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# THE SURGICAL ANATOMY AND PATHOLOGY OF THE SUPRASPINOUS AND INTERSPINOUS LIGAMENTS OF THE LUMBAR SPINE WITH SPECIAL REFERENCE TO LIGAMENT RUPTURES

BY

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# PREFACE

The subject of the present study was suggested by my esteemed teacher, Professor K. E. Kallio, Chief of the First Surgical Clinic (for Orthopedics and Traumatology), Central Hospital, University of Helsinki. He has from the outset followed the progress of my work with great interest and given invaluable counsel. I am happy to have this opportunity of expressing my deep gratitude and sincere appreciation to Professor Kallio.

I am greatly indebted also to my respected teacher, Professor U. Uotila, Chief of the Department of Forensic Medicine, University of Helsinki, who kindly made available to me the autopsy material, laboratories for microscopic preparations, facilities and equipment of his institute. He has always been ready with valuable and very helpful advice and criticism.

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# I. INTRODUCTION

For many years Professor K. E. KALLIO has drawn attention in his operations for prolapse of the disc to the interspinous ligaments between the spinous processes. Since autumn 1957 he has noted that clearly discernible changes in the interspinous ligaments are almost invariably present in cases of prolapse of the intervertebral disc. In some cases there is a definite defect, in others the ligament is completely flaccid when pressed with a sound. A search of the literature for accounts of the anatomy of normal interspinous ligament turned up very conflicting ideas on the subject. Interspinous ligaments have generally been conceived as thin membranes, but opinions vary regarding the course of the fibre bundles. RICHTER (1836) claimed that they usually run horizontally, FICK (1904) diagonally in an antero-superior — postero-inferior direction, KAJAVA (1911) postero-superior — antero-inferior, and WOERDEMAN (1955) vertically from the inferior margin of the superior spinous process to the superior margin of the inferior spinous process. TANDLER (1926) said that the fibre bundles in the interspinous ligaments formed a U-shaped pattern open dorsally. There was no information on whether defects can occur congenitally in these ligaments.

Opinions concerning the supraspinous ligament were also very divergent. Most workers, e.g. ARNOLD (1845), described it as strong tendinous fasciculus which terminates in the crista sacralis media. The supraspinous ligament was understood by GEGENBAUR (1885) and other workers to be nothing more than the thickened posterior margin of interspinous ligaments. SAPPEY (1888) asserted that there was no true supraspinous ligament in the lumbar region as a whole, and VALENTI (1920) claimed that this ligament was absent throughout the thoracic and lumbar regions.

As the views about these ligaments are conflicting, and as the lower part of the lumbar spine is surgically very important, a more detailed clarification of the anatomy of these ligaments seems to be required. Professor KALLIO therefore suggested that the present author investigate the anatomy and pathology of the interspinous ligaments and the supraspinous ligament of the lumbar spine as a doctoral dissertation.

## II. ANATOMICAL PRINCIPLES

The lumbar region of the human back is characterised by the strength of the vertebrae and their processes, which constitute its structural framework, and by the large muscular masses which take origin from or have their attachment partly in the spinous and transverse processes, partly in the pelvic and thoracic bones. Immediately under the skin and the subcutaneous fatty layer is the strong superficial lamina of the lumbodorsal fascia which connects with the spinous processes of the lumbar vertebrae and with the crista sacralis media and gives origin to the musculus latissimus dorsi. Below this is the even thicker aponeurosis of the musculus longissimus dorsi which arises in the same way from the spinous processes of the lumbar vertebrae and from the sacral crest. In the next layer is the strong musculus multifidus the fibres of which pass from the transverse processes of the vertebrae and extend across 1—3 vertebrae, passing to the inferior margin of the tip of the spinous process. On its medial aspect, between the spinous processes, lie the weak musculi interspinales. These bilateral muscle groups and aponeuroses are separated by the neural arches and the interjacent ligamenta flava, spinous processes, interspinous ligaments (= membranae interspinales, ligamenta spino-spinosa lata, ligamenta interspinalia I.N.A. -35) and the supraspinous ligament (= ligamentum apicum, ligamentum spino-spinoso rotunda, ligamentum quo apices vertebrarum connectuntur, ligamentum apicum processuum spinosorum, ligamentum supraspinale I.N.A. -35).

## III. PROBLEMS

Defects have been observed in the interspinous ligaments during operations. The literature does not help in deciding whether these defects can be of congenital origin. In addition, highly divergent and conflicting opinions have been expressed concerning the anatomy of supraspinous and interspinous ligaments. Nor is it known whether these ligaments undergo certain changes with age. The literature contains some data based on clinical observations of the rupture of supra- and interspinous ligaments, but there are no concrete accurate descriptions. The present study therefore aims to answer the following questions:

— What is the structure of normal interspinous ligament in the region of the lumbar spine?
— What is the structure of normal supraspinous ligament in the region of the lumbar spine?
— Are congenital defects possible in the interspinous ligaments of persons with a normal spine?
— What macroscopic and microscopic changes take place during life in the supra- and interspinous ligaments of the lumbar region?
— Are signs of rupture to be found in these ligaments?

## IV. MATERIAL AND METHODS

Autopsy material was used for the present work. The greatest part of it was obtained from the Department of Forensic Medicine, University of Helsinki. As most of the cases autopsied there are sudden, unexpected fatalities, suicides and murders, the present material should have the advantage of representing a cross section of the ordinary population. A smaller part of the material was received from the Department of Pathology and Anatomy, University of Helsinki, Children's Clinic, Central Hospital, University of Helsinki and the Section of Embryology, Department of Anatomy, University of Helsinki. Cases of violence to the pelvic region and the back or of operations affecting the back were not accepted for the material.

The material consisted of a total of 306 cases, 115 female and 191 male. The age distribution was as follows:

| Embryos and fetuses | Number | | Number |
|---|---|---|---|
| III—IX fetal month | 13 | 41—50 years | 31 |
| 0—1 year | 70 | 51—60 » | 29 |
| 1—10 years | 31 | 61—70 » | 31 |
| 11—20 » | 12 | 71—80 » | 29 |
| 21—30 » | 21 | 81—90 » | 10 |
| 31—40 » | 29 | | |

Anatomical study of the ligaments of the lumbar spine calls for careful preparation. This is very laborious in a cadaver and also so time-consuming as to be impossible if normal work was to continue in the institutes from which the present author obtained his material. The following method was therefore employed: With the dead body lying back upwards, a medial skin incision was made from the level of the lowest thoracic vertebrae to the sacrum. Using various instruments, the author removed a tissue sample covering the spinous processes as far as the neural arch, the interjacent ligaments and, on both sides of the row of spinous processes, the fascias, aponeuroses and muscles for c. 4—5 cm from the last thoracic vertebra to the crista sacralis media. With this method the ligaments examined suffered no damage in the handling phase.

The tissue sample thus obtained was pinned to a board with the sides of the spinous processes pointing upwards. The interspinous ligaments were prepared first. For examination of the supraspinous ligament the author then cut the spinous processes c. 1/3 of the distance from the tip and fastened the preparation thus obtained with the supraspinous ligament and the tips of the spinous processes upward on the baseplate. This was a relatively easy method of exposing every ligamentous system with all its details and of obtaining a correct idea of their relation to one another and thwir environment. A stereomicroscope was used in the work.

The crista sacralis media was taken as the fixed point in counting the vertebrae. According to RAUBER-KOPSCH, c. 8 per cent of men have only 4 lumbar vertebrae and every twentieth vertebra has ribs. This was disregarded in the present investigation and it was assumed that every individual has 5 lumbar vertebrae, the vertebra immediately cranially from the sacrum being taken as the fifth lumbar vertebra.

The gross examination was always made from a preparation which had received no previous treatment. The time from death to the time of preparation ranged from 1 to 3 days. The sections for microscopic study were placed in 10 per cent neutral formalin immediately after preparation.

A great number of the samples included bone and had to be decalcified after fixation. Some of the preparations were treated with the EDTA method (ethylene-diamine-tetra-acetic acid, disodium salt, DOTTI et al. 1951, SREEBNY & NIKIFORUK 1951, HAHN & REYGADAS 1951, BIRGE & IMHOFF 1952, HILLEMAN & LEE 1953) at 37° C temperature; the pH of the solution was 7.2—7.4. The advantage of this method was successful histochemical staining procedures for the samples (SCHAJOWICS & CABRINI 1956). Its drawback, however, was the time it consumed. A part of the preparations was decalcified with a mixture of sodium formate and formic acid (LILLIE 1954). Sections, c. 5 $\mu$ thick, were made mostly in the sagittal, frontal and horizontal planes from different parts of the ligaments. They were first stained routinely by Weigert-van Gieson's method (ROMEIS 1948). The following staining methods and procedures were then used for various purposes: Weigert-Hart resorcin-fuchsin staining for elastic fibres (MOVAT 1955), Sudan IV staining for fats (GATENBY & PAINTER 1946), Kossa's silver staining to demonstrate calcium salts possibly present in the tissues (ROMEIS 1948).

To establish the degenerative changes occurring in the ligaments, the histochemical methods used were toluidine blue, Alcian blue and periodic-acid-Schiff (P.A.S.)

Toluidine blue staining was performed with 0.05 per cent aqueous solution of the dye, pH 5.0, for 16 hours, after which the sections were given one quick rinsing in 96 per cent alcohol and then rinsed three times in absolute ethyl alcohol. Alcian blue staining was carried out according to LISON (1954).

Hyaluronidases decompose some acid mucopolysaccharides. To establish the role of the mucopolysaccharides broken down by them in the formation of dyes, the author treated some of the preparations with testicular hyaluronidase ("RONDASE", Evans Medical Supplies Ltd, 1 mg/ml in 0.85 per cent saline) prior to toluidine blue and Alcian blue staining. The sections were incubated for 3 hours at 37°C in a thermostat (PEARSE 1960) and the control series in a corresponding solution without enzyme for 3 hours at 37°C.

The periodic-acid-Schiff (P.A.S.) staining was performed according to McMANUS (1948). As glycogen also causes a P.A.S. — positive reaction, a part of the sections were treated with a 1 per cent diastase solution ("DIASTASE", E. Merck AG.) for 2 hours at room temperature before staining (GRAUMANN & CLAUSS 1959), and the control series were kept for the same time in a comparable solution without enzyme.

The quantitative method used to study the structure of the interspinous ligaments was UOTILA's histoquantitative method. The procedure is, briefly: A microscopic section is taken from the tissue and suitably stained. The microscopic slide is placed in a projector constructed for the purpose. It throws an image of a part of the preparation on the table top underneath. An arbitrary number of segments of a line of arbitrary direction is plotted and the proportion of different tissue components in terms of millimetres is counted from the microscopic image projected on them. The proportion of each tissue in the total of tissues can be calculated from the results. The mathematical bases of the method have been explained by UOTILA (1940). The method was later supplemented by UOTILA & KANNAS (1952), TALA (1952), ISOTALO, LÖFGREN & UOTILA (1955), and many other authors. TALA was the first to use a method in which, in order to speed up the work, a note is made on the lines drawn on paper at the projection plane of the proportions of the different tissues in letters and the segments of line are later measured in a light room. The present author employed this modification in his work.

# V. THE SUPRASPINOUS LIGAMENT IN THE REGION OF THE LUMBAR SPINE

## A. MACROSCOPIC ANATOMY

*Earlier investigations:* Very many investigators have reviewed the anatomy of the supraspinous ligament, although usually in fairly summary form. RICHTER (1836) described it as a thin, fairly long band which, bounded by the interspinous ligaments, passes from one tip of the spinous process to another and constitutes a continuous bond of union between them.

SÖMMERRING (1839) stated that the supraspinous ligament was reinforced by the tendons of the dorsal extensor which fuse with it or even constitute its main component. ARNOLD (1845) described the supraspinous ligament as a strong tendinous band which takes origin from the protuberantia occipitalis externa, passes across the tips of all the spinous processes right to the inferior end of the crista sacralis media from which its fibres extend further to the posterior surface of the coccyx.

Nothing new was introduced by OESTERREICHER (1845). D'ALTON (1850) claimed that the interspinous ligaments change imperceptibly into supraspinous ligament which is seen flaccid and round between the different spinous processes.

Supraspinous ligament was stated by JAMAIN (1853), DURSY (1863) and FAU (1865) to terminate in the crista sacralis media. The same view was held by HOLLSTEIN (1865) who described the supraspinous ligament as being strengthened in the region of the lumbar spine by the fibrous bands which run only from one spinous process to another and touch the interspinous ligaments between them. AEBY (1868) suggested that the fibres passing from the interspinous ligaments continue beyond the tips of the spinous processes and merge with the supraspinous ligament which then disappears gradually on passing downwards. This author did not describe more accurately the site of termination of the ligament. Nothing new was contributed by MOYNAC (1880), TILLAUX (1880), BEAUNIS & BOUCHARD (1885). GEGENBAUR (1885) and HEITZMANN (1886) said that the supraspinous ligament was merely the thickened posterior margin of interspinous ligaments.

Completely different from all other opinions concerning the supraspinous ligament was the view postulated by SAPPEY (1888). He held that there is no true supraspinous ligament in the whole lumbar region, but only a tendinous raphe of the tendons and aponeuroses of the dorsal muscles which is its ostensible replacement.

FICK (1904) advanced the opinion that the supraspinous ligament is divided into several layers, the most superficial extending across 3—4 vertebrae, the midmost over 2—3 vertebrae and the deepest, finally binding together 2 adjacent vertebrae. HENLE (1901), BREITENSTEIN (1906), SOBOTTA (1907), STRASSER (1908), SCHMIDT (1909), KAJAVA (1911) and BORN (1913) introduced nothing new. It was suggested by VALENTI (1920) that the supraspinous ligament in the thoracic and lumbar regions as a whole is only a tendinous raphe made up of the dorsal muscles. ROUVIERE (1924), on the other hand, stated that the supraspinous ligament was united in the lumbar region with the tendinous raphe of the dorsal muscles.

It was asserted by BUCHANAN (1925) and TANDLER (1926) that the supraspinous ligament extends to the sacrum. The same view was held by BLUMBERG (1926), TESTUT & JACOB (1929), ROUVIERE (1930), BROMAN (1931), KADANOFF (1934), OKAJIMA (1934), SIEGLBAUER (1940), RAUBER-KOPSCH (1941), HEPBURN (1943), GRAY (1944), TERRY (1944), MARSHALL & LAZIER (1946), CUNNINGHAM (1947), CALLANDER (1948) and KIMBER et al. (1948).

BENNINGHOFF (1949) said that the supraspinous ligament is a fibrous band which seems to pass from tip to tip of the spinous processes. Nothing new emerged from the studies of TÖNDURY (1949), ANSON (1950), EDVARDS (1950), FRANCIS & KNOWLTON (1950), MAISSONNET & COUDANE (1950), TOLDT-HOCHSTETTER (1951), GRANT (1952), HAFFERL (1953), SOBOTTA (1953), SPALTEHOLZ (1953), WALDEYER (1953), BRAUS-ELZE (1954), WOERDEMAN (1955), HAMILTON (1956), LAST (1956) and WOODBURNE (1957).

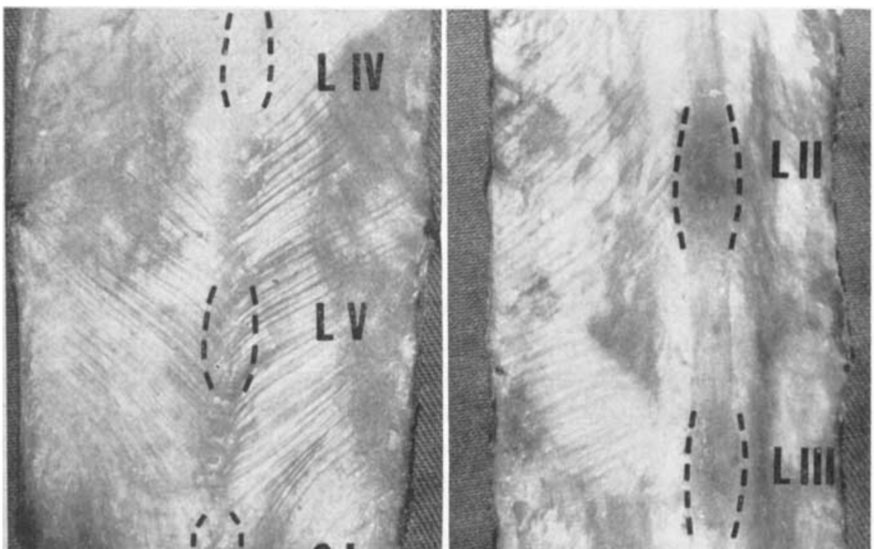
The views of the nature of the supraspinous ligament are thus very divergent. The majority of workers state that it terminates in the crista sacralis media. Opinions differing from this are that there is no true supraspinous ligament in the lumbar region at all (SAPPEY 1888, VALENTI 1920) and that the supraspinous ligament gradually disappears on advancing in the caudal direction (AEBY 1868).

## Own investigations

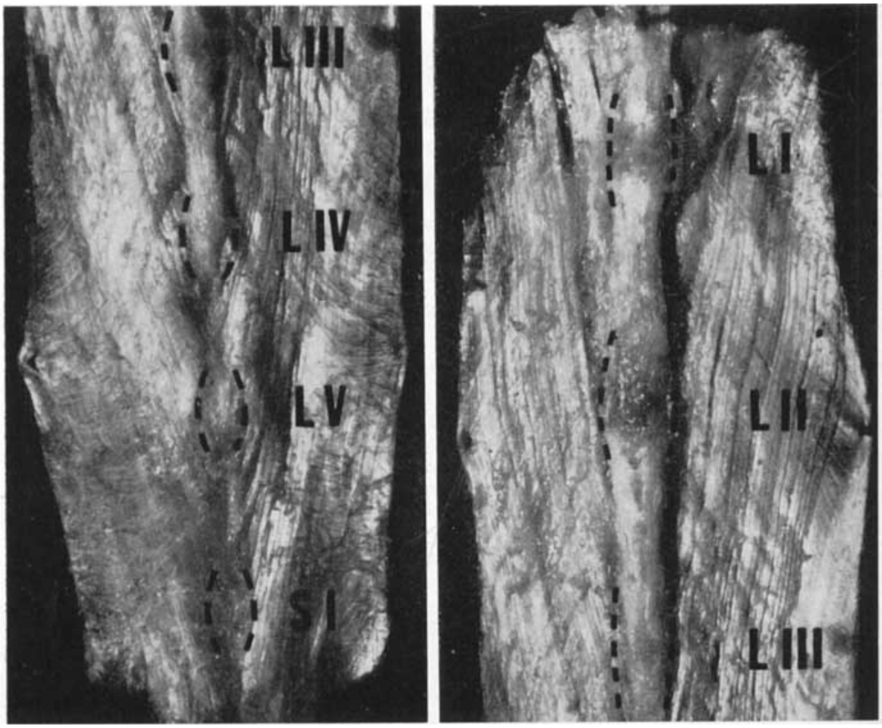
Two adjacent spinous processes and neural arches are connected by a powerful ligamentous system the different parts of which are closely connected and merge into one another without leaving a distinct boundary. The part which joins the tips of the spinous processes is called the supraspinous ligament.

