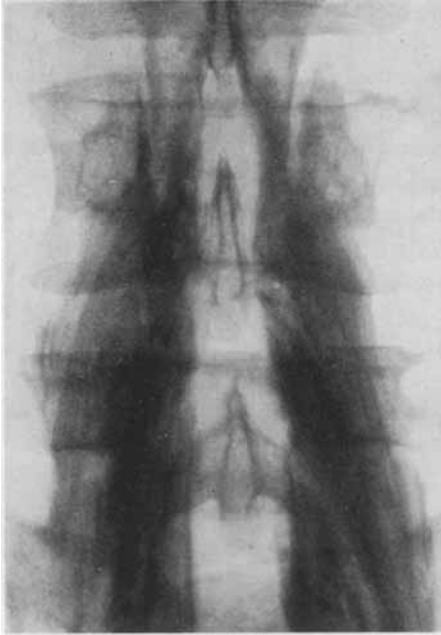


Fig. 4



Fig. 5

Fig. 4. Normal finding. Spinous processes are high and thin. Extremely streaky contrast medium structure. Upper, pointed spinous process margin L 4 'dips' into the ligament and the contrast medium reaches only halfway up the contour of the spinous process.

Contrast medium has no contact with spinous process L 5 which appears to be embedded in a tissue impenetrable to the medium and probably of ligamentous origin.

Fig. 5. Normal finding. Spinous processes L 3 and 4 are rounded and broad. Cranially, a sufficient attachment surface for the interspinous ligaments at the upper margin of the spinous process. Contrast medium therefore reaches the spinous contour much higher up than in Fig. 4.

influence. In Fig. 4 the contrast medium has not established any contact at all with the contour of spinous process of L 5; the process as a whole is evidently embedded in tissues impenetrable to the contrast medium and it is possible that the interspinous ligament encircles it completely.

RISSANEN pointed out that the ligament was thinnest in its central part; according to him, the interspinous ligament viewed in the projection of the roentgenogram was shaped somewhat like an hour-glass.

The roentgenologic form, however, is usually the exact opposite. This may be due to technical factors of projection, but the similar appearance of the ligaments at different depths does not support this suggestion. The

cause of the difference in ligament form is possibly contingent upon the difference in tissue turgor.

The medial sharp contour originates when the ligament prevents the contrast medium deposit from spreading right up to the median line. Laterally, on the other hand, there is no impassable obstacle and consequently the contour of the contrast medium is considerably irregular in this direction. The more or less streaky structure, seen laterally and caudally in particular, appears to be dependent on the penetration of the contrast medium between the dorsal muscle fibres (Fig. 4). Another example of a normal roentgenologic finding may be seen in Fig. 6.

#### LIGAMENTS IN DISPLACED SPINOUS PROCESSES

Spinous processes with a laterally divergent course were encountered in the present material as follows: 17 of L 3, 40 of L 4 and 23 of L 5. In one case all 3 spinous processes were displaced, and in 7 cases 2 were deviated.

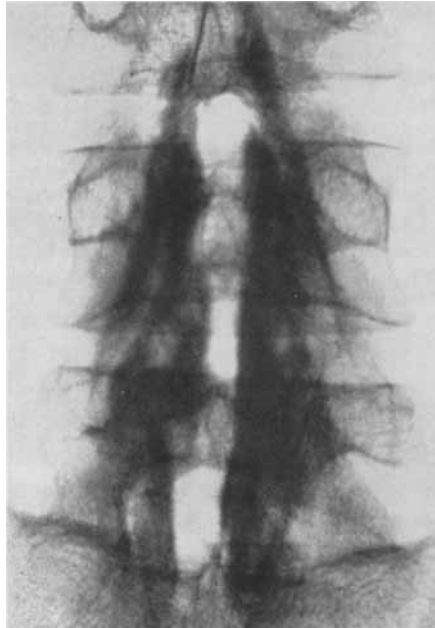


Fig. 6. Normal finding. Interspinous ligament L 4—5 rather thin and of uniform breadth. L 5—S 1 ligament somewhat asymmetric.

The commonest type of deviation was that the caudal part of the spinous process was displaced laterally while the cranial margin was usually on the median line and level with the main row of spinous processes (Fig. 7).

Such displacement of the spinous process naturally also affects the attachment of the ligament to the spinous process which becomes asymmetrical and displaced laterally. The half of the ligament that is situated on the side to which the spinous process is displaced is attached to the lower margin of the process, while the attachment of the opposite half extends higher up (Fig. 7). The upper margin of the spinous process may sometimes deviate from the median line (Fig. 8), with the vertebra as a whole simultaneously rotated slightly to the left. The ligament attachment is asymmetric in this case, too.



Fig. 7



Fig. 8

Fig. 7. Left half of interspinous ligament L 4—5 is attached cranially to the lower margin of the displaced spinous process L 4, while the right half is attached to the lower part of the spinous process on this side.

Fig. 8. Displacement of spinous process L 5 with right-sided deviation of its upper margin. Contrast medium adheres on the right side to the deviating spinous process margin, on the left side it achieves contact with the process considerably lower down.

## CAVITY FORMATION

According to BAASTRUP (1933), as early as 1824 MAYER demonstrated the presence of true joints with an articular cavity and a synovial membrane between the spinous processes of the lumbar spine, so-called 'Diarthroses interspin. Mayeri'. FICK (1904), describing the normal anatomy of the interspinous ligaments, stated that a uni- or multilocular 'joint cavity' had sometimes been seen in them. He did not mention, however, whether he regarded it as a *pathologic or normal phenomenon*. BAASTRUP's conclusions concerning interspinous ligaments were for the most part arrived at indirectly through an analysis of roentgenologic changes pertaining to the spinous processes. But he offered no personal observations throwing new light on the circumstances connected with these cavities.

It was pointed out by BRAILSFORD (*op.cit.*) that bursa and arthritic changes develop readily between the spinous processes in the presence of increased lumbar lordosis. Adventitious bursae were encountered especially in the tall, slender visceroptotic type of skeleton with a long, narrow, flexible spine. WINDHOLZ (1937) studied the spinous processes roentgenologically and made anatomic comparisons. He stressed specifically the common occurrence of exostoses on the lower external margin of the spinous process, bony projections that were of varying size and shape. Between the exostoses and the adjacent spinous processes he encountered true joints with cartilage-covered articular facets and a fibrous articular capsule. They were found regularly in cases in which the static-mechanical functions of the spine had sustained changes caused by pathologic processes.

The first description of a case of lumbar interspinous cavity studied histologically that the author has been able to find in the literature is the one published by FAULONG, LEGER & AHRAS (1949). They stated that the spinous process is «a poor relation of the rich vertebral pathology». They found in a case in which spinous processes L 3—4 had been resected because of back pain and new bone formation at the margins of the spines, an articular cavity with cartilage-covered surfaces and capsule in the interspace L 3—4. Histologic examination of the preparation revealed that there was a cavity unlined with cell elements in the middle of a block of fibrocartilage.

YAMADA, NISHIWAKI & YASUKAWA (1954) performed spinal fusion on a 29-year-old heavy labourer with intractable low back pain which they attributed to morbus Baastrup. The man had previously been exposed to hyperlordosis trauma. A sketch showed the presence of cavities between spinous processes L 3—4 and L 4—5. They called these cavities bursae.

The morphology of interspinous ligaments in human subjects of different ages was studied histologically by SCAPINELLI (1958). He demonstrated in an interspinous ligament of a kyphoscoliotic patient of 39 a cavity with a wall reminiscent of that in a mucosal bursa or an articular synovial membrane.