The supraspinous ligament examined by the present author is a direct continuation of the ligament of the same name in the thoracic region. Three different parts can be distinguished in the supraspinous ligament of the lumbar region:

(1) The superficial layer. It lies most dorsally above the superficial lamina of the lumbodorsal fascia although the lowest fibrous layers are partly interwined tightly with it (Fig. 2). This part of the ligament consists of long, slender fibre bundles which run across 3—4 successive spinous processes, attaching itself to every tip during its passage. It is in this part of the supraspinous ligament that the greatest variations in strength are




*Figs. 1 and 2: A man of 59. Lumbar part of the back on the midline after the removal of skin and subcutaneous fat, with the fascia lumbodorsalis most superficial. Fig. 1 shows the region LIV—SI with no supraspinous ligament. Fig. 2 shows, between LII and LIII, a distinct and strong supraspinous ligament. It is already considerably weaker between LIII and LIV.*




*Figs. 3 and 4: The fascia lumbodorsalis has been removed from the preparations shown in Figs. 1 and 2. The aponeurosis of the longissimus muscle is uppermost. Fig. 3 shows that the supraspinous ligament ends in LIV. Fig. 4 shows a strengthening of the supraspinous ligament in the cranial direction.*

found. It may be a relatively robust, roundish band, width 5—6 mm even and thickness 3—4 mm, in which case it is very easy to expose; but it may also consist merely of a few extremely thin fibrous bundles which can be exposed only after careful work. The latter cases are considerably rarer than the former. Intermediate forms between the two extremes are the most common.

(2) The midmost layer. A characteristic feature of this layer is that the fibrous bands which generally pass across 2—3 spinous processes are very markedly interwined with the superficial lamina of the fascia lumbodorsalis and partly also with the fibrous bands emerging from the aponeurosis of the musculus longissimus dorsi and the tendons of the musculus multifidus (Figs. 3 and 4). This part of the ligament is usually thin, often around 1 mm.

(3) A deep layer which is clearly the strongest of all (Figs. 3 and 4). While notable individual variations in strength are observable, especially

in the superficial layer, in this part they are few. The deepest layer consists of fibrous bundles which join the tips of two adjacent spinous processes only and thus do not extend beyond the tip of a single spinous process. Very strong fibrous bundles lead into this part from the aponeurosis of the longissimus muscle. In the cranial parts of the lumbar region this aponeurosis is often made up of rough fibrous bundles, sometimes slightly removed from one another, which are joined in the transverse direction only by thin membranes. The bulk of these bundles are attached to the tips of the spinous processes themselves, but others continue between them to strengthen the supraspinous ligament. The framework in this deepest layer of the ligament, however, is always made up of strong fibrous bundles which pass straight from one spinous process tip to another. They are reinforced from the tendon of the musculus multifidus which, coming diagonally from the caudal direction, attaches itself to the tips of the spinous processes. This tendon, which reinforces the deep-lying part of the ligament, has a role which varies very considerably individually. Sometimes a great part of the tendon of the musculus multifidus is attached to the supraspinous ligament, in which case its role is naturally appreciable.

The deep layer of the supraspinous ligament is ventrally in direct contact with the interspinous ligaments, and these derive their origin partly from the supraspinous ligament. It is therefore difficult both macroscopically and microscopically to draw the line between them. Fibrous bundles depart from here and, moving caudally and ventrally, attach themselves to the upper margin of the inferior spinous process bounding the interspinous space. They thus constitute a certain part of the interspinous ligament, which will be discussed in greater detail in connection with this ligamentous system.

The three parts described are no separate entities. The separation was artificial, based partly on the length and course of the fibre bundles, partly on the fibres entering from the sides from other tendons and aponeuroses. Together, they constitute a very strong band which joins effectively the tips of the spinous processes and prevents them from moving too far apart during ventral flexion of the spine. Thus the most important task of the supraspinous ligament is perhaps to limit ventral flexion of the spine, for which it is indeed very efficacious attached as it is to the tip of the spinous process which functions as a lever arm. The tasks of this ligament include in part the function of origin and exit for some muscles.

The supraspinous ligament is circumscribed distinctly and sharply in the dorsal direction only. In the other directions it is considerably less defined. The width and thickness of this ligament are therefore impossible to measure exactly. The thickness averages 5—7 mm in the antero-posterior direction, whereas c. 6—8 mm can be regarded as the average width, depending on the thickness of the spinous processes.

It was stated earlier that the supraspinous ligament is a strong tie. This only applies, however, to the ligament in the superior part of the lumbar spine. Moving caudally, the tie gets thinner. It was seen in the review of the literature that the supraspinous ligament has generally been believed to extend in the caudal direction up to the crista sacralis media. This is not the true state of affairs. The present author prepared this ligamentous system carefully in 100 cases and in 73 per cent of them the supraspinous ligament ended in LIV, in 22 per cent in LIII and in 5 per cent in LV. The criterion applied was that if a single longitudinal fibrous bundle was established running from the tip of one spinous process to another the ligament still existed.

If this is accepted, the supraspinous ligament never extends to the sacral crest. It must be noted, moreover, that the last space in which the ligament is encountered is almost always considerably weaker than the other spaces. Figs. 1—4 illustrate the situation. Figs. 1 and 2 show the lumbar part of the back on the median line after the removal of skin and subcutaneous fat, leaving the fascia lumbodorsalis most superficial. In Fig. 1 is seen the region from the tip of the spinous process of LIV to the tip of the spinous process of SI. It appears clearly from the illustration that no fibres belonging to the supraspinous ligament can be demonstrated in this area. In Fig. 2 the LII—LIII space is the most easily distinguishable, revealing a distinct and beautiful supraspinous ligament. The ligament is much thinner and weaker by the time it reaches the LIII—LIV space. Figs. 3 and 4 show the same preparation with the fascia lumbodorsalis removed. The aponeurosis of the musculus longissimus dorsi is closest to the surface. There is no supraspinous ligament in the LIV—SI spaces and the band terminates in the tip of the spinous process of LIV, as can be seen clearly in Fig. 3. Fig. 4 shows the LI—LIV area where the supraspinous ligament is much stronger in the superior than in the inferior lumbar region.

There is thus no supraspinous ligament in the lowest lumbar spaces. This area has only a tendinous raphe which originates at the crossing of the fibrous bundles from both sides of the aponeurosis of the musculus longissimus dorsi. This tendinous raphe, on the median line, is joined on the dorsal aspect considerably more loosely by the superficial lamina of the fascia lumbodorsalis. If the preparation is made so that the fascia and aponeurosis are severed right at the tips of the spinous processes when exposing the ligaments it is possible to bring out even a thick tendinous band which can easily be mistaken for supraspinous ligament. However, it is merely the tendinous raphe mentioned. The same fibre bundles of the longissimus that constitute this raphe extend, partly unbounded, ventrally beyond the tip of the spinous process in a winding course and form the most dorsal part of the corresponding interspinous ligament. There are no fibrous bundles here directly connecting the tips of the spinous processes. Even the fibrous bundles of the longissimus which are in direct contact with the tip of the spinous process end either in the tendinous raphe midway between the tips of the spinous processes or turn ventrally to form the interspinous ligament. Again, however, there are no fibre bundles among them directly connecting the tips of the spinous processes.

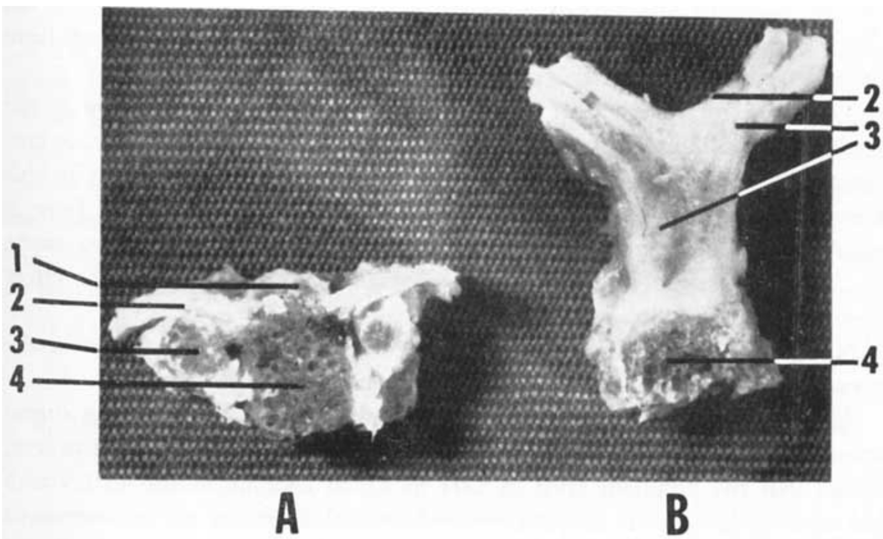



*Fig. 5: Horizontal section of the tips of the spinous processes with attached soft parts: (A) spinous process of LII, (B) spinous process of LV. 1 = supraspinous ligament, 2 = fascia lumbodorsalis, 3 = fibre bundles of the aponeurosis of the musculus longissimus dorsi, 4 = tip of the sectioned spinous process.*

Fig. 5 shows two preparations typical of horizontal sections from the tips of the spinous processes of LII and LV, inclusive of the soft parts attaching to them. Preparation A, the tip of LII, shows as a distinct elevation the supraspinous ligament immediately above the bone and, on both sides of it, the fascia lumbodorsalis which is attached directly to the bone. On both sides of the spinous process are strong fibre bundles of the aponeurosis of the musculus longissimus dorsi. Preparation B, the tip of LV, shows extremely great differences compared with A. The supraspinous ligament is missing, and topmost there is only the fascia lumbodorsalis.

It is interesting to see that unlike the spinous process of LII it is not attached directly to the bone but forms a loose attachment with the aponeurosis of the musculus longissimus dorsi and with the tendinous raphe formed by its criss-crossing fibrous bundles. This observation can always be made even when the fascia is very easily detached from its base in making the preparation. It will also be seen from the illustration how the fibre bundles of the aponeurosis of the longissimus lie exclusively in the tip of the spinous process, forming a fairly high column of roughly its size in which only the lowest layers are in direct contact with bone. Three important changes have consequently taken place in this interval: (1) the supraspinous ligament has disappeared, (2) the fascia lumbodorsalis has lost its point of attachment with the tip of the spinous process, (3) the fibre bundles of the aponeurosis of musculus longissimus dorsi have moved from the side of the spinous process to its tip.

The direct attachment of the fascia lumbodorsalis to the bone at the tips of the spinous processes near the superior lumbar vertebrae, serves essentially to reinforce the function of the supraspinous ligament in this area. In the inferior parts of the lumbar region the attachment to bone is missing, replaced simply by a loose connection with the tendinous raphe of the aponeurosis. The fascia lumbodorsalis thus cannot have the effect here that it has in the upper spaces.

No changes clearly demonstrable to the naked eye were found in the present material in the supraspinous ligament during life.

*Discussion:* The most common view in the literature is that the supraspinous ligament extends to the sacrum. The present author, however, found that the ligament ends in LIII in 22, in LIV in 73 and in LV in 5 per cent of his cases. As the deep and central layers of the supraspinous ligament interwine closely with the tendons and aponeuroses of the dorsal muscles to form a uniform band their preparation requires extreme care. If the ligaments are exposed first by severing the fascia and aponeurosis down the side of the spinous processes, a fibrous band is elicited in which it is very difficult to distinguish between the bundles of the supraspinous ligament and those of the tendons of the dorsal muscles. It is therefore understandable that unless special attention is paid to the lower parts of the lumbar spine the tendinous raphe of the dorsal muscles there can be mistaken for the supraspinous ligament. Again, if the superficial layer of the ligament is poorly developed the supraspinous ligament may appear to be completely missing on superficial examination.

The articular surfaces of the articular processes of the lumbar vertebrae are in an almost sagittal plane. Consequently, the principal movement of the vertebrae is forward and backward bending and the axis of the movement is parallel to a straight line running through the middle points of the articular surfaces of both sides. According to STRASSER (1908) and FICK (1911), however, the axis of the principal movement runs more ventrally, close to the centre of the intervertebral disc. The spinous processes thus form a dorsal lever arm and the supraspinous ligament attached to their tips constitutes the most effective limitation to excessive ventral flexion. This ligament is absent in the lower parts of the lumbar spine. The tendinous raphe, which has no fibres directly connecting the tips of the spinous processes, is incapable of replacing the supraspinous ligament. Hence the lower part of the lumbar spine is weaker in this respect than the upper part.

*Summary: Three different parts can be distinguished grossly in the supraspinous ligament: (1) the superficial layer in which the fibres extend across 3—4 spinous processes, (2) the midmost layer in which the fibres extend across 2—3 spinous processes and (3) the deep layer in which the fibres connect only two adjacent spinous processes. The midmost and the deep layer are interwined with the tendons and aponeuroses of the dorsal muscles. The ligament ended in LIII in 22, in LIV in 73 and in LV in 5 per cent of the samples. It never extended as far as the sacrum. In the lowest lumbar spaces there is only the tendinous raphe of the dorsal muscles. There are no direct fibrous connections between the tips of the spinous processes.*

## B. MICROSCOPIC ANATOMY AND CHANGES OCCURRING WITH AGE

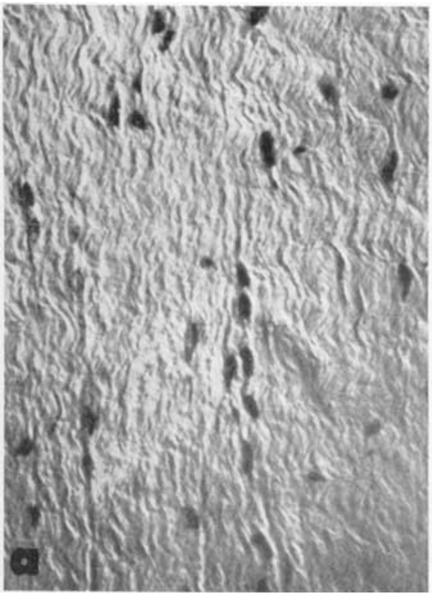
*Earlier investigations:* There are only few reports in the literature on the microscopic anatomy of the supraspinous ligament. Most workers have contented themselves with macroscopic examination only. FICK (1904) stated that the deepest layers of the supraspinous ligament originate as a thin layer of fibrocartilage. He reported that besides collagenous fibres the ligament contains cartilaginous strands and thin elastic fibres. GRAY (1944) also suggested that there is fibrocartilage at the points of attachment of the supraspinous ligament to the spinous processes, but made no mention of structure in other parts of the ligament.

Age changes were mentioned by FICK (1904) who said that in older persons the fibrocartilage also covers the tips of the spinous processes, and that ossification can be stated in these subjects in the part with fibrocartilage. No other reports on changes occurring with age have been found in the literature.

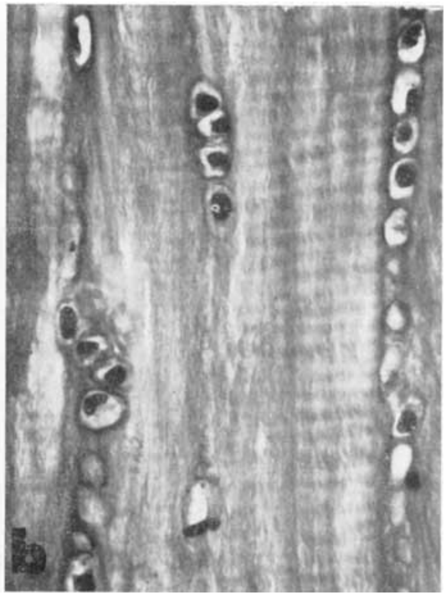
*Own investigations:* Three different parts can be distinguished macroscopically in the supraspinous ligament: the superficial, the central and the deep layer. These three parts differ very distinctly under the microscope in adults. In children the superficial and midmost layers are composed chiefly of longitudinal long fibrous bundles, the deep layer of the tendinous bundles joining the tips of two adjacent spinous processes and the numerous criss-crossing fibres attached to them from the lateral direction. All the three parts are thus composed chiefly of tendinous tissue. With advancing age, considerable changes occur, affecting above all the midmost and deep layers of the ligament. By the age of approximately 20, cartilage cells form between the bundles of collagenous fibres. These cells later increase in number and by the age of 40 the midmost and deep layers of the supraspinous ligament consist almost exclusively of fibrocartilage. The midmost layer is composed chiefly of parallel fibres, the deep layer of closely interwined fibrocartilage. The differences are brought out well by ordinary Weigert-van Gieson staining, but even more clearly by, for instance, Alcian blue or toluidine blue staining (Figs. 6a, 6b, 6c). Neither cartilage cells nor metachromasia can be demonstrated in the most superficial layer of the ligament; it consists of typical tendinous tissue even in older people. The midmost and deep layers, on the other hand, reveal pronounced metachromasia on toluidine blue staining and a blue colour on Alcian blue staining, both of which disappear on moving ventrally to the area of the interspinous ligament. The same stains reveal neither metachromasia nor cartilage cells anywhere in the area in children. Nor are the differences between the various parts of the supraspinous ligament and the interspinous ligament as distinct in children as in older people.

The fibres of the deepest layer of the supraspinous ligament connect the opposing edges of the spinous processes and continue inside the bone. At the tips of the spinous processes there is a fairly thick layer of interwined fibrocartilage which enters the bone perpendicularly and connects the superficial and midmost layers of the ligament. Metaplastic bone formation on the marginal surfaces inside the fibrocartilage is demonstrable at both sites after the 30th year of age. In older persons this process may achieve such great proportions that the tip of the spinous process is ossified almost to the dorsal surface of the ligament. In the deepest layer of the ligament ossification occurs on the side of both spinous processes, shortening the true fibrocartilaginous ligament. It is possible in such a case to see under the microscope how by the age of 40 the bony islets extend far into the ligament and yet in places inside the bone there are still tongues of fibrocartilage (Fig. 7).

*Fig. 6: Supraspinous ligament of a woman of 41 in the LI—LII space. Toluidine blue,* × 400.



(*a*) *superficial layer, typical tendinous tissue*



(*b*) *midmost layer composet chiefly of parallel fibrocartilage*

(*c*) *deep layer composed chiefly of interwined fibrocartilage*

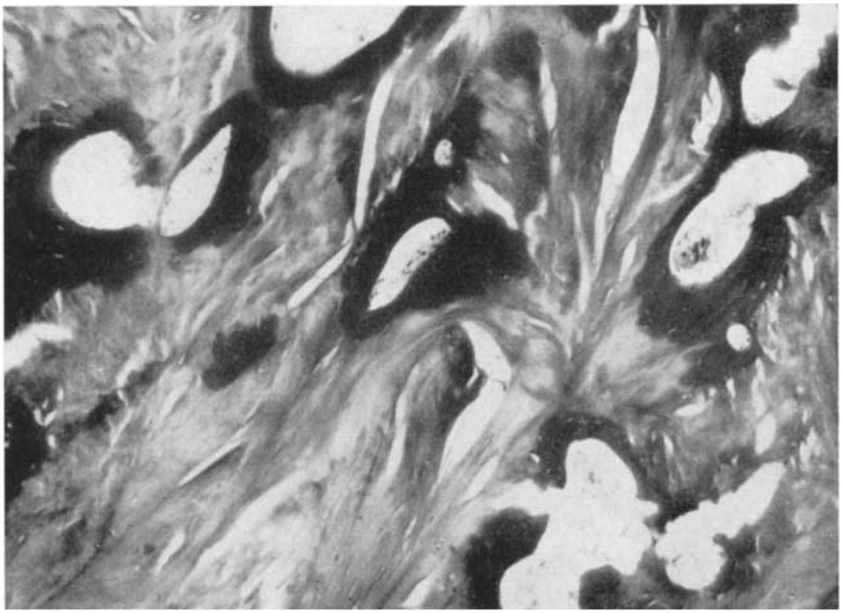


*Fig. 7: Metaplastic ossification ana fibrocartilage in the deep layer of the LI—LII space of the supraspinous ligament, close to the bony surface of the spinous process of LI. Weigert-van Gieson, × 120. A man of 40.*

Besides genuine bone, diffuse calcification is very often demonstrable after the age of 30 in the deep and midmost layers of the supraspinous ligament. The deposit of calcium is most pronounced in the fibrocartilaginous part of the ligament beside the newly-formed bone. It is more unusual approximately in the middle of the interspinous space in the ligament.

All the layers of the supraspinous ligament are composed of relatively dense tissues. It is often possible, especially in children, to establish islets of fatty tissue in the middle of the interspinous ligaments but not in the supraspinous ligament. The proportion of loose connective tissue is also very small in the supraspinous ligament. Blood vessels are even fewer than in the interspinous ligaments. Elastic fibres are scanty. Resorcin-fuchsin staining brought out few fibres, usually none at all.

All the layers of the supraspinous ligament seem to be very firmly attached to the bony surfaces by fibrocartilage, and new bone forms at the points of attachment, partly inside the fibrocartilage. The superficial lamina of the lumbodorsal fascia is also attached directly to the bony surface at the tips of the spinous processes and the fibre bundles extend inside the bone. Microscopy gives the impression that the ligaments joining the tips of the spinous processes are very strong and effective in limiting excessive separation of the spinous processes.

It was concluded earlier that fibrocartilage formation occurs with age in the midmost and deep part of the supraspinous ligament and that metaplastic ossification begins at the points of attachment of the ligament. Many other changes occur with age. The most common of these is the infiltration of fine-grained fat into the intermediate substance. This begins at a relatively early phase, often in the second decade of life. In the present work, however, no pronounced fatty infiltration was observed, even in older persons, in the supraspinous ligament. No difference was observed in this respect from the corresponding interspinous ligament.

In a 40 year old person the author found for the first time isolated cyst-like outpouchings in the ligament close to the bony surface of the spinous process at the point of attachment of the deepest layer of the supraspinous ligament to the bone. The cysts were filled with a mass of homogeneous or scaly appearance which stained faintly yellow with Weigert-van Gieson. A part of the mass contained in the cysts did not stain at all by this method but looked greyish; the mass from an individual cyst also stained very unevenly. Fig. 8 shows this type of cyst in the supraspinous ligament of

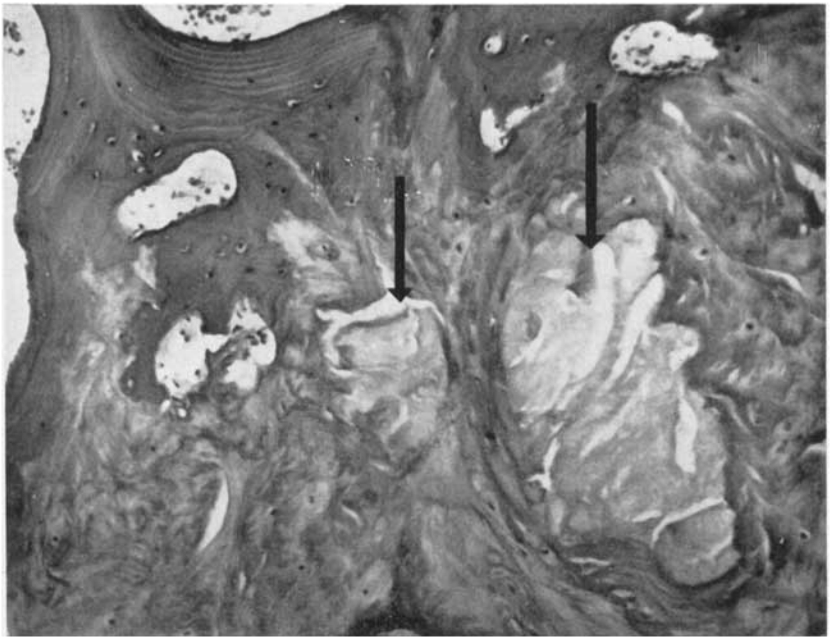


*Fig. 8: Two foci of degeneration in the deepest layer of the LI—LII space of the supraspinous ligament of a woman of 41, close to the bony surface of the spinous process of LI. Weigert-van Gieson, × 120.*

a woman of 41 in the LI-LII space. Changes of the type described above were observed very frequently in connection with ruptures of the lowest interspinous ligaments. They are described in greater detail in that context.

The supraspinous ligament thus undergoes considerable changes with age. The most distinct of these are metaplasia of the tendinous tissue into fibrocartilage, calcification and metaplastic ossification, all demonstrated in every old person in a milder or more pronounced degree. The other changes are more uncommon and mild, with the exception of fatty infiltration. No signs of rupture of the supraspinous ligament were found, even on microscopic examination.

As was mentioned in the chapter on gross anatomy, the supraspinous ligament usually terminates in the spinous process of LIV. The fibrous bundles of the aponeurosis of the musculus longissimus dorsi which in the superior lumbar vertebrae join the sides of the spinous processes, converge at the tips of the LIV and LV, as will be seen from Fig. 5. Microscopy discloses at the tips of the spinous processes a thin layer of interwined fibrocartilage by which the most ventral fibre bundles are attached to the bones. The fibrous bundles on the dorsal side are generally interconnected only by loose connective tissue, as can be seen from Fig. 9. These are

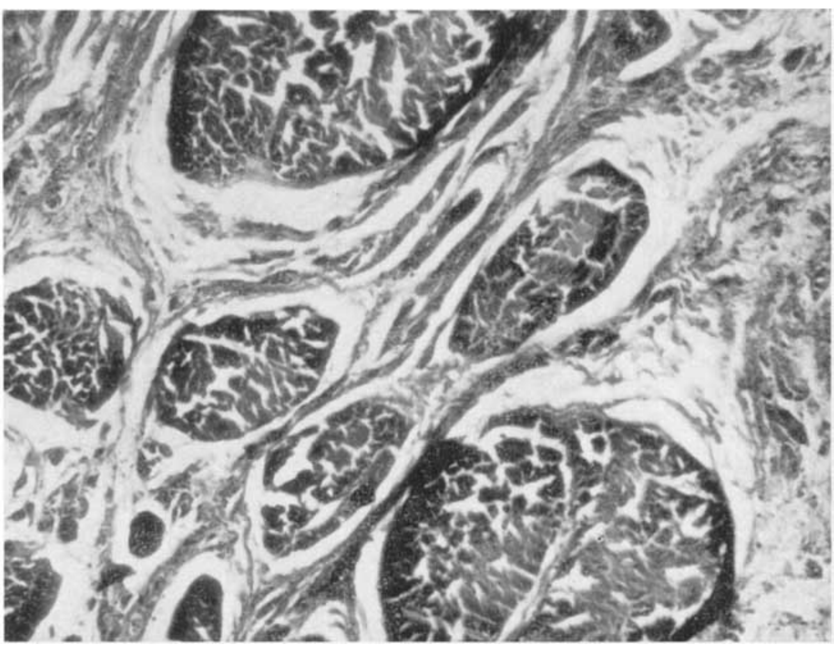


*Fig. 9: Horizontal section of the soft tissues, from immediately beside the median plane, at the tip of the spinous process of LV. The tendinous bundles are separated by layers of loose connective tissue. A man of 40. Weigert-van Gieson, × 120.*

the fibrous bundles which move ventrally to form the most dorsal part of the interspinous ligament. In the median plane the layer corresponding to the tendinous raphe consists of interwined tendinous tissue. There is considerable individual variation. It is possible in many cases to see here fatty tissue between the fibre bundles, just as in the middle of the interspinous ligaments, and profuse loose connective tissue separating the roundish tendinous bundles. In other cases the amount of loose connective tissue is so small that the tendinous fibre bundles are more closely interconnected.

*Discussion:* All the components of the supraspinous ligament mentioned by FICK (1904) can be established in adults. The midmost and the deep layer not only contain fibrocartilage at their points of attachment but are entirely composed of it.

In children, on the other hand, all the parts of the supraspinous ligament are composed of tendinous tissue. The metaplasia of the tendinous tissue into fibrocartilage begins, however, fairly early in the midmost and deep layers. SCHAER (1936) and DEPALMA (1952) reported metaplasia of tendinous tissue into fibrocartilage in the shoulder in connection with degeneration of the tendon of the supraspinatus. How the fibrocartilage found in different tendons and ligaments constitutes a reaction mechanism to continuous overstrain of the tissue was described by ALBERTINI (1929). KROMPECHER (1937) and GLÜCKSMANN (1939) postulated the theory that the prequisite for and cause of the chondrogenesis of fibrocartilage is traction and pressure. Early metaplasia thus warrants the assumption that there is a marked strain in daily life on the midmost and deep part of the supraspinous ligament. In its function as an agent limiting ventral flexion of the spine, on the one hand, and as the point of departure of the tendons of the dorsal muscles, on the other, the supraspinous ligament is subjected to continuous traction. In extension of the spine the tips of the spinous processes approach one another and may cause pressure on the deepest parts of the ligament. These theories can perhaps explain the metaplasia of tendinous tissue into fibrocartilage which then undergoes further metaplastic bone formation with age, already mentioned by FICK (1904), and calcification.

Fatty degeneration is common in the supraspinous ligament and this is probably a normal degenerative process that comes with age. ALBERTINI (1929) stated that it was very common already in relatively young subjects in other tendons and became more pronounced with age.

*S u m m a r y : Histologically, all parts of the supraspinous ligament are composed of tendinous tissue in children. With increasing age the middle layer and the deep layer show metaplasia into fibrocartilage. By the age of 40 the deep layer consists of interwined and the midmost layer chiefly of parallel fibrocartilage, the superficial layer of tendinous tissue. The fibrocartilaginous part of the ligament undergoes metaplastic ossification and calcification. Mechanical stress has been regarded as the primary cause of the formation of fibrocartilage. Fatty infiltration occurs as a degenerative change provoked by age. Cystic degeneration is also observed in the supraspinous ligament with age.*

## VI. INTERSPINOUS LIGAMENTS IN THE REGION OF THE LUMBAR SPINE

### A. EMBRYO, FETUS AND INFANT MATERIAL

*Earlier investigations:* The embryonal development of the interspinous ligaments has received no more than occasional mention in the literature. GEGENBAUR (1885) and HENLE (1901) stated that even prior to the development of the spinous processes there is a medial connective tissue sheet into which the spinous processes grow. All intervertebral ligaments, according to HAMILTON et al. (1952), are composed of the parts of the sclerotomes that lie between the different neural arches.

When the human embryo develops, the neural arches originate from the primordia growing in the dorsal direction on both sides of the neural tube. These primordia usually meet in the fourth fetal month, closing the neural arch (FISCHEL 1929, FRAZER 1931, KEITH 1933, HAMILTON et al. 1952). The primordium of the spinous process begins to grow directly from the point of union.

No mention was found in the literature of whether children with normal bones have intact interspinous ligaments or whether congenital defects are present.

*Own investigations:* In an embryo at the beginning of the third fetal month, before the neural arches have united, there is nothing to distinguish the future site of the interspinous ligaments. No special medial connective tissue strand can be differentiated in the area. At the beginning of the fourth fetal month, when the primordia of the spinous processes have already come into existence, a wide strand is observed between them. This strand, which has originated from the connective tissue of the embryonic period, has cells slightly more densely on both margins while the centre is somewhat more delicate and has fewer cells. At the end of the same fetal month the primordium of the ligament is still composed almost exclusively of cell elements, although delicate collagenous fibres can be demonstrated with Weigert-van Gieson staining. From the fifth fetal month on the proportion of the collagenous fibre bundles gradually increases and the cell elements are less conspicuous. At this time, i.e. the fifth fetal month, the collagenous fibre bundles can already form an unbroken, fairly narrow interspinous ligament, although more frequently they first accumulate on both margins of the ligament. In the middle of the ligament can be seen major or minor islets of similar tissue rich in cells which constitute the original strand connecting the spinous processes.

After the neural arches met, the connective tissue between the primordia of the spinous processes seems to become denser and form the interspinous ligaments. Collagenous fibre bundle formation begins from the edges and continues to the middle of the cell band that at first looks strikingly wide. By the 5th—6th fetal month collagenous bundles have originated throughout the ligament. Islets of fat between the fibre bundles can still be seen however, even in children a few years old. They then diminish or disappear with the increase in the number of collagenous bundles and the density of the ligament.

Interspinous ligaments can often be very easily exposed in children under 1 year of age because there is usually on both sides of the ligament a thin fatty lamella which is easily detached from the ligament. The spinous processes of these infants are low protuberances which have not yet assumed the typical shape of a spinous process. The ligamenta flava and the aponeurosis of the musculus longissimus dorsi are relatively well developed in size. The interspinous ligaments, on the other hand, are fairly weak at this phase and above all low in the antero-posterior direction, an average of a few millimetres only. The preparation thus gives a picture in which the spinous processes, ligamenta flava and aponeurosis of the longissimus, raised as they are, skirt the thin and small interspinous ligament. There are no notable difference at this juncture in the thickness of these ligaments of the superior and inferior part of the lumbar region.

In children, the interspinous ligaments form a continuous tendinous membrane. Seen from the lateral aspect, the ligament often shows between the fibre bundles small depressions containing fat. These very small pits filled with fat can be demonstrated in most infants and in all spaces. In addition, the same structural abnormalities that are described in more detail in connection with the adult material can be established in children in the lowest lumbar spaces. The interspinous ligaments, however, in all the juvenile cases of the present study (101 subjects aged 0—10 years) were completely intact. In this age group they showed no perforation or other defects. This applied to the cases with normal bones. Cases with defects or abnormalities in the bones of the sacrum and the lumbar spine were omitted from the present material.

*Discussion:* The medial connective tissue plate that some workers have reported to exist before the development of the primordia of the spinous processes was not found in the present investigation. Only after the primordia of the spinous processes had originated was it seen in the space between them. Since collagenous fibre bundle formation often begins on the edges of the ligament primordia, the islets of fatty tissue often seen in children in the middle of the ligament can have an evolutionary basis. As the interspinous ligaments are intact in children, possible defects found in these ligaments in older subjects must originate later; they must be ruptured in one way or another.

*Summary: The interspinous ligaments develop simultaneously with the spinous processes from the connective tissue of the embryonic period. Collagenous fibre formation begins at the end of the fourth and beginning of the fifth fetal month in the ligament primordia composed of cells. It often starts from the margins of the ligament. Children often have fatty tissue islets between the fibres in their interspinous ligaments. No congenital defects were found in the interspinous ligaments of children with normal bones.*

## B. MACROSCOPIC ANATOMY

*Earlier investigations:* Many workers have discussed the anatomy of interspinous ligaments. The information available on these ligaments, however, is scanty and conflicting. RICHTER (1836) described the interspinous ligaments as broad, thin membranes composed of irregular fibres which usually run horizontally. These membranes fill the space between the spinous processes and extend from the base of the spinous process to its tip. In D'ALTON's (1850) view the interspinous ligaments are composed of diagonally arranged fibre bundles which, when the back is bent, separate radially and often reveal free openings between the fibre bundles.

The interspinous ligaments of the lumbar region were described by FICK (1904) as square plates with distinguishable anterior, posterior, superior and inferior margins. He suggested that these ligaments could be divided into several lamina each showing openings filled with blood vessels and fat. The fibres run diagonally in the antero-superior — postero-inferior direction, from the base and lower margin of the superior spinous process to the upper margin and tip of the inferior spinous process.

KAJAVA (1911) said that they had a postero-superior — antero-inferior course. Interspinous ligaments were described by TANDLER (1926) as thin membranes in which the fibre bundles constitute a U-shaped pattern open dorsally. The same view was held by BENNINGHOFF (1949).

WOERDEMANN (1955) stated that the fibres in the interspinous ligaments run vertically from the lower edge of the superior spinous process to the upper edge of the inferior spinous process.

In addition to the authors cited, all the investigators mentioned in the present work as studying the anatomy of the supraspinous ligaments macroscopically have also studied the interspinous ligaments. They advanced no views different from those detailed above.

The Italian VOENA has recently (1956 and 1957) published two articles on interspinous ligaments and their structure. His material consisted of 6 adult subjects. He distributed the interspinous ligaments into 3 types. Each of the first 2 had 2 separate systems which were closely associated with one another and with the supraspinous ligament. He held that the bundles of the first system of the 1st type departed from the neural arch and ended at the inferior margin of the superior spinous process. In the second, associated system the fibres started from the upper margin of the inferior spinous process, encircled the tip of the superior spinous process in an arc-like manner and terminated only in the lower margin of the following superior spinous process. The first system of the 2nd type was similar to that of the 1st type. The fibres of the second system, on the other hand, started from the upper margin of the inferior spinous process and ended in their entirety in the supraspinous ligament. VOENA included in the 3rd type cases which showed in addition to the fibres of the first system also felt-like tissue in the postero-inferior corner of the ligament. He regarded the 2nd type as most common because it was found in 3 of the 6 subjects. The 1st type was seen in 2 and the 3rd in one.