The investigation performed by RISSANEN showed that notable changes occurred with age in the interspinous ligaments, some of them visible to the naked eye. One of these changes was the formation of cavities. The older the person, the greater was the likelihood of a cavity in the middle of his interspinous ligaments. This cavity formation was more common in the L 4—5 space than in the L 5—S 1 and L 3—4 spaces. Incipient cavity formation was often seen in these three spaces in younger persons and in older subjects in the upper spaces as well. If there were cavities in several spaces they were usually largest in the L 4—5 space.

Cavities were found to begin to originate immediately after the 20th year of age. Not a single case was found in subjects under 20 in RISSANEN's series. It seemed as if the centre of the ligament first became soft and slack and the tendinous tissue disappeared from the area; later, to replace it, an empty cavity or one partly filled with fat and loose connective tissue appeared at its site. In younger subjects and in those in which the cavities were incipient the walls generally were irregular and rough. In older subjects and where the cavities were larger the walls usually grew smooth. Externally, the ligament may appear intact in spite of it containing a cavity.

In the series mentioned above a true 'kissing spine' was not an absolute precondition for the formation of cavities. Morbus Baastrup cases are relatively rare and were only established a few times with certainty in his material. Cavity formation was most marked in the lowest lumbar spaces, where the lordosis also was most evident. These observations lend support to the assumption that rubbing of the spinous processes against one another, either directly by destroying the tissues or indirectly by causing degeneration, had a role in the origination of cavities. It was very common in subjects over 50 for the cavities in the lowest interspinous ligaments to be bounded on the side of the spinous processes by tissue resembling hyaline cartilage cell colonies. The cavities originating inside the interspinous ligaments, together with the surfaces of adjacent spinous processes, thus made, at least in later years of life, joint-like formations with synovial membranes 'and articular capsules'. There must consequently have been notable chafing and pressure between the bony surfaces of the spinous processes, as has been proved in experimental studies of arthrogenesis (KROMPECHER & GOERTTLER 1938, KETTUNEN 1958).

The present author was able to demonstrate cavitation roentgenologically in 44 cases and 51 ligaments, i.e. in 19 per cent of the total cases. The cavities were distributed fairly evenly between the three lower spinous interspaces, but with a slight preponderance for the middle of these three. Cavities were very common in cases with displaced spinous processes; 19 of the 51 cavities were established in this group, although such spinal processes only constituted slightly over 10 per cent of the total. Cavities in the cases with displaced spinous processes occurred primarily in the age groups 21—30 and 31—40 years; the slightly higher ages were better represented in the other cases.

The difference between the incidence (75 per cent) of cavities in the age group 31—40 years in RISSANEN's material and the figure of 19 per cent for the present series is surprisingly large. It may naturally be due in part to dissimilarities in the two materials. Another factor may be that the frequency of ruptures in the present series is essentially greater than that in the autopsy material. It is likely that the present author diagnose as ruptures many ligamentous changes that RISSANEN would have classified

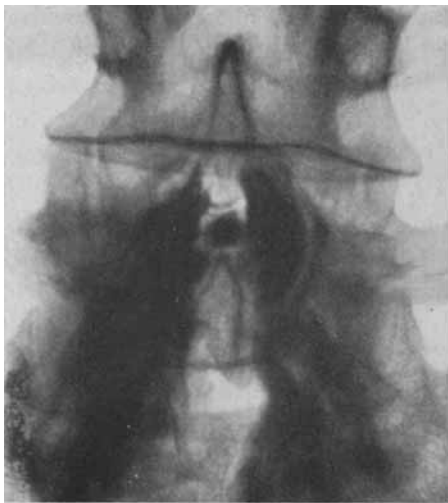


Fig. 9

Fig. 9. Cavity in interspinous ligament L 4—5 which is shown roentgenologically by an irregularly delimited, round spot of contrast medium in this interspace.



Fig. 10

Fig. 10. Cavitation. Spinous process L 4 deviated caudally to the right. A longish cavity lying along the left ligament contour fills a large part of interspinous ligament L 4—5.

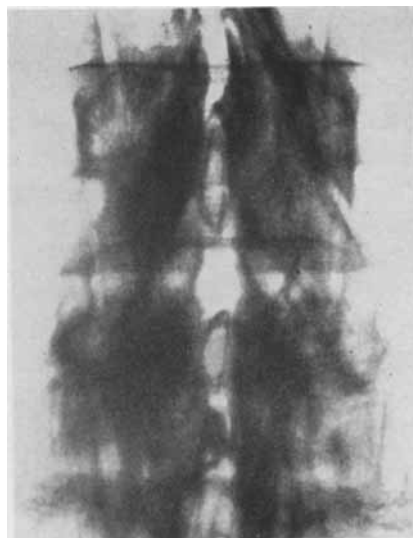


Fig. 11 a



Fig. 11 b



Fig. 11 c

Fig. 11 a) Cavitation, 2 mm in diameter, represented by a round spot of contrast medium, located in interspinous ligament L 3-4, and a spot of contrast medium  $4 \times 9$  mm in ligament L 5-S 1. b) Tomogram; 3 cm cut. Cranial cavity does not lie in this plane, the caudal cavity is more rounded in shape than in (a) owing to moderate extension of the lumbar spine. c) Tomogram; 4 cm cut. Cranial cavity begins to appear.

as cavities. It is perhaps not always certain to distinguish between them by roentgenologic means, nor is it highly significant since the difference between them may be subtle. A third reason for the difference may be that the cavities were contained between bilateral, fairly intact ligamentous parts which prevented the contrast medium from penetrating. Fourthly, a cavity filled completely with fatty tissue may sometimes have failed to produce roentgenologic evidence of its nature. All these possibilities are conceivable and in full conformity with observations on cadavers.

*The diagnosis of a cavity by contrast examination of lumbar interspinous ligaments is based on the demonstration of a rounded (Fig. 9) or somewhat elongated (Fig. 10) spot of contrast medium within the contrast-free zone produced by the ligament.* The shape is naturally dependent also on the degree of flexion or extension of the lumbar spine. This may be seen e.g. in Fig. 11 in which the tomograms were taken on another table than the one employed for the ordinary contrast roentgenogram, resulting in a certain degree of extension of the spine. The accumulation of contrast medium may be only 1 to 3 mm in diameter (Fig. 11, the L 3—4 interspace, and Fig. 12), but also as much as 6 to 10 mm (Fig. 13). In tomograms with 1 cm between the



Fig. 12. Cavitation. A rounded, relatively small cavity in interspinous ligament L 4—5.

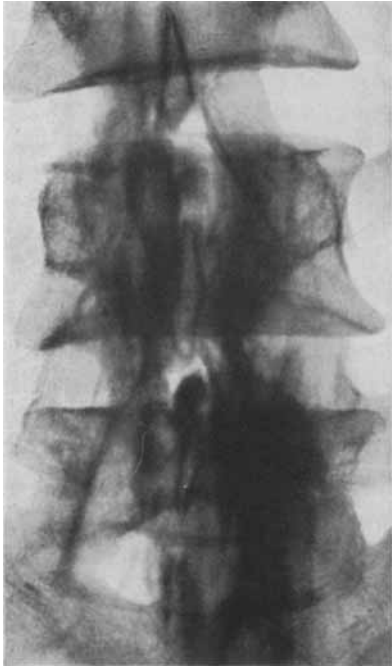


Fig. 13 a



Fig. 13 b

Fig. 13 a) Cavitation. A rounded, medium-sized cavity in ligament L 3-4; a large, sharply delineated, longish cavity in interspace L 4-5. Very thin lumbo-sacral ligament. b) Tomogram; 3 cm cut. A streak of contrast medium caudally to the right in ligament L 4-5 connects the spot of medium with the deposit lying outside the ligament, probably a rent in the right half of the ligament.

sections the cavity is sharply delineated in 1 or at the most 2 cuts showing that its boundaries in an anteroposterior should be roughly the same as in a lateral direction. The contour may be completely regular (Fig. 13) but is more often irregular (Fig. 9), obviously depending on the quality of the surface within the cavity.