To summarise, the views on these ligaments and their structure are very divergent and conflicting. Interspinous ligaments have generally been conceived of as thin membranes, and every possible variation of the course of the fibres in them has been reported. The majority of the investigators, however, have suggested that the fibrous bundles run in an antero-superior — postero-inferior direction.

*Own investigations:*

The interspinous ligaments in the lumbar region are formations of a relatively complex character. Although the structural principle is the same throughout the region, the fact that the supraspinous ligament ends in LIV or LIII and that the nature of the aponeurosis of the longissimus is somewhat different in the upper and lower parts of the lumbar region makes its structure different in the 2 (sometimes 3) lower spaces from that in the upper spaces. It was mentioned in connection with the review of the supraspinous ligament (Chapter V) that only interconnections between the fibre bundles of the aponeurosis of the longissimus in the superior parts of the lumbar region are fine membranes. In the lower parts, on the other hand, they constitute a strong, continuous and very dense sheet of tendinous tissue. Hence the LI—LII, LII—LIII and LIII—LIV spaces are similar on the whole and the ligament of, say, the LI—LII space can be regarded as typical of all of them. The ligaments of the LIV—LV and LV—SI spaces possess a good number of features in common and the interspinous ligament of the LV—SI space is taken as the model here. The ligament of the LIII—LIV space also belongs to this type sometimes, and at other times constitutes a kind of transitional form between the two types. In describing the structure of the interspinous ligaments the most common types, in which the architecture of the ligaments emerges beautifully, will be taken first. The variations in structure are considered subsequently.

(a) Interspinous ligament LI—LII

Four parts can be distinguished in the interspinous ligament in this region, differentiated by the points of departure and attachment and the course of the fibre bundles (Figs. 10a and 10b).

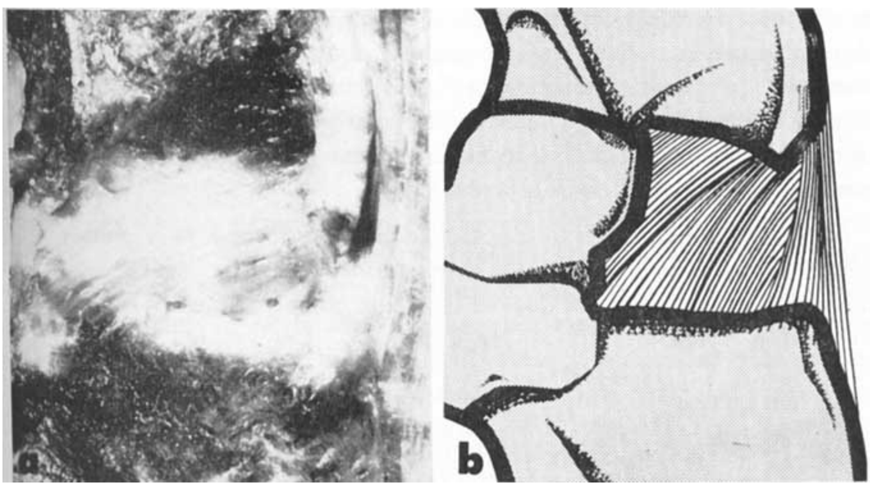



*Fig.10: (a) Photograph of the left side of the interspinous ligament LI—LII of a man of 54. The fibres have a typically postero-superior — antero-inferior course. On the right of the picture, fibre bundles of the aponeurosis of the longissimus and the tendon of the musculus multifidus cut close to its point of attachment to the tip of the superior spinous process.*

*(b) Sketch of the interspinous ligament of the LI—LII space. The ventral, ventromedial, dorsomedial and dorsal part of the ligament and, to the right of it, the supraspinous ligament can be seen.*

(1) Ventral part. It is composed of fibrous bundles which arise from the inferior margin of the more cranial spinous process on the boundary of the interspinous space, from its most ventral 2/3 and, passing diagonally forward and downward, end mostly in the ligamentum flavum and partly in the arch and articular capsule of the corresponding vertebra. This part of the ligament is generally strong, does not show very great individual variations.

(2) The ventromedial part is composed of fibre bundles which arise from the inferior margin of the superior spinous process, from its most dorsal 1/3, pass diagonally in an antero-inferior direction and end in the superior margin of the ventral half of the inferior spinous process. The fibre bundles thus have to pass between two bony surfaces of different vertebrae.

(3) The dorsomedial part is composed of fibre bundles which depart from the deepest part of the supraspinous ligament where it connects only two spinous processes, from there turn diagonally in a ventrocaudal direction and end in the central 1/3—1/2 of the superior margin of the inferior spinous process. This part of the interspinous ligament is usually the thinnest and weakest, sometimes altogether membranous.

(4) The dorsal part is composed of fibre bundles of which those closer to the median plane derive from the supraspinous ligament and those situated more laterally from the tendons of the aponeurosis of the longissimus. The proportion of both varies individually, but the latter are usually more numerous. The fibres run fairly steeply downward and end in the most dorsal 1/3 of the superior margin of the inferior spinous process.

Of the four parts thus distinguished in the superior interspinous ligaments of the lumbar region, the supraspinous ligament participates in the formation of the two most dorsal. The main course of the fibres is postero-superior — antero-inferior.

(b) Interspinous ligament LV—SI

This ligament can be divided into three parts on the basis of the points of departure and attachment of the fibre bundles (Figs. 11a and 11b).

(1) The ventral part is composed of the fibre bundles which arise from the inferior margin of the superior spinous process on the boundary of the interspinous space, from its most ventral 2/3, pass diagonally downwards and forward and end for the most part in the ligamentum flavum.

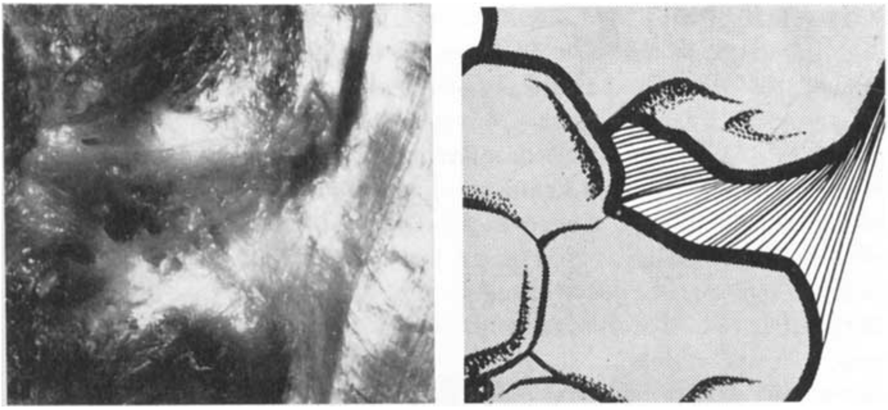


*Fig. 11:* (*a*) *Photograph of the left side of the interspinous ligament of the LV—SI space of the same preparation as in Fig. 10. Some superficial criss-crossing fibre bundles above the basic fibre bundles running in a postero-superior — antero-inferior direction. Dense aponeurosis of the longissimus on the right.*

(*b*) *Sketch of the interspinous ligament of the LV—SI space. The ventral, medial and dorsal part of the ligament are of typical appearance.*

Some of the bundles are attached to the arch or articular capsule of the same vertebra. These bundles are thus of exactly the same kind as in the upper spaces, though often still more robust.

(2) The medial part is composed of fibre bundles which arise from the most dorsal 1/3 of the inferior margin of the superior spinous process, run diagonally in a ventrocaudal direction and attach to the superior margin of the inferior spinous process, about half way from its base.

(3) The dorsal part is composed solely of the strong fibre bundles arising from the aponeurosis of the longissimus. These bundles are attached to the superior margin of the dorsal half of the inferior spinous process. As the aponeurosis of the longissimus forms a continuous sheet at this level, the aponeurosis really continues straight into the most dorsal part of the interspinous ligament. This part thus differs most from the corresponding parts of the interspinous ligament of the superior spaces. The fibre bundles of the aponeurosis, after converging caudally from both sides reach the tip (and not the sides, unlike the upper spaces) of the superior spinous process and turn in the ventral direction, finally attaching at the upper edge of the lower spinous process. The majority of these fibre bundles, which constitute the dorsal part of this interspinous ligament, come from a homolateral aponeurosis. Some fibres pass to the opposite side, others remain to form the tendinous raphe between the spinous processes. The dorsal part of the ligament is always fairly strong.

The interspinous ligament of this space has no definite boundary dorsally. The most dorsal part is composed of the fibre bundles of the aponeurosis of the longissimus and the same pronounced aponeurosis continues a good distance laterally from near the ligament.

There are thus considerable differences in the structure of the superior and inferior interspinous ligaments of the lumbar region. In the absence of the supraspinous ligament in the lowest lumbar spaces, its work is performed by the dorsal part of the interspinous ligament and, if its fibre bundles at the tip of the spinous process relax, by the medial part of the ligament in which the fibre bundles pass between the bony surfaces of two different vertebrae. It seems possible that the fibre bundles of the dorsal part can move apart and away from the tip of the spinous process since they are generally joined by loose connective tissue.

The structural principle and architecture of the interspinous ligaments of both the superior and inferior part described in the foregoing hold good in general. In some cases, however, there are many different components which supplement this beautiful basic structure. On the other hand, many abnormal differences from the normal structural pattern can also be found. There is, again, a difference between the superior and inferior parts of the lumbar region. The interspinous ligaments of the LI—LIV (LIII) spaces in well over 80 per cent of the cases are formed exactly as described above, without any additional components. The ligaments of the LIV—SI spaces are constructed as described in only a little over 20 per cent. They always have a system of this type as their basic framework, but there are additional components.

To summarise, a dorsal, medial and ventral part are distinguishable in the inferior interspinous ligaments. The dorsal part consists of the tendon bundles of the longissimus. The fibres have a postero-superior — antero-inferior course.

### (c) Variations from the basic architecture

In the upper parts of the lumbar region there are usually superimposed on the above basic structure very thin fibres which criss-cross vertically the fibrous bundles of the basic part of the ligament. These thin fibres usually depart from the superior margin of the inferior spinous process or radiate from the tendon of the musculus multifidus at the tip of the spinous process. Where this muscle is partly attached to the supraspinous or interspinous ligament the proportion of the fibrous bundles emerging from it is considerable. In several cases the thin fibrous bundles can be followed right up to here from the lumbodorsal fascia, although most of them interwine with the supraspinous ligament en route. When this happens the fibres usually disappear little by little in the basic part proper of the ligament. It is more rarely that they can be followed to the superior spinous process and the ligamentum flavum.

Very strong fibre bundles are found in a few cases only in the interspinous ligaments of the area. These bundles run from the superior margin of the lower spinous process and, criss-crossing fibrous bundles belonging to the normal architecture, advance towards the base of the spinous process and ligamentum flavum where they terminate. A V-shaped pattern (Fig. 12) open dorsally originates. It resembles somewhat the description

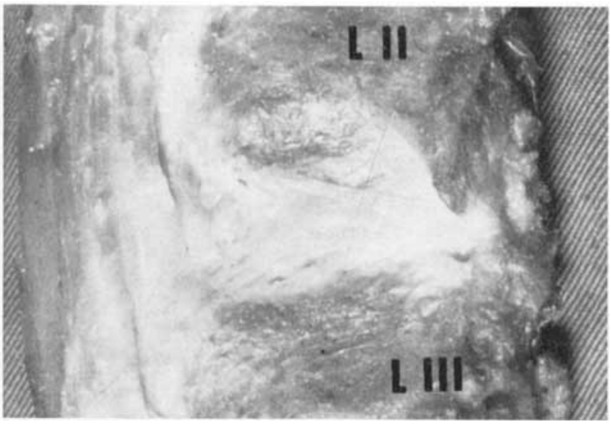



*Fig. 12: The interspinous ligament LII—LIII, viewed from the right. The V-shaped pattern open dorsally which is formed by the superficial fibrous bundles was found in c. 4 per cent of the material. A man of 45.*

given e.g. by TANDLER and BENNINGHOFF of the interspinous ligaments. Such patterns are relatively uncommon. They were found in the superior interspinous ligaments in only 4 per cent of the preparations. Furthermore, when a structure of this type is seen on one side, the other side often follows the basic type. On the other hand, the V figure may occur in one space only while the other spaces conform to the normal type. If these criss-crossing fibres are exposed and removed, fibre bundles belonging to the typical architecture can be seen underneath. They are often weaker than normal in these cases.

Thirdly, the basic structure in the superior interspinous ligaments of the lumbar region may be joined by fairly strong fibre bundles which pass superficially along the upper and lower margins of the spinous processes in the region of the juncture of the ligament and the bone and which then disappear in the ventral part among the fibre bundles of the true interspinous ligament. Only a few cases of this type were found. Rare, they are probably of no notable significance.

In the upper lumbar spaces the deviations from the typical basic structure are infrequent and slight. In the two lowest spaces on the other hand there is a good number of all kinds of additional components and divergences from normal architecture. The most common is the appearance of fairly thin fibre bundles criss-crossing the surface of the fibre bundles which constitute the actual framework, giving the ligament a slightly reticular surface appearance. These fibres sometimes depart from the superior margin of the lower spinous process, run ventrocranially and end partly in the ligamentum flavum and the inferior margin of the superior spinous process, partly disappear among the fibre bundles of the true ligament. In a very great number of the cases these fibre bundles issue from the layer on the ventral surface of the aponeurosis of the longissimus dorsi. Some of these fibres have no connection with the spinous processes and descend from the surface of the aponeurosis direct to the surface of the interspinous ligament into which they gradually disappear. These fibre bundles vary considerably in thickness. They are very thin in some cases, sometimes so thick that a superficial examination of the ligament first gives the impression that the course of the fibres is antero-superior — postero-inferior. Such diagonally arranged strengthening superficial fibres were demonstrated in the interspinous ligaments of the two lowest lumbar spaces in over 50 per cent of the cases. Fig. 11a shows some of them.

In the lower parts of the lumbar spine the musculus multifidus is partly attached to the interspinous ligament relatively often. When this happens, parts radiate from the tendon over a wider area of the ligament surface, mostly on the dorsal part. Individual fibre bundles which depart from the superior or inferior margin of the spinous process and make their way ventrally along the margin of the spinous process were seen in some rare cases.

Considerably more common and typical exclusively of the lowest interspinous ligaments of the lumbar region is a thick, isolated fibre bundle which connects the tips of the spinous processes on one or both sides. These fibre bundles run directly from bone to bone. In some cases, when the tendon of the musculus multifidus has a wide area of attachment, a somewhat similar formation may originate, but mostly it is a completely isolated formation that is involved. It seems very natural that such a fibrous band can compensate at least in part for the absence of the supraspinous ligament. The formation is not particularly rare. It was found in slightly over 10 per cent of the present material either in one or both of the lowest lumbar spaces. As is the case also with the other characteristics, symmetry is not necessary here either and the band is mostly found only on one side of the ligament. Figs. 13a, b and c illustrate one such case.

Another special structural feature, also observed only in the lowest lumbar spaces, is a strong fibrous band which departs from the inferior margin of the fourth or fifth lumbar spinous process, runs as a completely independent bundle dorsally and caudally but, instead of ending in the

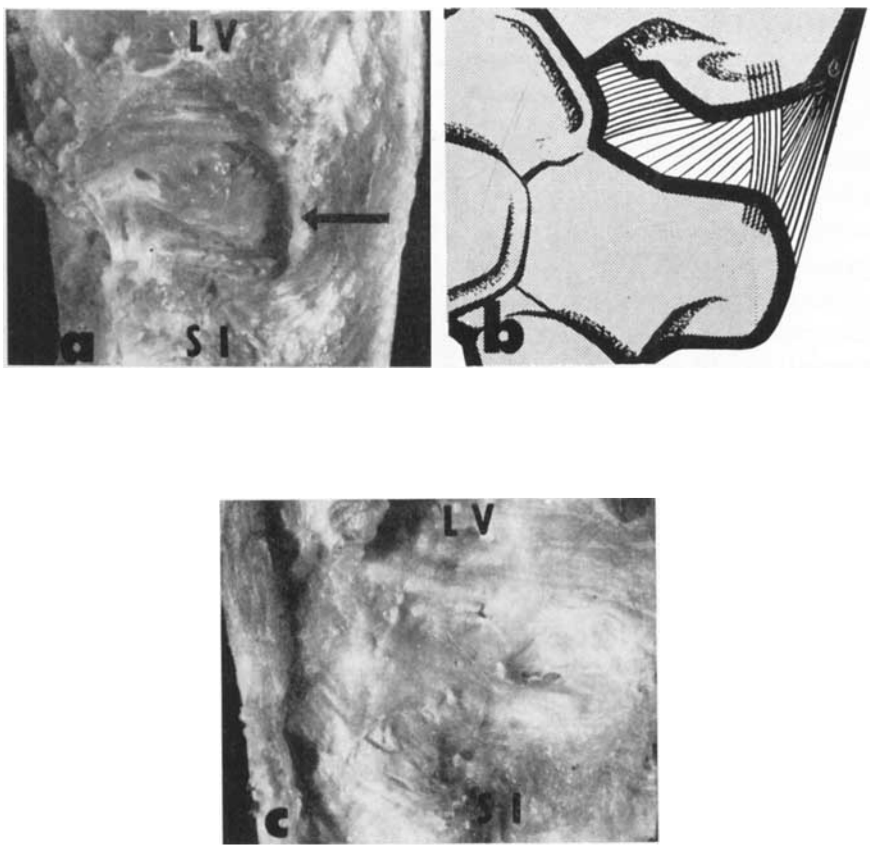



*Fig. 13:* (*a*) *Photograph of the left side of the interspinous ligament LV—SI of a man of 19. The fibrous band (arrow) joining the tips of the spinous processes is visible, also the shallow pit with slightly inclined walls that has originated on the ventral aspect. A formation of this kind was found in the lowest interspinous ligaments in c. 10 per cent of the cases.*

(*b*) *Sketch made from photograph* (*a*)

(*c*) *Photograph of the right side of the same ligament. Here the structure was typical.*

lower spinous process runs close beside its tip, continues on the ventral surface of the aponeurosis of the musculus longissimus dorsi and finally terminates among its fibres. A formation of this type, slightly reminiscent of the previous one, was established in einther one or both of the lowest lumbar spaces on either or both sides in about 15 per cent of the cases.

The presence of a transverse fibre bundle which runs either between the tips of two adjacent spinous processes or from the inferior margin of the upper spinous process past the tip of the lower spinous process to the ventral surface of the aponeurosis of the longissimus sometimes causes other changes in the ligament. Incidentally, a part, sometimes a very considerable part, of those fibres of the aponeurosis of the longissimus dorsi which normally curve ventrally to form the most dorsal part of the interspinous ligament, attaches in fact to this band. In some cases fibre bundles of the medial part of the ligament, too, seem to be missing on this side. This part of the interspinous ligament is consequently considerably thinner, and a shallow pit with slightly inclined walls originates on the ventral side of the transverse fibrous band. Fig. 13a shows a typical example of such a depression. When the transverse fibre bundle is bilateral in a certain space and the fibre bundles of the aponeurosis of the longissimus are attached to it on both sides, the interspinous ligament is often very thin in this space. Cases of this type are rare. There were only 5 in the present material. In the majority of the cases in which the transverse fibre bands were seen the interspinous ligament was of normal thickness and shape. A smaller number showed a shallow depression and a slight thinning of the ligament. In a few cases only was the pit seen on both sides.

There is one more abnormality worth mentioning, seen every now and then in the lowest interspinous ligaments of the lumbar region. The fibre bundles of the aponeurosis of the longissimus are sometimes attached to the opposite margin at the tip of the spinous process. It follows from this that a shallow pit again originates on one side of it in the corresponding interspinous space while the other side is completely normal in appearance. Fig. 14 illustrates a case of this kind.

The small pits and depressions containing fat or fat-like tissue seen in children can also be found in adults between the strong fibre bundles of the interspinous ligaments. In children these formations were nearly equally common in all the interspinous ligaments of the lumbar part, but in adults they are more numerous in the lowest spaces. Fig. 15 illustrates formations of this kind in the interspinous ligament of the LV—SI space. The fibre bundles are intact and emerge better than usual thanks to the pits between the bundles.

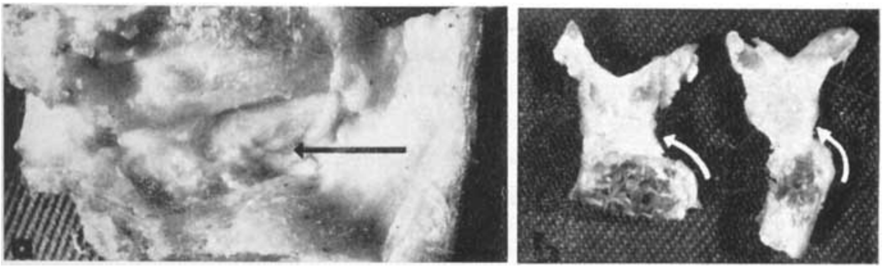


*Fig. 14:* (*a*) *Photograph of the left side of the interspinous ligament LV—SI of a woman of 38. A shallow pit can be seen (arrow) caused by the attachment of the ligament-forming fibres to the right margin of the spinous process.*
(*b*) *Horizontal section of 2 spinous process tips of LV, viewed from the cranial aspect. The right-hand section is of the case in Fig. 14a. The left-hand section is from a woman of 67 who also had a shallow pit in the LV—SI space. Both sections display a shift to the right of the tendinous masses in the tip of the spinous process.*

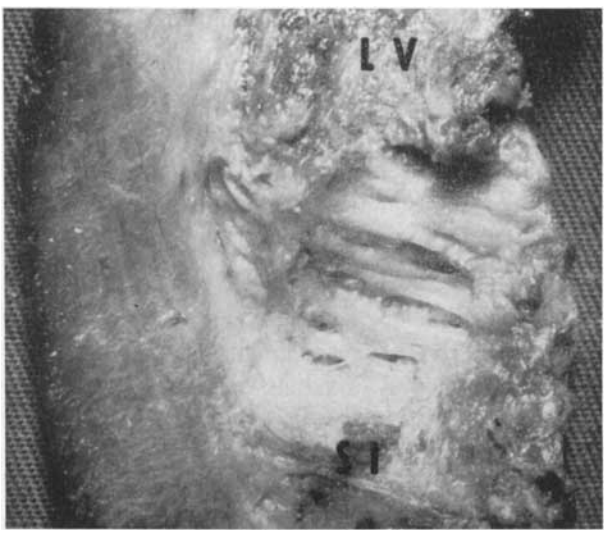



*Fig. 15: The right side of the interspinous ligament LV—SI in a woman of 63. Between the fibre bundles are pits containing fat. The course of the fibres is typical and clearly visible. The fibre bundles themselves are intact.*

The interspinous ligaments completely fill the space that is present between two adjacent spinous processes. The dimensions of these ligaments must obviously depend on the size of the interspinous space. Persons of robust physique, whether men or women, have strong and long spinous processes. In those with slender bones the processes are shorter. In the lumbar region, too, there are differences between the upper and lower part. The midmost spinous processes (LIII, LIV) are usually the longest and best developed. Substantial variations can be seen in the spinous process of the first sacral segment. It is often as well developed as the lowest lumbar spinous processes, but it can also be quite a small rudimentary protuberance at the beginning of the crista sacralis media. Similar size variations are also observed in the ligament.

Interspinous ligament LIII—LIV is usually the largest in size. The antero-posterior measurement, i.e. the distance from the ligamentum flavum to the supraspinous ligament, averages 24—30 mm against c. 18—24 mm in the LV—SI space and practically the same in the highest lumbar region. The height of the ventral part of the interspinous ligament is c. 9—13 mm in the LIII—LIV space, of the dorsal part close to the tip 6—10 mm. In the LV—SI space the height is c. 7—11 mm in the ventral part and c. 5—8 mm in the dorsal part. In the uppermost space the height is mostly the same as in the central parts, except that there is not such a great difference between the ventral and dorsal measurements.

In adults, the ligament is much higher in the ventral than in the dorsal part. This is due to the bony prominences, spurs of a kind, which originate with age on the lower surfaces of the tips of the spinous processes. These prominences shorten the distance between the tips, and the tips of the spinous processes may ultimately be very close to one another.

The thickness of the interspinous ligaments also varies considerably. There are cases in which all the ligaments are almost of membranous thinness, but these are very rare. It is somewhat more common for the dorsomedial part of the upper lumbar interspinous ligaments to be weaker than the other parts. The lower spaces also can sometimes be very thin when the abnormalities mentioned above are present. Otherwise, in a typical case, a man of c. 20 has interspinous ligaments c. 1—2 mm thick in the upper lumbar region and c. 2—3 mm thick in the two lowest spaces. This is when the measurement is taken from the centre of the ligament, usually the thinnest place. The thickness of the interspinous ligaments increases considerably on moving ventrally towards the ligamentum flavum and dorsally towards the supraspinous ligament or the aponeurosis of the back.

A man of c. 20 years of age was taken as an example because considerable thickening of the interspinous ligaments is a fairly regular occurrence in older subjects. The reasons for this will be discussed in the context of changes occurring with age.

*Discussion:* As reported e.g. by KAJAVA (1911), the principal course of the fibre bundles in the interspinous ligaments is postero-superior — antero-inferior. Several workers, however, have claimed that the course is antero-superior — postero-inferior. The transverse fibres encountered on the surface of the ligaments may sometimes, especially in the lowest lumbar spaces, give the latter impression on superficial examination. When the transverse fibres are stronger V-shaped patterns may originate in the upper interspinous ligaments, as reported by TANDLER (1926) and BENNINGHOFF (1949).

There are differences in the structure of the upper and lower lumbar interspinous ligaments, attributable to the absence of the supraspinous ligament in the lowest spaces. In such cases the dorsal and medial part of the lowest interspinous ligaments assume some of the duties of the supraspinous ligament, prevent excessive moving apart of the spinous processes.

*Summary: The interspinous ligaments of the LI—LIV spaces, on the one hand, and those of the LIV—SI spaces on the other, usually resemble each other structurally. Four parts are distinguished in the uppermost interspinous ligaments of the lumbar region: ventral, ventromedial, dorsomedial and dorsal. The supraspinous ligament participates in the formation of the two most dorsal parts. Three parts are distinguished in the lowest interspinous ligaments: ventral, medial and dorsal. The dorsal part is composed of the fibre bundles of the longissimus. The principal direction of the fibres is postero-superior — antero-inferior.*

*The structure of the interspinous ligaments is complicated by various additional components and abnormalities. They were rare in the uppermost spaces but were found in the lowest spaces in nearly 80 per cent of the cases. The most common in the inferior spaces were: (1) superficial transverse fibres of different strength (2) fibrous bands connecting the sides of the spinous process tips, (3) fibrous bundles passing from the tip of the spinous process to the ventral surface of the aponeurosis of the longissimus, (4) at the tip of the spinous process the fibre bundles move to the opposite side. Many of these factors may cause shallow pits in the ligaments.*

## C. MICROSCOPIC ANATOMY OF THE INTERSPINOUS LIGAMENTS

*Earlier investigations:* The microscopic anatomy of the interspinous ligaments has been reported in a few studies only. SAPPEY (1888) stated that they consist of four kinds of tissue: (1) thin elastic fibres, (2) fibres containing spindle-shaped cells, (3) fibres containing cylindric cells and

(4) isolated cells in certain parts of the ligament. FICK (1904) reported only collagenous bundles and elastic cells in the interspinous ligaments. He was supported by VOENA (1957).

*Own investigations:*

The framework of the interspinous ligaments consist of tendinous tissue. The microscopic picture is dominated by strong collagenous fibre bundles with a typical parallel arrangement or diagonally criss-crossed. The longish, flattened fibrocytes lie in rows between the fibre bundles. The number of cells is considerable in children, smaller in adults in whom collagenous fibre bundles predominate. The picture obtained from the ligament (Fig. 16) is no different from that of normal tendinous tissue in

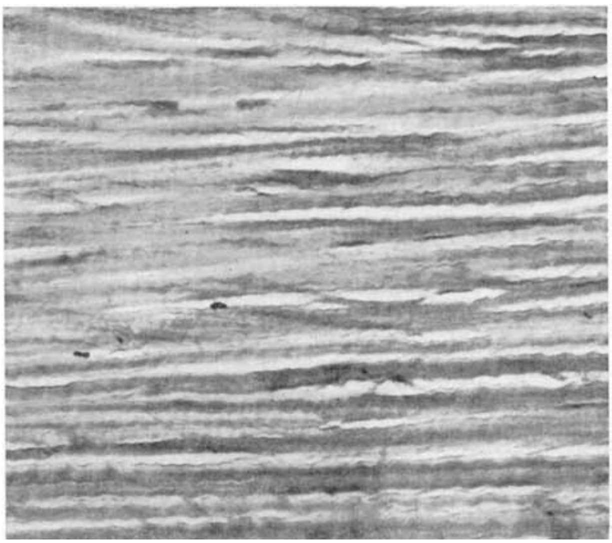


*Fig. 16: Sagittal section of interspinous ligament LV—SI of a youth of 18. Typical tendinous tissue. Weigert-van Gieson, × 400.*

this respect (PETERSEN 1930, HAM 1953). In the more detailed analysis of the age-induced changes it will be seen that tendinous tissue constitutes about 80—90 per cent of the cross section of a healthy ligament.

In children and adolescents a periosteum rich in cells and similar to that on the lateral sides of the spinous process is found immediately beside the bone where the interspinous ligament attaches to the spinous process. The cell-rich layer has much fewer and sparser collagenous fibres than the true ligament, and most of the fibres are interwined. In adults, it is no longer possible to establish such a layer in the central parts, at the site of attachment of the ligament, although it is still often demonstrable on the lateral sides of the spinous processes. The collagenous fibre bundles of the ligament continue without changing course to the bony surface of the spinous process and on inside the bone. The attachment to bone of the interspinous ligament thus does not differ in this respect from the attachment of an ordinary tendon to bone (WEIDENREICH 1923, SCHNEIDER 1956). On the other hand, the fibre bundles on both the margins of the ligament continue as far as the outermost layer of the periosteum, on the lateral sides of the spinous processes, merging with this layer. The flattened fibrocytes of the tendinous tissue are replaced right beside the place of attachment by cartilage cell spindles, but they are very scanty in persons who have just ceased to grow. In younger individuals also, fibrocartilage is more profuse at the site of attachment of the fibre bundles in the most dorsal part of the ligament, i.e. among the fibre bundles coming from the aponeurosis of the longissimus. The volume of fibrous cartilage increases considerably with age, especially at the site of attachment of the dorsal and medial part of the ligament. Near the tip of the spinous process the fibre bundles have a relatively straight attachment to the bone, right-angled even. In the central and ventral parts of the ligament, on the other hand, the fibres attach at a very acute angle to the bony surface.

Paratenon and endotenon composed of loose connective tissue are distinguished in the actual tendon. Exactly similar formations can be established in the interspinous ligament. There is a thin layer of loose connective tissue on both sides the ligament. It is connected with the layers of loose connective tissue between the collagenous fibre bundles. Besides delicate collagen fibres and fixed connective tissue cells, there are sporadically fairly large clusters of various mobile connective tissue cells, mostly in the vicinity of the blood vessels.

An adult has very few blood vessels in the actual tendinous tissue of the ligament. In the interstices of the collagenous fibre bundles there are extremely few vessels, but they are slightly more numerous on both sides of the ligament and in the central layers composed of loose connective tissue or fat. The majority of the vessels are thin capillaries and small veins.

Elastic tissue is very poorly represented in the interspinous ligaments. The few elastic fibres follow a criss-crossing winding course between the collagenous fibre bundles. Compared with the tendinous tissue of the ligament, elastic fibres are more numerous around the islets composed of loose connective tissue and fat and around the blood vessels. Elastic fibres are considerably more numerous also on both sides of the ligament, in the part corresponding to the paratenon, than in the middle. The same interspinous ligament shows an increase in elastic fibres in the most ventral part of the ligament, i.e. where it is attached to the arch and changes into the ligamentum flavum, as can be seen in Figs. 17 a and b. The same

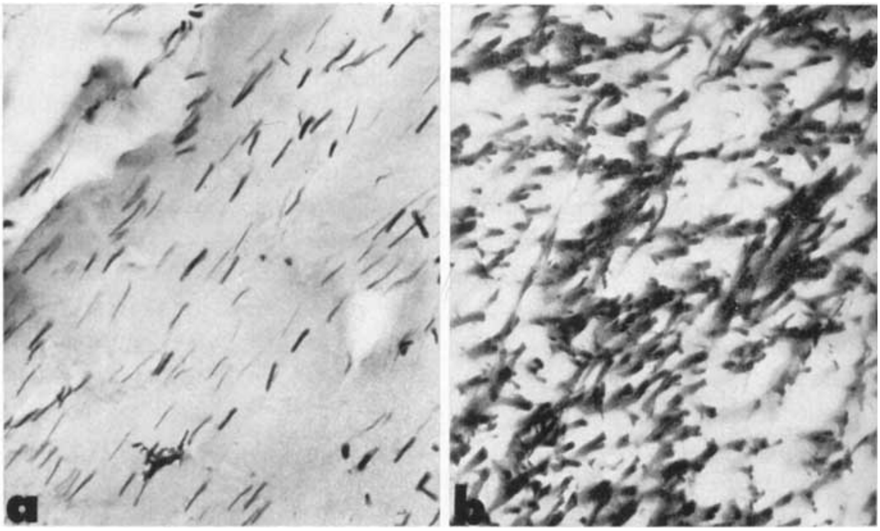


*Fig. 17: Two places of the horizontal section of interspinous ligament LII—LIII of a man of 35, to demonstrate elastic fibres: (a) from the middle of the ligament, (b) from near the ligamentum flavum. Few elastic fibres in the middle of the ligament, many and thicker on the boundary of the ligamentum flavum. Weigert-Hart resorcin-fuchsin, × 400.*

ligament also has areas containing more and less numerous elastic fibres, but without any regular patterning. Elastic fibres show no difference in number between the superior and inferior interspinous ligaments of the lumbar region. They are practically equally scanty in all of them. The number of elastic fibres seems to diminish slightly with age.

Small, isolated fatty tissue islets are met very frequently in the middle of the interspinous ligaments, between the collagenous fibre bundles, especially in children. These islets may appear on the lateral side of the ligament as small fat-filled pits between the fibrous bundles, but in the majority of the cases they do not extend to the surface (Fig. 18). These fatty islets are present throughout the area of the ligament, but they are slightly more numerous and more frequent than elsewhere on the boundary between the interspinous ligament and the ligamentum flavum. These formations may be very dense in children a few years of age. There are very

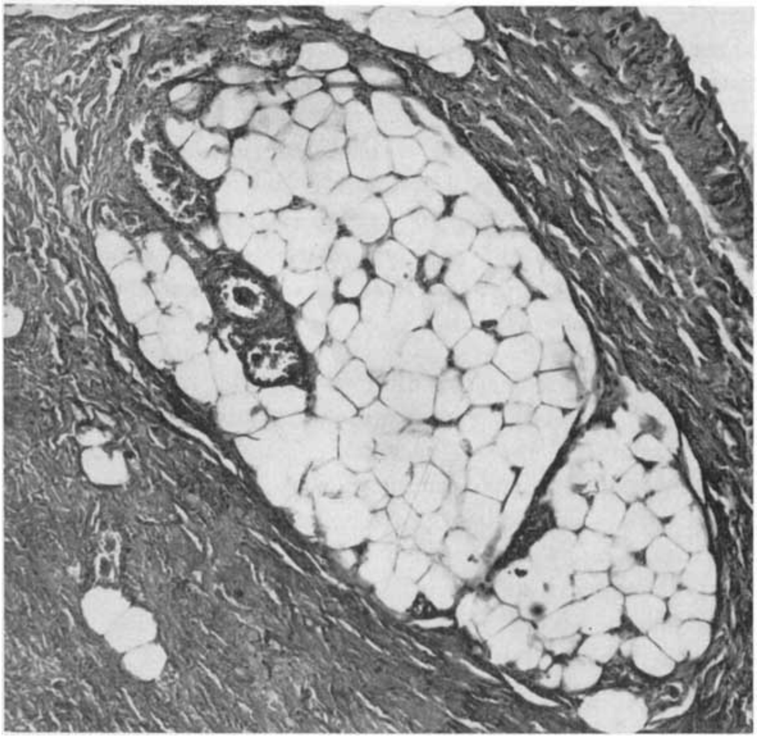


*Fig. 18: Fatty tissue islet amidst collagenous fibre bundles in interspinous ligament LII—LIII. The margin of the ligament is seen in the right upper corner. Blood vessels of different size in the left upper and right lower corner of the islet. A boy of 3, horizontal section of the ligament, Weigert-van Gieson, × 40.*

often numerous blood vessels connected with these islets. The fatty tissue islets decrease in size and number with age.