The spot of contrast medium usually adheres more or less intimately to the general contrast deposit on one side. This shows that the ligament is thin and that the contrast medium has probably penetrated the ligament from that side. A frequent indication of where this has occurred is a streak of contrast medium connecting the contrast medium accumulations outside and inside the ligaments. Such finer details can best be analysed with the aid of tomography (Fig. 13). Figs. 10 and 17 are examples of the frequent

occurrence of cavities in displaced spinous processes. It is often quite difficult to classify the penetration of contrast medium in a ligament. Borderline cases occur primarily between cavities and partial ruptures. This problem will be discussed in more detail in connection with the latter type of change.

#### RUPTURES IN THE LIGAMENTS

NEWMAN (1952) pointed out that injuries resulting in the springing apart posteriorly of two vertebrae frequently occurred in everyday life. This may happen in a fall on a slippery surface with the legs stretched out in front, a fall downstairs or from a horse or bicycle, or a skating accident. A similar strain to the spine may occur when a heavy weight is lifted with the spine flexed but the knees straight. The result of violence of this nature, when of sufficient force, is to tear, among other, the supraspinous and interspinous ligaments.\* The region of the spine affected is the one where the mobile lumbar spine meets the immobile pelvic girdle, and this is generally the lumbosacral junction. NEWMAN called the result of a trauma of this kind 'sprung back'.

Torn or inefficient interspinous ligaments in the lower part of the lumbar spine were often encountered by KALLIO (1960) in disk operations. Since the autumn of 1957 he has carried out cutaneous ligamentous reconstruction in some of these cases using skin from the edge of the incision as repair material. A similar method has been tested experimentally in rabbits by JOKINEN (1958).

RISSANEN established that the interspinous ligaments of children are intact. This was not always the case with adults who relatively often have defects in certain parts of the ligament system. He considered that the ligaments must therefore be ruptured in one way or another, and called these defects ruptures.

The ruptures found in interspinous ligaments were of two types:

1) Partial ruptures which showed on either the right or the left side of the ligament as a rent across one half of the ligament. The other half of the ligament was intact, although generally much slacker than usual. The rent extended to the cavity that was almost always present in the centre of the ligament in cases of this type.

2) Complete ruptures with a fairly wide rent through the ligament; the opening was either empty or filled with fatty tissue.

The rupture was typically and always localized at a certain site, a constant one, in the interspinous ligament. This point of predilection was

the medial portion of the ligament, the ventral and dorsal parts being usually intact. The complete ruptures were usually oval in form, with an anteroposterior axis; in some cases they were rounded. They were well demarcated and sharply defined from the rest of the ligament.

It was reported by NEWMAN that the supra- and interspinous ligaments ruptured completely in the space between the spinous processes when subjected to trauma although apart from sketches he advanced no proof of this. RISSANEN, on the other hand, found no signs of rupture of the supraspinous ligaments in any of his 306 cases, even on microscopy. In the ruptures of the interspinous ligament that he noted, the posterior part was always intact and only the medial part was torn in the area where the fibre bundles pass obliquely between two bony surfaces of different vertebrae.

Histologic examination showed that the rupture of the interspinous ligament always occurred in tissues showing varying degrees of degeneration but never in healthy tissue. The more interesting of the degenerative changes was cystic degeneration. It had morphologic features similar to those seen in ruptures of the tendon of the supraspinatus in the shoulder reported by SCHAER (1936). The changes were also in some respects similar to those occurring in ruptures of different tendons reported (BJÖRKROTH 1943, DAVIDSON 1956, ORELL 1958).

Ruptures were found by RISSANEN in about 21 per cent of subjects over 20 years of age; two-thirds of these were partial, and one-third complete. The first case, an isolated one, was found in a subject of under 30; there was a peak in the 30—40 year age group, above which the incidence was relatively even. The present series showed a considerably higher rupture frequency, i.e. 47 per cent, of which 21 per cent were partial and 26 per cent complete. The considerable difference in the incidence will be discussed later.

Twenty-two of the cases of rupture were women and 87 men. Since in the total material there were 63 women and 166 men, the relative incidence among women was clearly lower than among men, 35 per cent against 52 per cent respectively. The ratios were reversed in the autopsy material, but the difference was no more than 7 per cent.

a) *Partial ruptures.* Partial ruptures were demonstrated roentgenologically on the right side in 28 cases and 31 ligaments and on the left side in 21 cases and as many ligaments, i.e. in all in 49 cases, or 21 per cent. The incidence was highest in the L 4—5 interspace which displayed more ruptured ligaments than all the other interspaces together. The pathologic changes were more numerous in the lumbo-sacral interspace than in the L 3—4 in-

terspace. The percentual distribution of the cases in age groups of a reliable magnitude from the statistical angle is fairly uniform and is around 20, according to the table below.

Years	Total number of cases	Number of cases with partial rupture	%
11—20	9	4	44
21—30	42	7	17
31—40	77	17	22
41—50	71	14	20
51—60	27	6	22
61—70	3	1	33

Table 11. Number of cases in the different age groups and the incidence of partial rupture.

*Partial ruptures appear after the injection of contrast medium as streaks which run parallel but not quite rectilinear to the superior or inferior surface of the vertebral bodies (Fig. 14). The streaks depart from the main contrast medium deposit at the outer contour of the ligament and penetrate to the median line of the ligament, where they often increase in breadth, (Figs. 15*

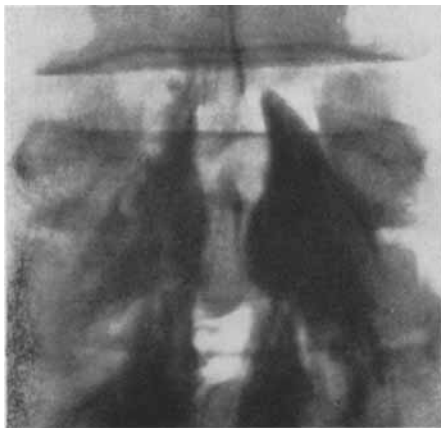


Fig. 14

Fig. 14. Partial rupture. Streak of contrast medium on the right side of interspinous ligament L 5—S 1, suggesting rents in its structure.

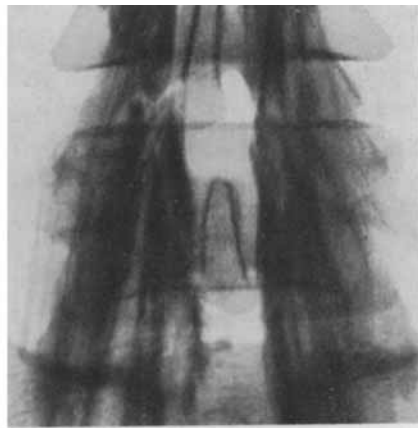


Fig. 15

Fig. 15. Partial rupture. Lumbo-sacral ligament has an irregular right-sided contour. A streak of contrast medium increasing in breadth towards the centre of the ligament represents a partial rupture.



Fig. 16



Fig. 17

Fig. 16. Partial rupture. A typical finding to the left in the L 4-5 interspinous ligament.  
 Fig. 17. Partial rupture. A long, oval spot of contrast medium adherent to the right caudal ligament contour in the L 4-5 interspace is indicative of a shallow partial rupture. Large cavity in the L 5-S 1 ligament to the left.