*Discussion:* Microscopy thus revealed nothing contradictory to earlier investigations.

The principal structural component of the interspinous ligaments consists of collagenous fibre bundles; elastic fibres are very scanty. The ligament is thus capable of withstanding considerable traction but no notable stretching.

The definite periosteum established in children in the middle of the place of attachment of the ligament to the spinous process has disappeared by adulthood. WEIDENREICH (1923) and SCHNEIDER (1956), in their studies on the places of attachment of other tendons and ligaments, concluded that they lack a periosteum. WEIDENREICH claimed that when bone growth ceased the periosteum was ossified at the site of attachment. The same may be assumed of the attachments of the interspinous ligaments.

*Summary: The framework of the interspinous ligaments consists of collagenous fibre bundles between which there is scanty loose connective tissue and, especially in young subjects, sporadic fatty tissue islets. The fibre bundles are attached to the bone at an acute angle and the periosteum is missing in the place of attachment. Elastic fibres are sparse in the actual ligament, but profuse on the boundary of the ligamentum flavum.*

# VII. AGE-INDUCED CHANGES IN THE INTERSPINOUS LIGAMENTS

## A. Macropathologic changes

*Earlier investigations:* The present author has found only a few reports on macropathologic changes in interspinous ligaments. FICK (1904), in describing the normal anatomy, stated that a uni- or multilocular »joint cavity» has sometimes been seen in the interspinous ligaments. There is no mention of whether he regarded it as a pathologic or a normal phenomenon. BRAILSFORD was the first to report a syndrome which BAASTRUP (1933a, 1933b) reviewed more thoroughly in his roentgenologic-clinical observations. Some workers call it »kissing spine», others Baastrup's disease, Morbus Baastrup. BAASTRUP suggested that when a person has pronounced lordosis and long spinous processes the tips of the processes press against one another destroying the soft tissues between them. True articular surfaces with joint cavities may originate between the tips of the spinous processes. The present author has found no reports of anatomic and histologic studies on the subject.

*Own investigations:*

Notable changes occur with age in the interspinous ligaments, some of them visible to the naked eye. To obtain a more concrete idea of the grossest and greatest changes the present author employed the quantitative method of Uotila (see p. 14) to determine the composition of certain interspinous ligaments of one plane in persons of different ages; in other words, the quantity of the different tissue components, fibrocartilage, tendinous tissue, loose connective tissue, fatty tissue and blood vessels was determined. A sixth component was adopted and called a cavity. The analysis covered a total of 20 persons relatively evenly distributed in age between 2½ and 67 years. Only cases in which the ligaments were intact when viewed from outside were accepted for the series. The components determined for each subject were from three interspinous ligaments, i.e. the ligaments of the LI—LII, LIV—LV and LV—SI spaces.

No attempt was made to analyse the ligament as a whole. The intention was to obtain a cross section of mutually corresponding places in each ligament studied and to analyse this site, thus producing comparable results. The results obtained should indicate the gross changes occurring with age in this cross section plane in the different ligaments. As the principal course of the fibre bundles is postero-superior — antero-inferior, the sections needed for the measurements were prepared so that the plane started at the upper margin of the lower spinous process, c. 6 mm ventrally from the tip and continued perpendicularly to the fibre bundles of the ligament, terminating halfway down the lower margin of the upper spinous process. The section on the slide was thus almost identical with the section from the frontal plane. It contained a cross section of the ligament and the bony surfaces at each end as the necessary fixed points for measuring. After decalcification the sections were stained by Weigert-van Gieson's method and measured. Four distances were measured in each section: (1) the straight or broken line from one bony surface to another, (2) the cross section perpendicular to it in the centre point of the section, (3) and (4) cross sections parallel to (2) mid-distant between the centre point of the ligament and both bony surfaces. In both cases two adjacent sections were measured and the mean calculated. The results are given in Table 1.

In considering the results the attention is drawn first to the considerable quantitative changes in the tendinous tissue. Children and adolescents seemed to have a slightly greater percentage of tendinous tissue in the two lower interstices than in the LI—LII space. The differences were not great, but the trend was clear. Around the age of 20 the proportion of tendinous tissue showed signs of a decrease in the two lower spaces; this was very clear and pronounced around 30 years of age. In older subjects the percentual tendinous tissue decreased almost constantly in the lower spaces compared with the upper space. The decrease could even be very marked; the values ranged from c. 80 to 90 per cent in young subjects, but were as low as c. 40 per cent by 30 years of age. The general range of variation, however, was 50—60 per cent. Fig. 19 shows graphically the quantity of tendinous tissue in the different interspinous ligaments at different ages in the plane measured by the author. It shows more clearly the development mentioned above.

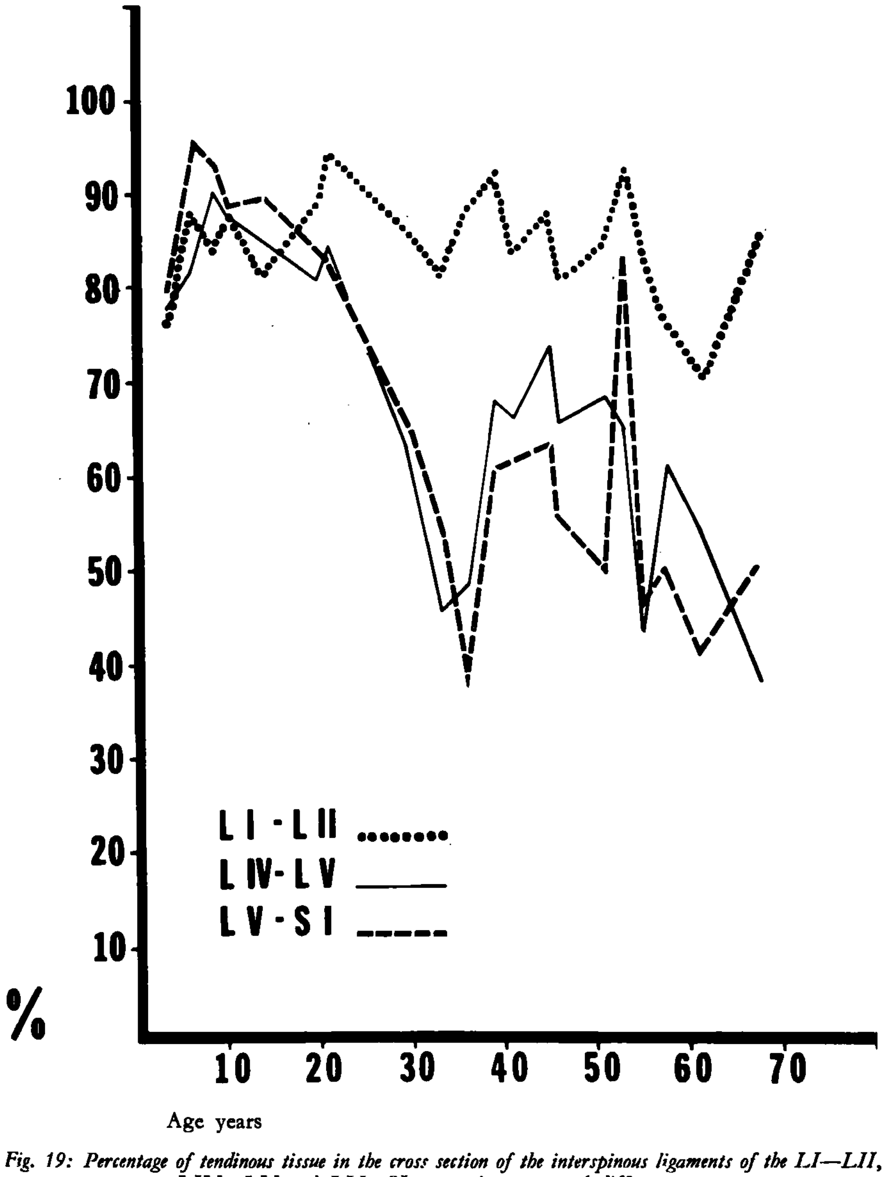



*Fig. 19: Percentage of tendinous tissue in the cross section of the interspinous ligaments of the LI—LII, LIV—LV and LV—SI spaces in persons of different ages.*

## TABLE 1

*The proportion of the different components in the measurement plane of the interspinous ligaments in persons of different ages.*

| Age | Space | Fibro-cartilage % | Tendon % | Loose connective tissue % | Fat % | Cavity % | Blood vessels % |
|---|---|---|---|---|---|---|---|
| 2½ yrs. | LV—SI | 3,1 | 78,8 | 5,4 | 12,7 | — | — |
| | LIV—LV | 2,0 | 77,2 | 3.6 | 17,2 | — | — |
| | LI—LII | 2,9 | 75,7 | 8,3 | 11,9 | — | 1,2 |
| 4½ yrs. | LV—SI | 3,2 | 95,4 | 0,3 | 1,1 | — | — |
| | LIV—LV | 3,0 | 83,4 | 1,4 | 12,7 | — | 0,5 |
| | LI—LII | 2,5 | 88,0 | 2,7 | 6,6 | — | 0,2 |
| 7½ yrs. | LV—SI | 3,1 | 91,5 | 5,4 | — | — | — |
| | LIV—LV | 2,1 | 90,3 | 3,4 | 3,0 | — | 1,2 |
| | LI—LII | 1,7 | 84,4 | 8,9 | 4,0 | — | 1,0 |
| 9 yrs. | LV—SI | 3,0 | 88,3 | 4,0 | 4,5 | — | 0,2 |
| | LIV—LV | 3,1 | 87,7 | 2,6 | 6,2 | — | 0,4 |
| | LI—LII | 1,0 | 87,7 | 11,0 | — | — | 0,3 |
| 13 yrs. | LV—SI | 3,8 | 89,2 | 6,3 | 0,5 | — | 0,2 |
| | LIV—LV | 2,2 | 83,7 | 4,9 | 7,7 | — | 1,5 |
| | LI—LII | 2,5 | 81,2 | 3,6 | 12,0 | — | 0,7 |
| 19 yrs. | LV—SI | 4,6 | 83,4 | 11,1 | 0,5 | — | 0,4 |
| | LIV—LV | 5,2 | 80,2 | 14,1 | — | — | 0,5 |
| | LI—LII | 1,9 | 89,3 | 8,8 | — | — | — |
| 20 yrs. | LV—SI | 3,2 | 80,4 | 16,4 | — | — | — |
| | LIV—LV | 3,5 | 81,6 | 14,7 | — | — | 0,2 |
| | LI—LII | 2,5 | 93,0 | 4,2 | — | — | 0,3 |
| 29 yrs. | LV—SI | 3,0 | 63,4 | 33,4 | — | — | 0,2 |
| | LIV—LV | 2,2 | 62,6 | 6,6 | 0,2 | 28,3 | 0,1 |
| | LI—LII | 5,8 | 84,9 | 9,3 | — | — | — |
| 32 yrs. | LV—SI | 3,3 | 52,8 | 38,6 | — | 4,9 | 0,4 |
| | LIV—LV | 9,1 | 45,4 | 37,1 | — | 8,0 | 0,4 |
| | LI—LII | 5,0 | 81,0 | 13,8 | — | — | 0,2 |
| 35 yrs. | LV—SI | 9,8 | 37,7 | 17,8 | 1,1 | 33,3 | 0,3 |
| | LIV—LV | 4,2 | 48,6 | 45,0 | — | 1,1 | 1,1 |
| | LI—LII | 1,0 | 87,5 | 9,5 | 1,8 | — | 0,2 |
| 38 yrs. | LV—SI | 1,5 | 62,4 | 32,7 | 1,8 | — | 1,6 |
| | LIV—LV | 2,4 | 67,8 | 27,7 | 0,4 | 1,2 | 0,5 |
| | LI—LII | 1,0 | 91,1 | 7,6 | — | — | 0,3 |

| Age | Space | Fibro-cartilage % | Tendon % | Loose connec-tive tissue % | Fat % | Cavity % | Blood vessels % |
|---|---|---|---|---|---|---|---|
| 40 yrs. | LV—SI | 2,3 | 62,1 | 32,1 | 2,1 | 1,1 | 0,3 |
| | LIV—LV | 1,7 | 65,5 | 26,7 | 0,8 | 3,7 | 1,6 |
| | LI—LII | 1,5 | 82,9 | 15,2 | — | — | 0,4 |
| 44 yrs. | LV—SI | 4,7 | 63,4 | 16,4 | 5,6 | 9,6 | 0,3 |
| | LIV—LV | 7,1 | 73,3 | 11,6 | — | 7,6 | 0,4 |
| | LI—LII | 1,6 | 86,3 | 10,9 | 0,4 | — | 0,8 |
| 45 yrs. | LV—SI | 15,6 | 55,7 | 28,7 | — | — | — |
| | LIV—LV | 7,2 | 65,1 | 14,2 | 0,2 | 13,2 | 0,1 |
| | LI—LII | 4,9 | 80,0 | 15,1 | — | — | — |
| 50 yrs. | LV—SI | 5,2 | 48,9 | 37,6 | 5,0 | 3,2 | 0,1 |
| | LIV—LV | 5,4 | 68,4 | 24,7 | 0,7 | 0,6 | 0,2 |
| | LI—LII | 3,8 | 83,7 | 12,3 | — | — | 0,2 |
| 52 yrs. | LV—SI | 9,3 | 83,3 | 7,7 | — | — | — |
| | LIV—LV | 1,4 | 63,9 | 28,5 | 5,3 | — | 0,9 |
| | LI—LII | 3,2 | 86,7 | 6,6 | 3,5 | — | — |
| 54 yrs. | LV—SI | 5,5 | 46,4 | 24,5 | — | 22,6 | 1,0 |
| | LIV—LV | 6,9 | 42,7 | 20,7 | — | 29,5 | 0,2 |
| | LI—LII | 7,6 | 82,1 | 6,4 | 2,6 | — | 1,3 |
| 56 yrs. | LV—SI | 8,3 | 50,2 | 31,9 | — | 9,3 | 0,3 |
| | LIV—LV | 5,5 | 60,7 | 25,4 | — | 8,1 | 0,3 |
| | LI—LII | 2,8 | 76,2 | 21,0 | — | — | — |
| 61 yrs. | LV—SI | 6,9 | 41,0 | 42,4 | 0,9 | 8,4 | 0,4 |
| | LIV—LV | 5,6 | 54,1 | 31,9 | — | 8,4 | — |
| | LI—LII | 4,3 | 69,2 | 26,0 | — | — | 0,6 |
| 67 yrs. | LV—SI | 8,0 | 49,9 | 36,0 | — | 5,5 | 0,6 |
| | LIV—LV | 3,2 | 38,6 | 27,7 | 1,1 | 29,3 | 0,1 |
| | LI—LII | 3,7 | 82,4 | 13,2 | — | — | 0,7 |

The table also shows that when the percentage of tendinous tissue decreases in the lowest lumbar spaces the quantity of loose connective tissue or cavities increases in the same space. In other words, one of them or both have replaced the tendinous tissue. The quantity of loose connective tissue rose to 45 per cent in some cases, whereas it was only a couple of per cent in young subjects. The area of cavities in the surface of the cross section was a little over 30 per cent at its maximum. Normally they were not found at all.

The formation of cavities in the lowest lumbar spaces of the interspinous ligaments with advancing age is a very common phenomenon. The older the person, the greater is the likelihood of a cavity in the middle of his interspinous ligaments. This cavity formation is most common in the LIV—LV space, then in the LV—SI and LIII—LIV spaces. Incipient cavity formation is often seen just in these three spaces in younger persons, in older subjects also in the upper spaces. If there are cavities in several spaces they are usually greatest in the LIV—LV space.

To indicate how common this cavity formation is, a sample of 20 persons aged 61—70 and 20 persons aged 31—40 was studied for macroscopically demonstrable cavitation in the interspinous ligament in the LIV—LV space. It was possible to establish in the former with the naked eye minor or major cavity formation in 17 cases (85 per cent), in the latter group in 15 cases (75 per cent). In the rest of the cases the centre of the ligament was more or less slack than the edges, thus indicating disappearance of tendinous tissue.

Cavities began to originate at sites of predilection immediately after the 20th year of age. The cavity formation was more vigorous in those with pronounced lordosis. The formation of cavities began in the dorsal part of the interspinous ligament and spred gradually in a more ventral direction. It was common to find a very large cavity, e.g. in the LIV—LV and LV—SI spaces extending right up to the ventral part of the ligament, a somewhat smaller one in the LIII—LIV space and the very small beginning of a cavity in the dorsal part of the ligament in the LII—LIII space. It seems 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 appears at the site.

The cavities described can thus be either empty or partly filled with fatty tissue and loose connective tissue. They are mostly unilocular, more rarely labyrinthine, multilocular. In younger persons and in incipient cavities the walls are generally uneven, rough. In older subjects and larger cavities the walls usually grew smooth, especially where they faced the spinous processes. In such cases the edges of the spinous processes were sometimes worn oblique and pearly in colour. Externally, the ligament may appear intact although there is a cavity inside.

When cavity formation occurs in the middle of the ligament the result is thinning of the ligament wall. This process often acquires considerable proportions in the elderly, with only thin walls of the ligament remaining on both sides of the cavity. Very pronounced changes are also established sometimes in people under 30.

Not a single case of cavity formation was found in subjects under 20 in the present series, although in some cases the centre of the lowest ligaments appeared to be somewhat slacker than the edges. Fig. 20 shows

*Fig. 20: Frontal section of the interspinous ligaments of spaces LI—LII, LIV—LV and LV—SI, in this order, starting from the left. A woman of 20, the ligaments intact externally, dense and unbroken inside. Weigert-van Gieson, × 2.*

frontal sections of the interspinous ligaments of the LI—LII, LIV—LV and LV—SI spaces of a woman of 20. They are all unbroken and dense. Fig. 21, on the other hand, shows the frontal sections of the corresponding ligaments of a woman of 35. There are no changes in the LI—LII space, the LIV—LV space shows in the middle an incipient cavity formation, and there is a large cavity in the LV—SI space. Fig. 22 shows interspinous ligaments of the LIV—LV space with cavities of different size.

The illustrations also reveal clearly that when cavities originate within the ligaments, the ligaments are thickened considerably. In discussing the normal anatomy of interspinous ligaments (pp. 44) it was mentioned that the thickness of healthy ligaments in a person under 20 years of age is c. 1—2 mm in the uppermost lumbar spaces and c. 2—3 mm in the lowest.

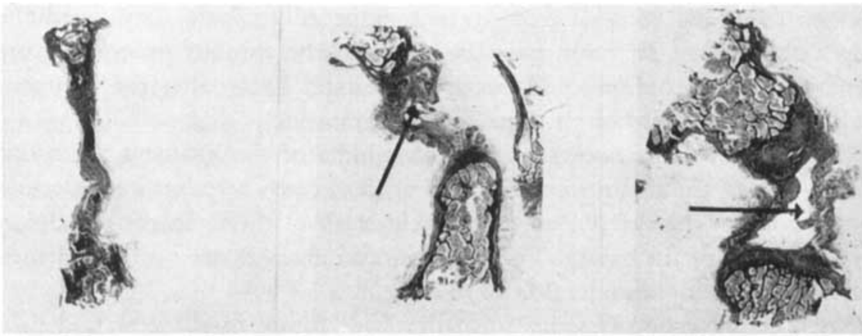


*Fig. 21: Frontal section of the interspinous ligaments of spaces LI—LII, LIV—LV and LV—SI, in this order, starting from the left. A woman of 35, the ligaments intact externally. The ligament of the LI—LII space normal in the cross section; a few small incipient cavities in the middle of the ligament of the LIV—LV space; a large cavity in the middle of the ligament of the LV—SI space. Weigert-van Gieson × 2.*

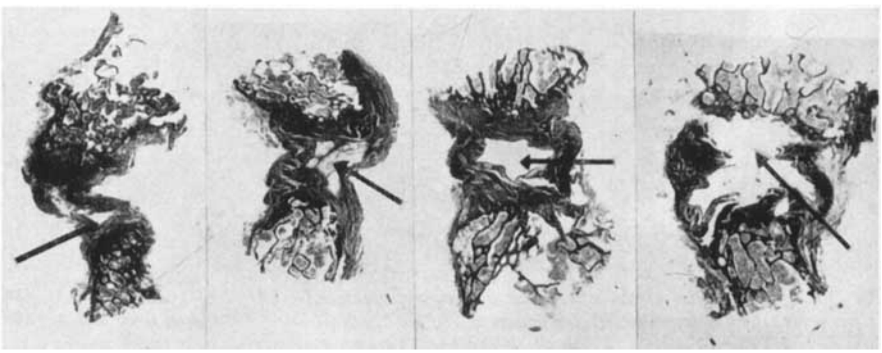


*Fig. 22: Cavities of different size in the interspinous ligament of the LIV—LV space. From the left: a woman of 32, a woman of 40, a man of 54 and a woman of 82. All the ligaments were intact in the external view. The illustrations show the frontal section of the ligaments. Weigert-van Gieson, × 2.*

The thickness of the interspinous ligaments of the LI—LII space and often also of the LII—LIII space usually does not change with age. Measured externally, thickening of the ligament with age is most pronounced in the LIV—LV space in which thicknesses of 8—12 mm are fairly common. It is more rarely that ligaments of this thickness can be found before the age of 30. In some cases interspinous ligament LV—SI is the thickest, but mostly both it and the ligament of the LIII—LIV space are slightly thinner, range 4—10 mm.

Concurrently with the formation of cavities and thickening of the ligaments changes occur on the margins of the spinous processes to which the ligaments are attached. A thickening of exactly corresponding size is established in them and they lose the spindle-shaped form they have in young persons.

The thickening of the interspinous ligaments thus does not take place at the expense of the tendinous tissue but of the loose connective tissue and the fatty tissue. The true tendinous tissue, on the other hand, may be reduced to thin layers on both margins of the ligament.

Similarly to cavity formation, the thickening of the ligaments also shows individual variation. This phenomenon is most permanent in the LIV—LV space, then in the LIII—LIV space. Considerable variation occurs on the other hand in the ligament of the LV—SI space. The graph on p. 53, showing the percentage of the tendinous tissue in the measured plane of different interspinous ligaments in persons of different ages, displays a clear peak at the ligament of the LV—SI space in a person of 52. The amount of tendinous tissue in this space is similar to that in the ligament of the LI—LII space. The ligament was only c. 2 mm thick in this space. A total of 14 (slightly under 8 per cent) such examples, viz. showing a great difference between the ligaments of the LIV—LV and LV—SI spaces, was found in subjects over 20. In a typical instance there could be a large cavity in the middle of the interspinous ligament of the LIV—LV space and a ligament thickness of 8 mm whereas in the LV—SI space the ligament could be of uniform density and only 2 mm thick. In one of these cases, while detaching the sample, the author happened to remove the neural arch from a slightly wider area and thus established sacralisation on the right aspect of fifth lumbar vertebra. In the other cases the preparation was detached from so close to the base of the spinous process that no formation of this type could be observed.

As shown in Fig. 15, fatty aggregates can sometimes be seen between the fibre bundles. Where a cavity had originated in the middle of such a ligament it was sometimes possible to pass a sound between the fibre bundles although there was no actual rupture in the ligament.

*Discussion:* Origination of cavities in the middle of interspinous ligaments is a very common phenomenon. The present series shows, however, that real »kissing spine» is not an absolute precondition for their formattion. Morbus Baastrup cases are relatively rare and were only established a couple of times with certainty in the present material. Cavity formation begins in the dorsal part of the ligament and is most pronounced in two or three of the lowest lumbar spaces, where the lordosis also is most pronounced. The cavities emerge earlier and more vigorously in persons with marked lordosis. These observations lend support to the assumption that the rubbing of the spinous processes against one another, either directly by destroying the tissues or indirectly by causing degeneration, has a role in the origination of cavities. There is reason, on the other hand, to assume that other factors also are involved.

*Summary: The percentage of tendinous tissue in the lowest interspinous ligaments begins to decrease and that of loose connective tissue to increase immediately after the 20th year of age. Cavities originate at the same time in the middle of the lowest interspinous ligaments. Their formation is most common in the LIV—LV space where it was established macroscopically in as many as 75 per cent of subjects aged 31—40. At the same time, the ligaments thicken considerably measured on the outside. The changes become rare on moving upwards.*

## B. Histopathologic changes

*Earlier investigations:* The author has found no information in the literature on the histopathologic changes occurring in interspinous ligaments.

On the other hand, histopathologic changes occurring in different tendons during life have been reported. ALBERTINI (1929) stated that the fatty degeneration of the tendinous tissue was general, and SCHAER (1936) reported that he had found it in the tendon of the supraspinatus in the shoulder in practically all persons after the age of 50. Calcification is also common in this site. DEPALMA (1952) reported breaking and fragmentation of the fibre bundles in the tendon of the supraspinatus by the third and fourth decade, also hyalinisation, calcification, proliferation of cell elements and blood vessels and metaplasia of tendinous tissue into fibrocartilage. Cell proliferation and the accumulation of acid mucopolysaccharides in the degenerative processes of the different tendons have been reported by DELARUE et al. (1955). EUFINGER (1957) reviewed various forms of degeneration, inclusive of necrosis, in the tendon of the supraspinatus of the shoulder.

*Own investigations:* As could be assumed from observations with the naked eye the interspinous ligaments undergo with age very pronounced and deep changes in the microscopic picture.

One of the earliest changes observed by the author was the fine-grained fatty degeneration in collagenous fibre bundles. Some local, very small foci of fatty degeneration were found in a very mild form in the interspinous ligament of the LV—SI space in a subject of no more than 13 years of age; there was no corresponding condition in the ligament of the LI—LII space in the same individual. Fatty degeneration became more and more common with age and almost all middle-aged persons displayed milder or more marked fatty degeneration in both the upper and lower interspinous ligaments of the lumbar spine. It was usually more pronounced in the latter than in the former. The greatest changes were often established in the area of the medial part of a single ligament and areas containing great quantities of fatty particles alternated with areas that were fully or nearly normal in this respect. The degeneration could be considerable in the old, aged 80—90 years, with nearly the whole ligament showing fatty degeneration especially in the lowest interspinous ligaments. Besides the fine-grained fatty degeneration observed in them, sometimes the dye stained the surface of the fibre bundles evenly and diffusely. Figs. 23a and 23b illustrate Hematoxylin-Sudan IV staining of the interspinous ligaments of the LIV—LV space in women of 38 and 81 years.

Soon after the middle of the second decade changes began to appear in some persons in the lowest 2—3 interspinous ligaments, and around the age of 20 they were already relatively clearly visible in most subjects.

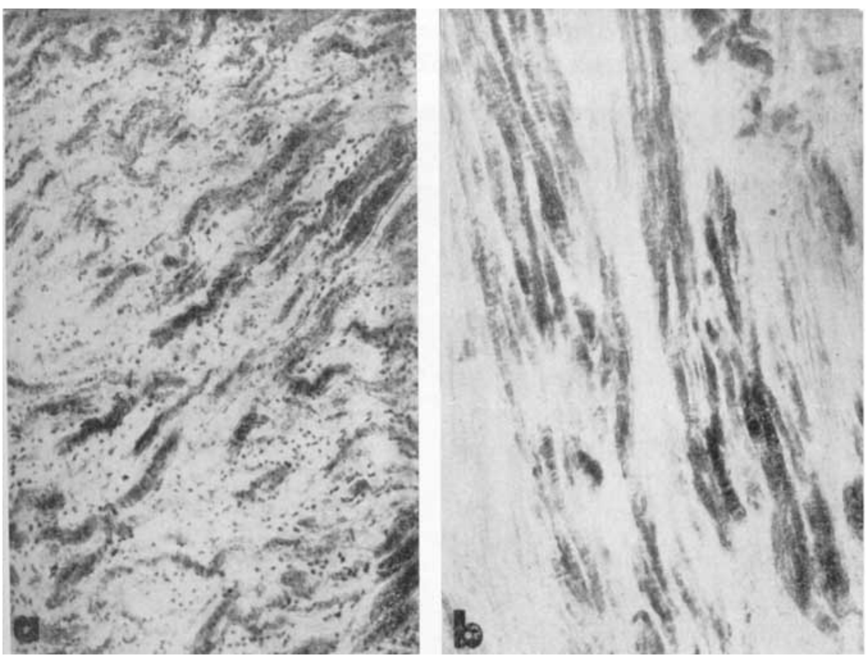



*Fig. 23: Fatty degenerations of various degrees in the interspinous ligaments of the LIV—LV space. Hematoxylin-Sudan IV, × 120.*
*(a) a woman of 38. Besides the fatty degeneration, the profusion of cells in the degenerated area attracted the attention.*
*(b) a woman of 81.*

The collagenous bundles were partly broken and destroyed in the middle of the medial part of the ligament, and in other parts the fibre bundles showed no reaction to Weigert-van Gieson or stained only faintly. In some places the tendinous fibre bundles had lost their normal dense structure (Fig. 24). The fibre bundles had shrunk in places, in a wavelike fashion. By the age of 20 it was sometimes possible to see extensive areas where intact tendinous tissue had ceased to exist, leaving only thin, frayed and broken fibres. The fibre bundles, however, were morphologically preserved here and there, but after the 30th year many of them too showed the incipient hyalinisation which achieves considerable proportions in old persons. The collagenous bundles appeared homogeneous and swollen in places.

A considerable decrease in the number of nuclei was often observed, especially in older people, in the areas of the ligament that stain faintly. Extensive areas had no cells at all. On the other hand, a sporadic but distinct accumulation of round cells at certain points in the degenerated tendinous tissue, and metaplasia of cartilage cells were seen (Fig. 25). More typical and common, however, was marked proliferation of fibroblasts and small blood vessels in the areas of degeneration. In the early phase

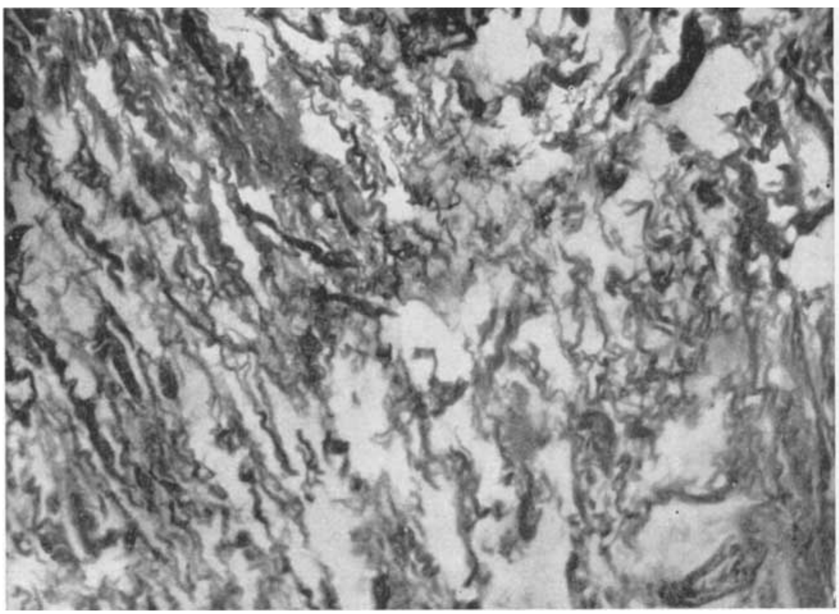


*Fig. 24: Incipient degeneration in the medial part of the interspinous ligament of the LV—SI space in a young man of 18. The fibre bundles have lost their dense structure, there is breaking and wavelike shrinkage. A part of the bundles stain very faintly. Weigert-van Gieson, × 120.*

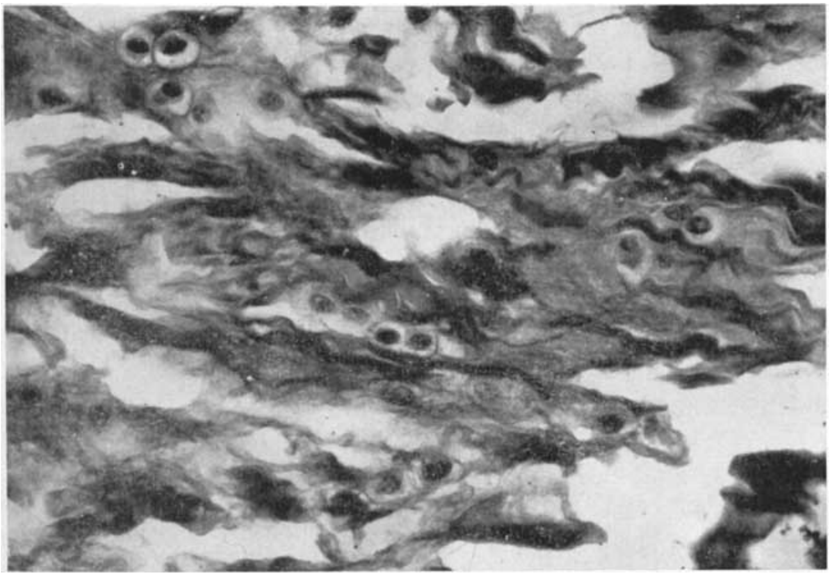


*Fig. 25: Partly necrobiotic, faintly staining, torn tendinous tissue in the middle of the interspinous ligament of the LV—SI space in the subject of Fig. 24. Cartilage cell metaplasia in the area. Weigert-van Gieson, × 400.*

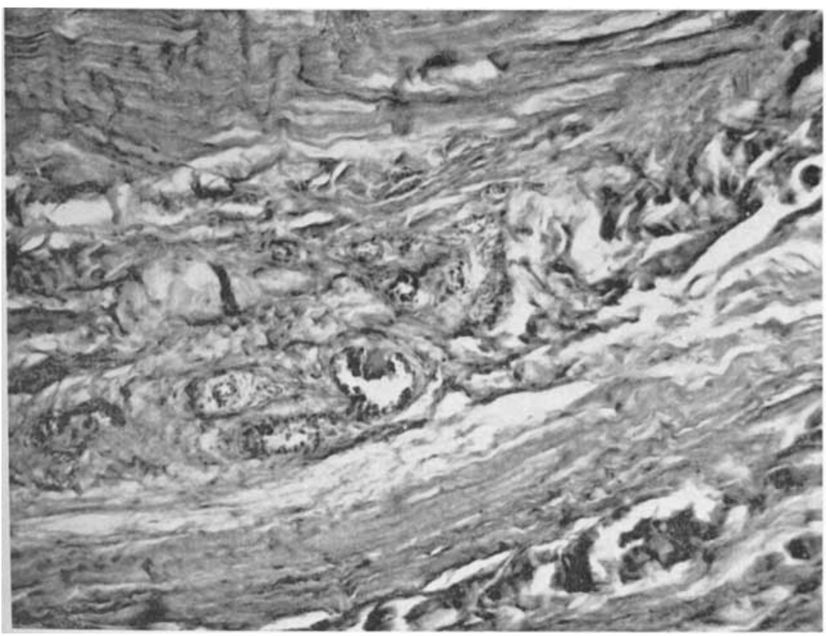


*Fig. 26: Incipient vascular and cellular proliferation in a focus of aegeneration in the interspinous ligament of the LIV—LV space. A man of 46. Weigert-van Gieson, × 120.*

this new formation often occurred only in well-demarcated places between the still preserved tendinous fibre bundles (Fig. 26); but later, when the tendinous bundles had been destroyed, it spread diffusely over wide areas. The proliferation of such granulation tissue was locally very pronounced in some cases (Figs. 27 and 28). Delicate newly-formed connective tissue, which often still included numerous fatty cells, could be established in the proliferation sites after the disappearance of the actual tendinous structure (Fig. 29).