Fig. 18. Complete rupture. Paraligamentous contrast medium accumulations are connected by an oblique bridge of medium which penetrates interspinous ligament L 4-5 and represents a rupture.



Fig. 19 a



Fig. 19 b

Fig. 19 a) Complete rupture. Transverse bridges of contrast medium in ligaments L 3—4 and L 4—5 revealing ruptures in these ligaments. b) Tomogram; 3 cm cut. Changes are more distinct than in (a).

and 16). The streaks may also be of equal width, but are usually of different length and one to three in number. The ligament contour is almost always slightly irregular on the side of the departure of the streaks, and sometimes only an irregularity in which the contrast density is increased represents the partial rupture (Figs. 17 and 24).

It is often difficult to draw a line between partial ruptures and cavities. In Figs. 15 and 16 the streak of contrast medium is distinctly broader towards the centre of the ligament, which suggests the presence of a cavity. On the other hand it has to be admitted that the contrast medium spot which represents the cavity sometimes displays a canal communicating with the surface of the ligament (Fig. 13). All of RISSANEN's rupture cases, both partial and complete, had a minor or major cavity in the middle of the ligament. The obvious explanation is simply that the boundary between these two types of change is ill defined. When the contrast medium spot is large and there is no communication with the exterior, or when it is quite small, it is appropriate to speak of 'a cavity'. When the contrast medium spot is



Fig. 20 a



Fig. 20 b



Fig. 20 c

Fig. 20 a) Complete rupture. A large rupture in the lumbo-sacral ligament, slightly irregular contrast medium deposit. b) Tomogram; 3 cm cut. Cranially-centrally located densest accumulation of contrast medium in the ligament outlines a cavity. c) Tomogram; 4 cm cut. Rupture is of different height owing to the depth of the section.

small and the communicating canal is about as wide as or wider than its diameter, the principal pathologic feature is a rupture. Certain in-between variants of these findings tend to cause difficulties in interpretation.

b) *Complete ruptures.* This type of rupture was diagnosed in 60 cases and



Fig. 21. Complete rupture. A rupture of irregular shape in interspinous ligament L 4—5.



Fig. 22 a



Fig. 22 b

Fig. 22 a) Complete and partial rupture. A complete rupture in the lumbo-sacral interspace: a partial rupture on the left side in interspinous ligament L 4—5.  
b) Tomogram; 2 cm cut. Ruptures are more distinct than in (a).

75 ligaments, i.e. 26 per cent. The majority of the ruptures in this group were also in interspace L 4—5, followed closely by the lumbo-sacral interspace, while interspace L 3—4 contained by far the smallest number of ruptures. The incidence shows a certain increase with advancing age, as is evident from the following table.

Years	Total number of cases	Number of cases with complete ruptures	%
11—20	9	1	11
21—30	42	10	24
31—40	77	15	20
41—50	71	23	32
51—60	27	11	41
61—70	3	0	0

Table 12. The number of cases in the different age groups and the incidence of complete ruptures.

*Complete ruptures are fairly easy to diagnose after the injection of bilateral paraligamentous positive contrast medium. This forms a bridge between the two contrast medium deposits which originate when the contrast penetrates the ligament as the site of the rupture fills. The direction may be oblique (Fig. 18) or transverse (Fig. 19).*

The breadth usually exceeds half the distance between the adjacent spinous processes and the contrast medium may even fill in the interspace completely (Fig. 20). The structure of the contrast medium may be homogeneous or slightly streaky or blotched, and the bridge is sometimes considerably irregular in shape (Fig. 21). Complete and partial ruptures sometimes occur in the same subject (Fig. 22). The cavity that ought to be demonstrable in the centre of the ligament can be discerned clearly e.g. in Fig. 20.

The incidence of cavitation in the present series was much lower than in RISSANEN'S material, which was exactly the reverse for ruptures, as has been mentioned earlier. A possible tendency to diagnose ruptures too frequently may very well be due to the fact that large cavities are surrounded by a very thin and degenerated ligamentous wall that may be permeable to contrast medium and also easily damaged during operative procedures.

## FLACCID LIGAMENTS

The routine procedure in the operative uncovering of the caudal lumbar region included assessment of tension in the supraspinous and interspinous ligaments. Flaccid ligaments were encountered in 3 cases in the L 3—4 interspace, in 8 cases in the L 4—5 interspace and in 22 cases in the lumbo-sacral interspace; a total of 33 ligaments in 27 patients. The disappearance of tendinous tissue is presumably the reason for this type of finding. The age group 31—40 years was predominant and over half the cases belonged to it. Flaccid ligaments were almost twice as common in women as they were in men. Traumata were fairly rare in the case histories.

*The roentgenologic diagnosis of flaccidity of interspinous ligaments is based on the irregularity of the ligamentous contour as a whole, and this is usually combined with blotchy penetration of the contrast medium into the ligament (Fig. 23). The ligament may be filled to a greater or lesser degree by this blotchiness, and when this happens it is most intense centrally (Fig. 24). It is difficult to determine the boundary line between flaccidity and cavitation and both these types of change occur concomitantly in many ligaments. There should consequently also be, for example, a cavity in the*



Fig. 23 a



Fig. 23 b

Fig. 23 a) Relaxed ligaments. Contours of ligament L 4—5 and L 5—S 1 are irregular and in some places ill-defined, suggesting flaccidity of the ligaments. b) Tomogram, concomitant partial ruptures in L 4—5 interspace, a cavity lumbo-sacrally. Notably blotchy structure of contrast medium lumbo-sacrally, which is also characteristic of ligament flaccidity.



Fig. 24. Relaxed ligament with poorly defined and irregular contour in L 5—S 1 interspace to the left suggesting flaccidity. A cavity and possibly a concomitant partial rupture to the right. Right-sided partial ruptures also in ligament L 3—4 and L 4—5.

ligament in the L 5—S 1 interspace in Fig. 24. In Fig. 25 the interspace L 5—S 1 is dominated by a cavity, but it is sharply defined which would seem to be an indication of concurrent flaccidity in the ligament. On the other hand, only typical small spots and irregular contours suggestive of flaccidity are encountered in interspace L 3—4.

In addition to the cases mentioned earlier from the flaccid ligaments group there were a further 16 cases in the operation reports in which flaccid interspinous ligaments were found. It is hoped that their omission will not be taken as a reflection on the accuracy of the roentgenologic diagnosis. They are included in the pathological material, but under another diagnosis: cavities or ruptures. These changes so dominated the roentgenologic picture that it was considered best to classify the finding accordingly.

The roentgenologic and operative methods employed to establish changes in the three lower interspinous ligaments may perhaps from the broad viewpoint be regarded even after this analysis as meeting the criteria of reliability. The roentgenologic method is obviously the easier to apply of those two

methods. The exactitude is probably in most cases not the same as RISSANEN achieved, but his dissecting method required cadavers; for the assessment of ligament flaccidity, however, both the in vivo methods should be superior to the preparation of cadavers.



Fig. 25 a



Fig. 25 b

**Fig. 25 a)** Relaxed ligaments. Changes typical of a flaccid ligament in the L 3—4 interspace. Partial rupture to the right in ligament L 4—5. In lumbo-sacral interspace a large cavity with irregular margins suggesting concomitant ligament flaccidity. **b)** Tomogram; 4 cm cut. L 5—S 1 cavity and very diffuse ligament contours well shown.

## VII. DISK DEGENERATION, TRAUMA OF THE LUMBAR SPINE AND CHANGES IN THE INTER- SPINOUS LIGAMENTS

### DISK DEGENERATION

BAASTRUP (1933) was interested in the connection between spondylosis deformans and changes at the margins of the spinous processes as a cause of pain. He pointed out at the same time that it is possible to encounter gross osteoarthritis of the spinous processes without associated pathologic changes in the vertebral bodies.

The author considered an analysis of the correlation of disk degeneration and changes in the interspinous ligaments to be of interest. For this purpose the conventional lumbar roentgenograms in the material as a whole were examined for signs of the former; narrowed interspinous spaces, marginal deposits and sclerotic edges of vertebral bodies, as well as displacements between vertebrae were taken as signs of instability. The cases were then distributed into four groups according to these findings: normal = 0, and I, II and III degrees of degeneration. The table below shows the number of cases in these groups and the distribution of cases with ligamentous changes.

Degree of disk degeneration	Total number of cases	Cases with ligament changes	%
0	78	51	65
I	87	62	71
II	52	35	67
III	12	6	50

*Table 13. The incidence of changed interspinous ligaments in the total material. Cases distributed according to the degree of disk degeneration in the lumbar spine.*

It appears from the table that the changes in the three lower interspinous ligaments do not seem to have any connection with disk degeneration in the lumbar spine or in general with its severity. It has been shown as previously

stated, that ligamentous changes are of a degenerative character, partly the result of heavy local mechanical strain caused by anatomic factors as well as by certain other, more general factors affecting the organism as a whole. Disk degeneration is, as the name implies, also caused by degenerative changes but originates independently of them in the interspinous ligaments. *The changes, which are similar in character in the various sections of the spinal column, thus obviously have a different etiologic background.*

The connection between prolapse of disk and changes in the interspinous ligaments have been the subject of lively discussion in the literature. NEWMAN stated that a flexion injury to the posterior structures of the vertebral column, if carried beyond the point at which the neural arches of two vertebrae are torn asunder, will separate the vertebral bodies and damage the posterior longitudinal ligament and the annulus fibrosus which bind the bodies together. It is rational to regard disk prolapse as secondary to ligamentous damage. In support of this assertion he referred e. g. to FRIBERG & HIRSCH (1949) who showed by examination of 500 disks at necropsy that in the lower lumbar spine it is almost invariably the posterior arc of the disk that is damaged. This would seem to suggest that the injuring force separated the vertebrae posteriorly. If injury to the annulus were due to compression, torsion or grinding, the damage would not be confined to the posterior quadrant. Further proof might be found in NEWMAN's experience in operation for prolapsed disk: a torn or inefficient supraspinous ligament and an unstable vertebra were almost constant findings.

A similar reason for disk prolapse was advanced by HACKETT (1957): »When there is relaxation of the supra- and interspinous ligaments, an increased pressure on the intervertebral disks is permitted. This pressure may force the nucleus pulposus through the posterior longitudinal ligament giving rise to the increased symptoms of radicular pain.»

Of all the ruptures in the lumbar interspinous ligaments in RISSANEN's material, 92 per cent were situated in the two lowest ligaments. The majority of all disk prolapses were also situated in the two lowest vertebral interspaces. He therefore suggested that there may be some causal connection between these two facts. The prolapse usually occurs in the dorsal part of the disk, and hence from the purely mechanical point of view yielding of the most posterior parts of the spine should be of considerable, even decisive significance as a precondition for the prolapse.

A connection between disk prolapse and changes in the interspinous ligaments was also suggested by HVID (1959), but his reasoning was in direct opposition to that of the three authors mentioned earlier. He considered that

chronic overstretching of the interspinous ligament occurs in connection with degeneration of the disk in consequence of the narrowing of the corresponding intervertebral spaces. Provided that the small intervertebral joints are intact the two corpora try to approach one another and the two corresponding spinous processes concurrently draw apart. This displacement takes place around a frontal axis the site of which is governed by the location of the articular surfaces on the articular process. The result is stretching of the supraspinous and interspinous ligaments and it is conceivable that such distension or trauma may produce degeneration of the ligament.

Were a pathologic or, above all, a ruptured ligament the cause of disk prolapse, or vice versa, ligaments of this type ought to be a very common finding in homologous interspinous spaces. Those cases of the present series that had been subjected to a disk operation ought to lend themselves excellently in illustration of this question.

These cases total 85. Prolapse of the disk was established in the L 3—4 interspace in 2 cases and in one of these in the L 4—5 interspace as well; in a further 45 cases this interspace was the site of the prolapse which was eliminated. The lumbo-sacral disk was the starting point for a prolapse in 38 cases. The following table gives a general idea of the occurrence of pathologic ligaments in disk prolapses. The prolapses in interspaces L 3—4 and L 4—5 in the same case are entered in the table as occurring in separate cases.

Analysis of the figures shows that prolapses in the lumbo-sacral interspace are accompanied by a significantly greater number of changes in the interspinous ligaments than those in the immediately cranial interspace. This, however, pertains solely to the heterologous changes; homologous changes

Interspinous ligament	Prolapses	Changes in homologous ligaments		Changes in heterologous and homologous ligaments		Changes in heterologous ligaments only		Total ligament changes	
	N:o of cases	N:o of cases	%	N:o of cases	%	N:o of cases	%	N:o of cases	%
L 3—4	2	1	50	0	0	0	0	1	50
L 4—5	46	8	17	9	20	9	20	26	59
L 5—S 1	38	6	16	10	26	16	42	32	84
Total	86	15	17	19	22	25	29	59	69

*Table 14.* Incidence of changes in the three lower interspinous ligaments in homologous and heterologous interspinous spaces in 86 cases of disk prolapse operatively verified.

were established in practically the same degree in both interspaces and in about 40 per cent of the prolapsed cases. Flaccid ligaments and ruptures in the lumbo-sacral interspace are over-represented in this part of the series. A comparison between the incidence of ligamentous changes in the prolapse material and in the rest of the cases with back pain gave the following ratio:  $59/86 = 69$  per cent,  $73/104 = 70$  per cent, respectively.

Disk prolapse operatively verified, and a pathologic interspinous ligament at the same level thus displayed a congruence in 40 per cent of the cases. But in addition, over half the cases with homologous ligamentous changes also presented concomitant heterologous ligament changes. Heterologous ligament changes alone occurred in 30 per cent of the prolapses. Taking this into consideration, heterologous ligament changes were encountered in about 50 per cent of all cases of prolapse. The remaining 30 per cent of the prolapses were associated with intact interspinous ligaments.

The congruence between disk prolapse and changes in the corresponding interspinous ligament often established operatively, observed by NEWMAN and KALLIO, was thus no greater than 40 per cent in the present series. There was concurrently an incongruence in regard to the ligamentous changes which rose to 50 per cent and, furthermore, every third case had normal interspinous ligaments. The author's studies consequently do not support NEWMAN's and HACKETT's arguments concerning ligamentous changes as the cause of disk prolapse. It would appear very probable that their assumptions are incorrect, with the same applying to HVID's argumentation.

The incidence of pathologic ligaments was 69 and 70 per cent, respectively, in the cases with disk prolapse operatively verified and the unoperated cases with back pain. This comparison is in full agreement with the investigation results discussed on pp. 49—50 and also *speaks against an etiologic connection between disk prolapse and altered interspinous ligaments.*

#### TRAUMA

Minor signs of trauma of the lumbar spine as the reason for morbus Bastrup have been reported in the literature. They were mentioned e. g. by SCHUMANN & TRAUTMANN who in post-traumatic cases obtained low back pain in the spinal region which appeared spontaneously when the back was extended. These cases had marked bony growths on the spinous processes and narrowed interspaces between the processes. The reason for the clinical signs, these authors stated, was the static changes in the lumbar spine after traumata caused by faulty loading.

All the author's patients were questioned closely about any earlier trauma of the lumbar spine. No such injury was recalled by 148, while 81 answered in the affirmative. Only definite cases were included in this group. Some two-thirds of the 81 cases reported that they had lifted too heavy a load, about one-third that they had performed a movement that was unnatural and mostly that they had slipped and fallen or that a leg had given way under a load on the back; only isolated cases had been exposed to direct trauma to the lumbar region. All 81 cases referred their back pain to the causes mentioned.

The injuries were all of such types that they could well have caused a lesion of the interspinous ligament. There is reason in this context to recapitulate the electromyographic studies reported by FLOYD & SILVER (1951). These authors stated that in the standing position there is no contraction of the erector spinae muscles, but as the spine begins to bend forward these muscles contract until full flexion is reached; at this 'critical point' the muscles again relax leaving the spine supported by the ligaments. It is at this stage, when the spine is in a position of flexion with the erector spinae relaxed, that the ligaments of a damaged segment either fail to take the strain or in doing so produce pain.

Ninety-five changed interspinous ligaments were established in the 81 cases with a history of trauma, i. e. 117 per cent. The 148 cases without trauma covered a total of 117 changed ligaments, i. e. 79 per cent. This significant percentual difference seems to suggest that *lumbar spine traumata of the type mentioned tend to produce ligamentous changes roentgenologically verifiable, in the three lower interspinous ligaments.*

## VIII. CHANGES IN THE THREE LOWER LUMBAR INTERSPINOUS LIGAMENTS AND LOW BACK PAIN

Compression of nerve roots in consequence of prolapse of the intervertebral disk is the commonest cause of sciatica. It is not many decades since this was stated, but its great significance in the interpretation of low backache is contested by none. It appears, however, that this has resulted in such great interest in the pathology and clinical features of intervertebral disks that the possible influence of the region behind the spinal canal on conditions in the lumbar spine may have been overlooked completely.

For instance, a great number of ligaments in the most posterior part of the lumbar spine may be the possible site of symptoms. This is apparent e. g. from the fact that LERICHE (1930) was able to demonstrate a profuse supply of nerve endings in articular ligaments, and from COMROE's observation that the ligament is after the periosteum the human tissue that is most sensitive to pain.

However, the theory of the ligamentous origin of pain is not completely without advocates. As early as 1916 MAGNUSON (1944) stated before the American Roentgenological Society that low back pain and sciatic pain were to be attributed more to the strain of ligaments of the lower back than to any other cause. He mentioned in his paper that inflammatory and degenerative changes occurred equally often in the ligaments and joints of the lumbar spine as, say, in a knee which in such cases gave clinical signs of a different type. The weight of the body loads the joints and ligaments behind the spinal canal. On bending forward some of the load on the vertebra and disks is relieved but the posterior ligaments are stretched. If pathologic, degenerated ligaments lacking elasticity are involved, such movement may produce pain either from overstretching or from minute tears produced in this fibrous structure.

Whenever it is possible to demonstrate pathologic changes in the spinous contours, there is reason to suspect that they, or perhaps rather the changes in the interjacent or adjacent soft parts, are the cause of the lumbago which sets in sooner or later (BAASTRUP 1933 b). In 1940 this author stressed furthermore that the most frequent direct causes of pain are undoubtedly he-

matomata, reactive edema, and perhaps sometimes actual irritative processes in the periosteum of the ligaments as well; protracted muscle contraction was then the most common secondary cause. He regretted that none of these factors could be demonstrated roentgenologically.

FRANCK (1943) in 2,145 patients with back pain found 54 with a kissing spine as the cause of their symptoms, all of them having a marked tenderness on pressure between the affected spinous processes. Eleven of these were operated on; these patients had suffered repeated attacks of lumbago, especially on bending forward, and were resistant to every kind of expectant treatment. According to FAULON, LEGER & AHRAS, pressure on the spinous processes, or especially on the interspinous spaces, causes a more or less strong, however not constant, pain in 'interspinal nearthrosis', their name for 'kissing spine'. The roentgenologic examination offers the best diagnostic aid.

NEWMAN worked at a clinic dealing with backache where cases with infective or neoplastic signs had been eliminated. He considered that 20 per cent of the cases with pain in the lumbosacral area had symptoms deriving from rupture of the posterior ligaments of the spine, including sometimes the posterior longitudinal ligaments and annulus fibrosus. He established in these cases pain in the mid-line on palpation, either at the space between the spinous processes of the fifth lumbar and first sacral vertebrae, or between the fourth and fifth lumbar vertebrae. JOSEPH was of the opinion that deep, non-radiating, median low back pain, which he established in 60 of 805 lumbago cases, were caused by M. Baastrup. Pinching and tearing in the soft parts between the spinous processes were, in his opinion, the cause of the symptoms.

The expression 'ligament relaxation' was used by HACKETT (1957) as an idiom for pathologically altered ligaments, without any detailed verification of the more exact nature of these changes. He was of the opinion that this relaxation was the reason for the back pain in the majority of all his patients and, as previously mentioned, also of importance in the genesis of disk prolapse.

This review of the literature shows that there have been, in addition to the almost endless works not mentioned on the relation of intervertebral disks to low back pain and sciatica, investigators who have devoted themselves to studying the possible existence of another, chiefly ligamentous etiology of the clinical signs. The present writer has endeavoured to make the most of his material in this respect as well and in what follows records the procedure adopted in the investigation and the results achieved.

The first section comprises a comparison between the incidence of changes in the three lower interspinous ligaments in the control group and the cases with back pain. It was felt that a difference one way or the other between the groups in the incidence of ligament changes could provide an answer to the question of ligament damage being the causative agent of pain in the lumbar spine.

The mean age was considerably higher in the cases with back pain; this was due to the difficulty of finding older patients who had never had this symptom. In order to improve the comparability of the series only half the total of the 41—50-year group cases with back pain was taken into consideration, which means that the number of ligamentous changes was correspondingly reduced statistically. Occasional cases of a higher age were excluded in both groups.

	Total number of cases	Cases with ligamentous changes	%
Control cases . . . . .	39	21	54
Cases with back pain . . . . .	128	88	69

Table 15. Comparison between the incidence of ligament changes in the controls and the cases with back pain by age groups of proportional size.

The incidence of changes in the three lower lumbar interspinous ligaments shows a certain difference between cases with and without back pain, but the difference is not marked. The number of cases with ligamentous changes but without back pain is, however, surprisingly large. The simple fact that there are changes in the interspinous ligaments in the cases with back pain is consequently no indicator of the ligamentous character of the pain. At the same time this would be expected only in a small number of such cases. A typical example of freedom from symptoms despite disseminated ligamentous changes is seen in Fig. 26. The patient was a tall man of 24 who was a prominent athlete and a decathlon competitor. He was extremely agile and had an unusually flexible back and to assume ligament ruptures would occur was consequently not unreasonable. Yet he had never had any symptoms referable to the back. *There is thus no chance of showing a connection between low back pain and changes in the interspinous ligaments by purely roentgenologic means.*

It is nevertheless worth while considering the following clinical-roentgenologic approach. KELLGREN (1939) found that interspinous ligaments



Fig. 26 a) Complete rupture. A prominent athlete of 24, with very flexible back. Typical ligament ruptures in the L 3-4 and L 5-S 1 interspaces. No symptoms.

give rise to referred pain on intraligamentous injections of saline. This ligament pain is identical in character with the pain produced from muscle, a continuous ache felt deep in the limbs and trunk. The pain was segmental in nature and constant in its radius of distribution in repeated experiments. When the ligament between the L 4-5 spinous processes was injected, the pain was distributed over the buttock to the outer and anterior part of the thigh; and when the ligament between L 5 and S 1 spinous processes was injected the pain was felt from the buttock and outer side of the thigh and calf to the foot.

It was observed by BAASTRUP (1940) in many experiments in patients with spinous process lumbago that an injection of novocaine between the processes would stop an acute or chronic attack in the course of a few hours, while some tests with injections of this drug into the muscles where the pain was felt produced no relief. These observations and the good result of some operations on spinous processes in cases of chronic lumbago, with complete

or partial resection of the processes, seemed to BAASTRUP to indicate that the cause of pain was to be found in the processes or in the tissue between them. FRANCK, too, emphasized the result of novocaine injections and operated only in cases in which the injection had had a convincing effect in the form of cessation of the pain. FAULON, LEGER & AHRAS, on the other hand, did not place particularly great reliance on such injections and pointed out that the incorrect deposition of the fluid or its faulty diffusion, could lead to misinterpretations.

A sensation of pain arising from pressure over the interspinous interspace, so-called 'trigger-point pain', constituted according to HACKETT a strong indication of ligament relaxation and hence a pathologic ligament finding, and was suggestive of an etiologic connection between these changes and low back pain. He considered that he could confirm the diagnosis by means of a temporarily pain-killing local injection of an anaesthetic into the ligament; he treated a very large series of cases of this type with sclerosing injections and a curative effect was achieved in 82 per cent of them.

Twenty-three patients with lumbar symptoms which had earlier resisted therapy were treated by HVID ad modum HACKETT. Immediate and satisfactory relief of pain was produced in 17 cases by a tetrocaine injection into the interspinous ligament which was tender on palpation and considered to be the source of the pain. He achieved an excellent or good result for up to 2 years in 14 (82 per cent) of the cases. Sclerosing injections had no effect in 5 of the 6 cases which obtained no relief from pain from the anaesthetic injections.

In the majority of the present author's examinations of ligaments, pain was registered on palpation over the three lower interspinous spaces; this was not only at the beginning of the series. No pain was elicited in 135 cases, and 67 of these had normal ligaments. Sixty cases had pain on palpation over one or several interspinous spaces, and in this group only 19 cases had normal ligaments. Thus, if there was no pain on palpation, the interspinous ligaments were normal in every other case, but if the contrary was true only in barely every third case. These 60 cases with a pain response to palpation exhibited changes in 62 ligaments, whereas the 135 cases without pain on palpation had changes in 93 ligaments. Each comparison thus shows that *there is a certain connection between pain on palpation and changes in the lumbar interspinous ligaments.*

There is a very striking point which merits special emphasis. The 40 controls, none of whom had ever had any back pain, included only 3 patients who complained of pain on palpation over 4 interspinous spaces.

In spite of the small frequency of tenderness to palpation, this part of the material included 22 cases with roentgenologically verified changes in the interspinous ligaments. The corresponding figures for the cases with back pain were 155, 57 and 94. Against the 3 cases of tenderness on palpation among the 40 controls, there are 57 cases with tenderness on palpation among the 155 cases with back pain. This very marked difference in the ratio favours the assumption that *pain on palpation and back pain may have a common denominator, an etiologic connection, i. e. that the back pain in such cases arises from the region of the spinous process.*

A note was made in 46 of the cases as to whether anaesthesia prior to the injection of contrast medium eliminated the tenderness to palpation of the interspinous space. This was found to be so in 41 cases, leaving only 5 cases that failed to respond in this way. Thirteen of the cases that did respond were perfectly normal both roentgenologically and at operation, while only 2 of the 5 unresponsive cases were normal. The elimination of tenderness to palpation by injections of an anaesthetic agent before a ligamentography is thus no greater aid in differentiating between the presence of pathologic interspinous ligaments or their connection with back pain than the demonstration of tenderness on palpation. This does not rule out the possibility that intraligamentous injections may perhaps give more reliable information.

#### DISCUSSION

The very small incidence of pain on palpation in the control series constitutes strong evidence of a connection between pain on palpation and the back pain which was demonstrated in the rest of the series. Its localization speaks at the same time in favour of the assumption that the pain arises from the spinous region. When such pain was elicited over one of the three lower interspinous spaces, in about 50 per cent of the cases the underlying ligament was diseased, in 30 per cent of cases the underlying ligament was normal but an adjacent ligament pathologic, and in 20 per cent of cases the three lower interspinous ligaments were normal both at operation and roentgenologically.

Pain on palpation may thus be regarded as a more reliable indication that back pain arises from the region of the spinous processes than operative or roentgenologic demonstration of changes in the interspinous ligaments. It registers changes over a wider area and the pain-provoking pathologic process can be located in a tissue contiguous to the interspinous ligament.

One example of this is the area of insertion of the long dorsal muscles in the spinous processes.

It was consequently impossible to find a completely reliable method for diagnosing pain referable to the spinal region. The evidence of pain in response to palpation over the spinous interspaces, however, is probably a fairly reliable diagnostic aid. It may be concluded that in about half these cases a pathologic interspinous ligament is the cause of the pain; in other cases it probably arises from some adjacent tissue. *Ligamentography may be a differential diagnostic aid in cases of pain on palpation. Negative roentgenologic findings rule out a ligamentous mechanism of pain production with fair certainty. When, however, the roentgenologic findings are positive a ligamentous etiology of the pain is probable.*

## IX. SUMMARY AND CONCLUSIONS

This investigation was prompted by observations made in connection with disk operations. KALLIO frequently encountered changed ligaments in the two lower spinous interspaces while eliminating disk prolapse in the corresponding intervertebral spaces. These ligamentous changes were assumed to be of both theoretical and practical clinical significance in regard to the production of prolapse and low back pain.

This led RISSANEN to embark on his comprehensive examination of the lumbar supraspinous and interspinous ligaments of an autopsy material. The present author evolved a roentgenologic method for the demonstration of interspinous ligaments and the changes detectable in them. This method is reviewed and the roentgenologic findings in the different types of changes in the interspinous ligaments are analysed. The relationship between these changes and various anatomic and pathologic circumstances are considered.

The series consisted of 229 cases of which 189 had low back pain or sciatica; 40 with no history of back pain served as controls. It was not until the 51—60 year age group was reached that a distinct increase in the incidence of pathologic ligaments with advancing age was observed. Men displayed a higher incidence of ligamentous changes than women. Changes in the lumbosacral ligament were most common in the controls, while the L 4—5 ligament preponderated in the cases with back pain.

The posture of the lumbar spine appeared to affect the occurrence of changes in the three lower interspinous ligaments. As has been pointed out also by earlier investigators, changes were most common in the presence of marked lumbar lordosis, and the same was the case when the patient was capable of extending the lumbar spine vigorously. On the other hand the origination of ligament changes was not due to the height of the spinous process. Interspinous ligaments attached to displaced spinous processes were extremely frequently the sites of cavities and ruptures.

The minimum thickness of an interspinous ligament measure in the roentgenogram amounted to 4 mm; ligaments over 1 cm in thickness, however, were also fairly common. The L 3—4 ligament was thinner on the average than the ligaments closest to it caudally. Cavitation was most common in the thinnest ligaments in the L 3—4 interspace, whereas it was noticeably uniform in ligaments of differing thickness in the L 4—5 interspace.

Cavities, partial ruptures, complete ruptures and slack ligaments were the principal pathologic types that could be diagnosed roentgenologically and whose roentgenologic characteristics could be described in detail. These various types of changes differed little from one another and to some extent occurred concomitantly in the ligaments. The result may be the cause of difficulties in roentgenologic interpretation in either case, but they appear to have no practical significance.

No correlation could be shown between disk degeneration and the changes in the interspinous ligaments which also are of a degenerative character. Thus, these degenerative changes apparently have a divergent etiology. Prolapse of a disk and changes in the interspinous ligament at the same level were established in 40 per cent of the prolapses. This incidence is of the same magnitude as prolapse and a normal ligament or prolapse and a changed heterologous ligament and consequently does not support the earlier hypothesis of a causal connection between prolapse and pathologic ligament. It was possible, on the other hand, to demonstrate a certain connection between trauma of the lumbar spine and changes in the three lower interspinous ligaments.

Finally, the relationship between the changes in the three lower interspinous ligaments and low back pain was analysed. It revealed that after the control series and the cases with back pain had been adjusted to achieve comparability as regards age, the incidence of pathologic ligaments was higher in the latter group. However, every other symptom-free back was the site of ligamentous changes, evidence that a positive roentgenologic diagnosis and low back pain cannot be equated.

Tenderness on palpation over the three lower interspinous ligaments was elicited very rarely in the controls, but every third case with back pain reported painful sensations in response to palpation of an interspinous space; the underlying ligament was pathologic in half these cases. Tenderness to palpation therefore appears to be an indication of low back pain arising from the spinous processes. Pain was assumed to emanate e.g. from the sites of insertion of the long dorsal muscles in the spinous processes, but its interspinous-ligamentous etiology also seemed to be a factor to be considered. The significance of negative ligamentography in the differential diagnosis is emphasized and a certain clinical importance is accorded to positive roentgenologic findings.

#### ACKNOWLEDGEMENTS

The present work was supported by grants from the Sigrid Juselius Foundation to which my very best thanks are due.

## REFERENCES

- BAASTRUP, C. I.: On the spinous processes of the lumbar vertebrae and the soft tissues between them, and on pathological changes in that region. *Acta radiol.* 14 (1933), 52.
- Proc. spin. vert. lumb. und einige zwischen diesen liegende Gelenkbildungen mit pathologischen Prozessen in dieser Region. *Fortschr. Röntgenstr.* 48 (1933 b), 430.
- The diagnosis and roentgen treatment of certain forms of lumbago. *Acta radiol.* 21 (1940), 151.
- BJÖRKRÖTH, T.: Die subcutane Ruptur der distalen Sehne des Musculus biceps brachii. *Acta chir. Scandinav.* 89 (1943), 30.
- BRAILS福德, J.: Deformities of the lumbo-sacral region of the spine. *Brit. J. Surg.* 16 (1928—29), 562.
- BURCKHARDT, H.: Über Spondylitis (Spondylosis) deformans. *Med. Klin.* 30 (1934), 1349.
- COMROE, B. I.: *Arthritis*. Lea and Febiger, 1953.
- DAVIDSSON, L.: Über die subcutanen Sehnenrupturen und die Regeneration der Sehne. *Ann. chir. et gynæc. Fenniae.* 45, Suppl. 6, 1956.
- FAULON, L., LEGER, L. & AHRAS, A.: La lombalgie par néarthrose inter-épineuse. *Presse méd.* (1949), 34.
- FICK, R.: *Handbuch der Anatomie und Mechanik der Gelenke*. In *Handbuch der Anatomie des Menschen* ed. by Bardeleben Band II, 1, Teil 1, Fischer, Jena (1904).
- FLOYD, W. F. & SILVER, P. H. S.: Function of erectores spinae in flexion of the trunk. *Lancet* 260 (1951), 133.
- FRANCK, S.: Surgical treatment of interspinal osteoarthritis («kissing spine»). *Acta orthop. Scandinav.* 14 (1943), 127.
- FRIBERG, S. & HIRSCH, C.: Anatomical and clinical studies on lumbar disc degeneration. *Acta orthop. Scandinav.* 19 (1949), 222.
- HACKETT, G. S.: *Joint ligament relaxation treated by fibro-osseous proliferation*. II Edit. Charles C Thomas, Springfield, 1957.
- JOSEPHANS, G.: Kreuzschmerzen bei Dornfortsatzveränderungen. *Ztschr. Rheumaforsch.* 13, (1954), 361.
- KALLIO, K. E.: Syndrome of ruptured interspinous ligament and its repair by use of free skin graft. *J. Bone & Joint. Surg.* 42—B (1960), 403.
- Rupture of the lumbar interspinous ligament, diagnosed by contrast medium x-ray and reconstructed by free cutis graft. *Bulletin of the hospital for joint diseases*, vol. 21, N:o 2, 198.
- KELLGREN, J. H.: On the distribution of pain arising from deep somatic structures. *Clin. Sc.* 4 (1939), 35.

- KETTUNEN, K. O.: Skin arthroplasty in the light of animal experiments with special reference to functional metaplasia of connective tissue. *Acta orthop. Scandinav. Suppl.* 29, 1958.
- KOPSTEIN, G.: Knochenbefunde bei Kreuzschmerzen. *Fortschr. Röntgenstr.* 56 (1937), 2 Beiheft, 14.
- KROMPECHER, S. & GOERTTLER, K.: Die Grundlagen einer experimentellen Gelenkbildung. *Anat. Anz.* 87 (1938), 43.
- LEWIT, K.: Deviation of the spinous processes. *Brit. J. Radiol.* 30 (1957), 162.
- LUSCHKA, H.: Die Halbgelenke des menschlichen Körpers. Berlin, 1858.
- MAGNUSON, P. B.: Differential diagnosis of causes of pain in the lower back accompanied by sciatic pain. *Ann. Surg.* 119 (1944), 878.
- MAYER (Bonn) *Zit. Baastrup Fortschr. Röntgenstr.* (1933 b).
- NEWMAN, P. H.: Sprung back. *J. Bone & Joint. Surg.* 34-B (1952), 30.
- ORELL, S. R.: Till senrupturernas patologiska anatomi. *Nord. med.* 60 (1958), 1285.
- REINHARDT, K.: Beitrag zur Baastrupschen Krankheit. *Deutsche med. Wchnschr.* 76 (1951), 363.
- RISSANEN, P. M.: The surgical anatomy and pathology of the supraspinous and interspinous ligaments of the lumbar spine with special reference to ligament ruptures. *Acta orthop. Scandinav. Suppl.* 46, 1960.
- SCAPINELLI, R.: Caratteri strutturali di ligamenti interspinosi dell'uomo con particolare riguardo alle loro inserzioni. *Società emiliana romangola triveneta di ortopedia e traumatologia.* Vol. III fasc. II (1958), 493.
- SCHMORL, G. & JUNGHANNS, H.: Die gesunde und die kranke Wirbelsäule in Röntgenbild und Klinik. Thieme, Stuttgart, 1957.
- SCHUMANN, W. & TRAUTMANN, J.: Über röntgenologisch fassbare Veränderungen an den Lendenwirbeldornfortsätzen und ihre Bedeutung für die Pathogenese des Kreuzschmerzes. *Fortschr. Röntgenstr.* 76 (1952), 579.
- SPALTEHOLZ, W.: *Handatlas der Anatomie des Menschen* I. 12 Aufl. S. Hirzel, Leipzig, 1929.
- STEHR, L.: Lendenlordose und Kreuzschmerzen. *Arch. f. orthop. u. Unfall-Chir.* 38 (1937), 514.
- WINDHOLZ, F.: In discussion 2. Tagung der Österreich. Gesellschaft für Röntgenkunde und Strahlenforschung, Wien 1937. *Fortschr. Röntgenstr.* 56 (1937), 2. Beiheft, 15.
- YAMADA, K., NISHIWAKI, I. & YASUKAVA, H.: Supplemental study upon the pathogenesis of low back pain in Baastrup's disease. *Arch. Jap. Chir.* 23 (1954), 384.