Histochemical staining methods showed considerable changes in the areas in which the phenomena described above were demonstrated. It was possible to see on toluidine blue staining in the still preserved parts of the tendinous tissue areas which stained metachromatically in definite contrast to their environment. Metachromasia could be present diffusely in somewhat wider areas, or there were sporadic metachromatic spots as in Fig. 30. On the other hand a distinct metachromatic colour was seen in places around the vascular and cellular proliferations in the degeneration areas unless the true tendinous tissue had disappeared completely and been replaced by faint newly-formed connective tissue. Alcian blue staining

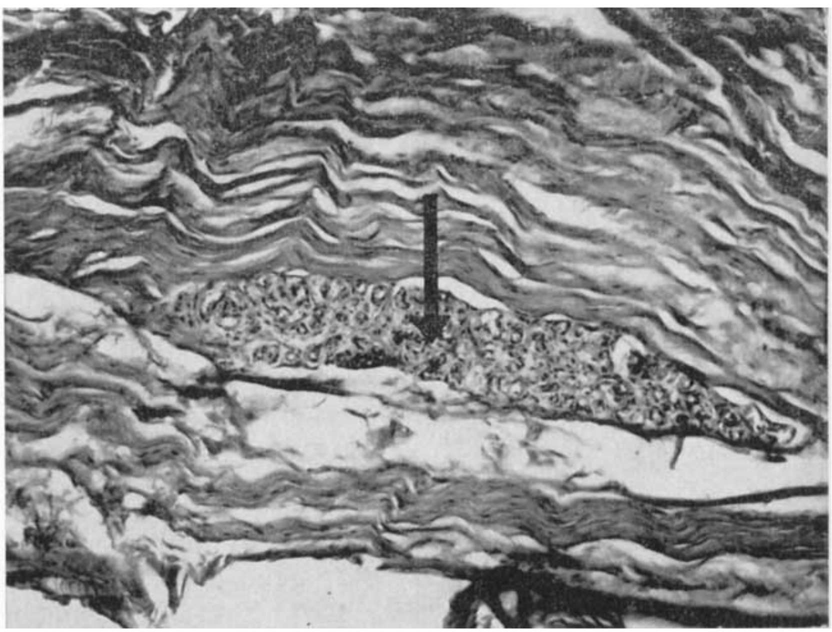


*Fig. 27: Marked local proliferation of the small blood vessels and cells (arrow) close to the edge of the cavity in the middle of the ligament. Edge of the cavity visible at the bottom of the picture. The same preparation as in Fig. 26, × 120.*

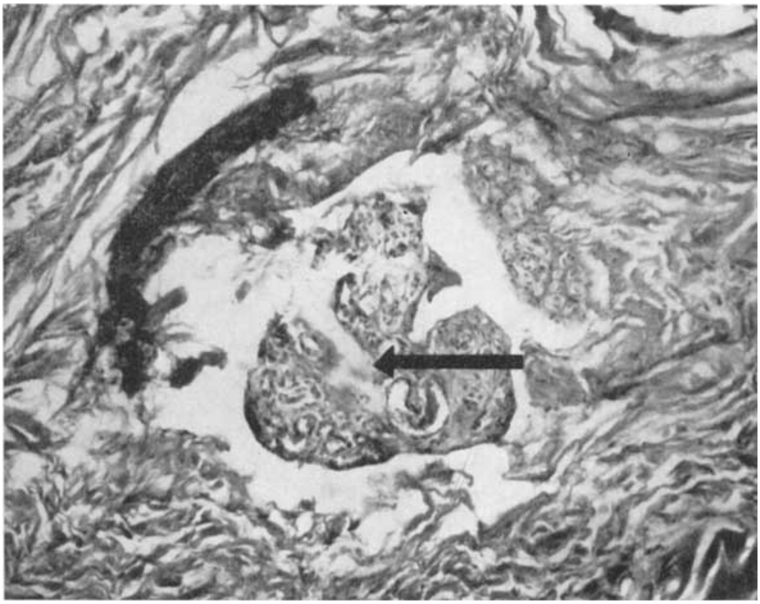


*Fig. 28: Local proliferation of blood vessels and cells in the middle of degenerated tendinous tissue of the ligament. The same subject as in Fig. 27, × 120.*

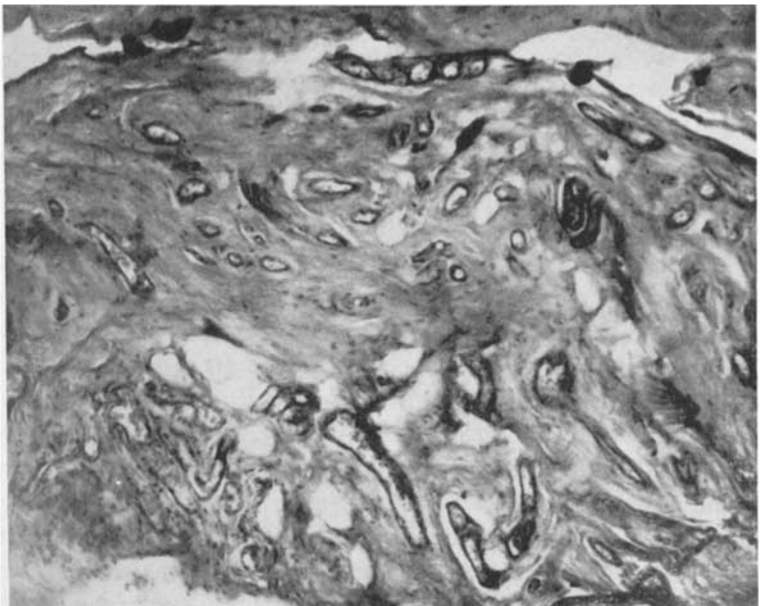


*Fig. 29: Newly-formed connective tissue in an area containing numerous blood vessels and cells in the interspinous ligament of the LIV—LV space. A man of 61. P.A.S. × 120.*

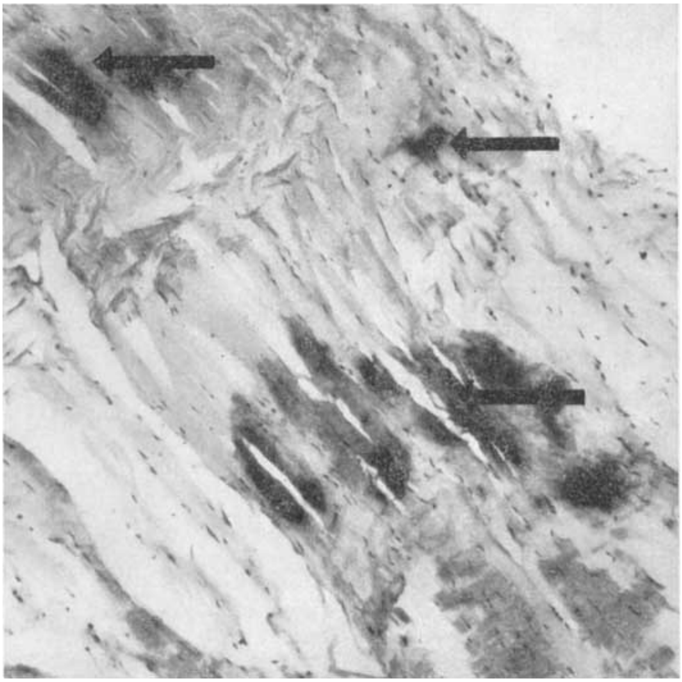


*Fig. 30: Metachromatically staining areas in the interspinous ligament of the LV—SI space close to the edge of the cavity in the middle. A man of 61. Toluidine blue, × 120.*

revealed in the areas of degeneration, among collagenous fibre bundles which still stained red, bluish-green places (Fig. 31). Mucopolysaccharides were consequently involved here. When the preparations in question were pretreated with testicular hyaluronidase and stained the metachromasia was found either to have disappeared or to have diminished in those places of the tendinous tissue in which it had been found in the untreated stained preparation. Some of the metachromatic areas, on the other hand, did not change their colour at all.

As testicular hyaluronidase decomposes hyaluronic acid, chondroitin sulphate A and C (MEYER & RAPPORT 1951, MEYER 1954, MEYER et al. 1959), one or more of these acid mucopolysaccharides may have been present in the places of degeneration. In some areas, however, metachromasia does not change on enzyme treatment and it is therefore possible that there are even other mucopolysaccharides in a degenerating ligament. Chondroitin sulphate B does not respond to the testicular hyaluronidase which may be found in the sites of degeneration, or there may be some

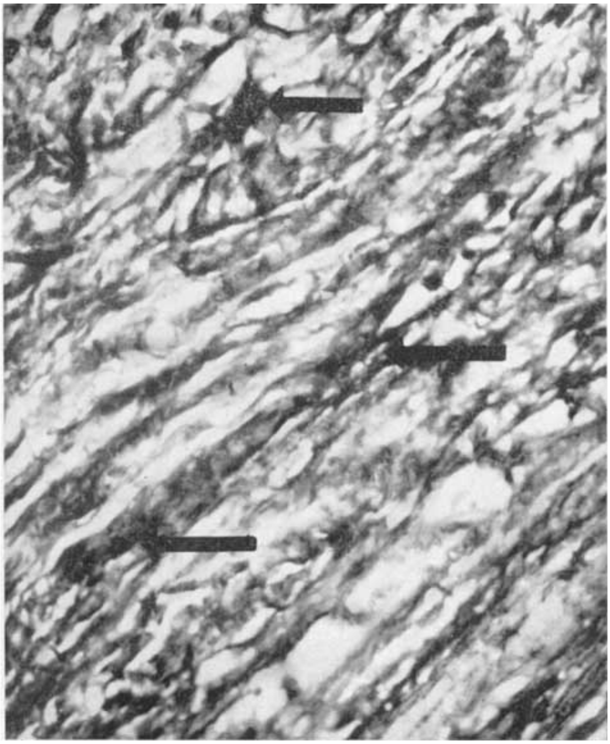


*Fig. 31: Alcian blue staining, from the middle of the interspinous ligament of the LV—SI space. Aman of 20. Places in the collagenous bundles staining the bluish-green of mucopolysaccharides.* × *120.*

less well-known mucopolysaccharides. The ligament in any case contains histochemically demonstrable mucopolysaccharides which are typical of degeneration and subsequent attempts at repair (ALTSCHULER & ANGEVINE 1954). The accumulation of mucopolysaccharides observed around the proliferations of fibroblast type cells shows that the proliferation of cells and blood vessels involves a reactive process.

Very heavily stained areas could be found sporadically in the still preserved tendinous tissue in preparations stained by the P.A.S. technique. Closer examination showed that some collagenous fibre bundles had stained heavily but very unevenly while the environment was negative (Fig. 32). Sometimes round cells also accumulated in these areas. There was no change in the stainability of preparations pretreated with diastase. Hence the agent in question cannot be glycogen. Hyaluronic acid and chondroitin sulphuric acids do not give P.A.S.-positive reactions (GLEGG et al. 1952,

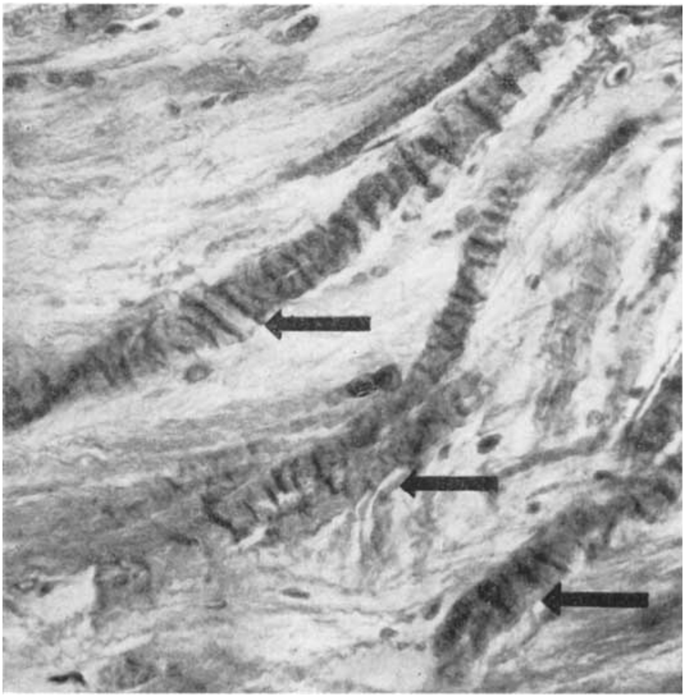


*Fig. 32: P.A.S.-positive areas in the interspinous ligament of the LIV—LV space in a man of 50. P.A.S. × 400.*

DAVIES 1952) and hence these agents are probably not in question here. P.A.S.-positive neutral mucopolysaccharides in different connective tissue components have been described (GLEGG et al. 1954). The areas of degeneration may contain these neutral mucopolysaccharides or possibly degeneration products of the mucopolysaccharides or proteins.

In children, all parts of the interspinous ligaments are composed of tendinous tissue. Marked metaplasia of the tendinous tissue into fibrocartilage especially in the lowest interspinous ligaments, was noted after the 20th year. This did not occur evenly throughout the ligament but only at the places of departure and attachment of the fibre bundles beside the bone. Fibrocartilage formation was most pronounced in the dorsal and medial part of the ligament. In the ventral portion it was hardly present at all or was very scanty, even in old persons. The quantity of fibrocartilage increased with age in the lowest interspinous ligaments (see Table 1). Considerable enchancement of the metachromatic property was observed concurrently in the area of the fibrocartilage. After 30 years of age it was sometimes possible on toluidine blue staining to see small patches in the middle of the metachromatic field of the fibrocartilaginous and tendinous area of the dorsal and medial part of the interspinous ligaments. These patches stained not metachromatically but bright blue, and they seemed to be homogeneous. Alcian blue stained the areas bluish-green, the colour of mucopolysaccharides. The changes established in younger subjects were generally fairly small, clearly demarcated patches longish or irregular in shape, in the centre of the metachromatic field. In older persons the changes could occur over larger areas. After testicular hyaluronidase treatment the metachromasia of the fibrocartilaginous area diminished slightly, but the areas that had stained blue show no change compared with the controls.

The principal mucopolysaccharide of the cartilage is chondroitin sulphate A which may have increased and caused intensification of metachromasia in the area of fibrocartilage. The disappearance of metachromasia may be caused by a fall in the acid mucopolysaccharide concentration, loss of the acid groups through binding with proteins or the disintegration of the molecular structure of polysaccharides (PEARSE 1960). When such patches appear in the middle of metachromatic areas it seems probable that some changes reminiscent of those described in the foregoing take place in the mucopolysaccharides and cause the disappearance of metachromasia.

After the 30th year of age swelling and rounding were established in the cartilage cells in places concomitantly with the changes reviewed above. In some places, especially in the fibrocartilage of the dorsal part of the ligament, there were roundish vacuoles in the middle of marked metachromasia. They were either isolated or in small groups or rows, reacted to no stain and appeared to be empty. As there were necrotic cartilage cells in the environment, it seems probable that the vacuoles were disintegrated cartilage cells whose contents had been washed away.

The fibrocartilage in middle-aged and older subjects was seen to have lost its typical structure in the central and dorsal parts of the ligament close to the bony surface. Fibrillation had diminished or disappeared in the intermediate substance of the cartilage which had become more homogeneous. At the same time, large cartilage cell colonies had formed, containing up to 30 cells in the section plane of the preparation (Fig. 38). The majority of them, however, were colonies containing a few cells. Fibrocartilage had thus been replaced sporadically by tissue resembling hyaline cartilage.

Metaplastic osteogenesis beside the bone surface began before the 30th year, especially in the fibrocartilaginous part of the lowest interspinous ligaments. It never, however, acquired such proportions as in the supraspinous ligament. In the area of the medial part bone metaplasia was almost non-existent, in the dorsal part slightly more marked. The precipitation of fine-grained calcium salts in degenerated interspinous ligaments, on the other hand, was a very common phenomenon especially in the fibrocartilaginous part but also in tendinous tissue in the middle of the ligament.

Small incipient cavities in which the tendinous tissue had disappeared completely could sometimes be demonstrated microscopically in the middle of the lowest interspinous ligaments before the 20th year. Here and there the sections showed completely empty areas, at first fairly limited but later also larger, in the middle of markedly degenerated tendinous tissue, broken, fragmented, frayed and necrotic fibre bundles. In the initial phases the cavities were not very clearly distinguishable from their environment, there was no distinct wall. However, well-demarcated walls gradually originated and once they formed, often before the 30th year, interesting features emerged on microscopy. The cavity walls on the side of the spinous processes were sometimes composed of dense connective tissue of homogeneous appearance. Its cell content was small (Fig. 33) and the cells were mostly some distance from the surface. There were transitional cases of this type to cases in which the cavity was bounded towards the spinous processes by fibrocartilage-like tissue which stained strongly metachromatic. It was very common in persons 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 and containing typical cartilage cell colonies. This tissue stained metachromatically (Fig. 34). It seemed, however, to undergo changes relatively soon. Weigert-van Gieson staining revealed how the small cartilage cell colonies, which had dominated at first, disappeared and were replaced by large colonies containing several tens of cartilage cells. Toluidine blue staining showed how metachromasia disappeared first from the edge of the cavity, later even deeper in the stroma which stained only faintly bluish or not at all. Some of the nuclei of the cartilage cell colonies were necrotic, in others all the nuclei had disappeared and all that was left was some mass which also had often lost its metachromatic quality.

The lateral walls of the cavities were sometimes dense granulation tissue with a high cellular and vascular content (Fig. 35). More frequently, the cavities were bounded by loose, adipose connective tissue on the surface of which could be seen a continuous mesothelial cell layer of either fairly high or flattened cells (Fig. 36).

The cavities did not reveal a smooth surface under the microscope; numerous villi, thinner and thicker folds emerged from the walls. The

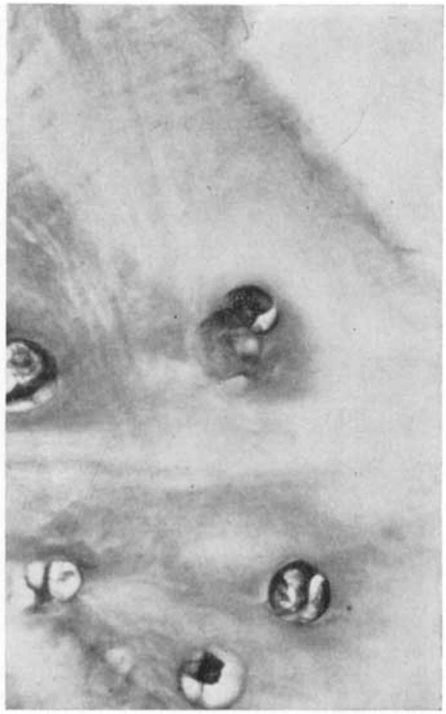


*Fig. 33: Margin of the cavity in the middle of the interspinous ligament of the LIII—LIV space. Weigert-van Gieson,* × *400. A woman of 69.*

*Fig. 34: Margin of the cavity in the interspinous ligament of the LV—SI space in a man of 61. Toluidine blue,* × *400. The extreme edge of the cavity does not stain metachromatically, but the deeper part shows a strong metachromatic reaction.*

villi were mostly composed of very delicate newly-formed connective tissue containing profuse cellular elements, blood vessels and fatty cells (Fig. 37); sometimes they consisted of tissue resembling degenerated hyaline cartilage (Fig. 38).

The cavities originating inside the interspinous ligaments thus, together with the surfaces of the adjacent spinous processes, made ut 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).

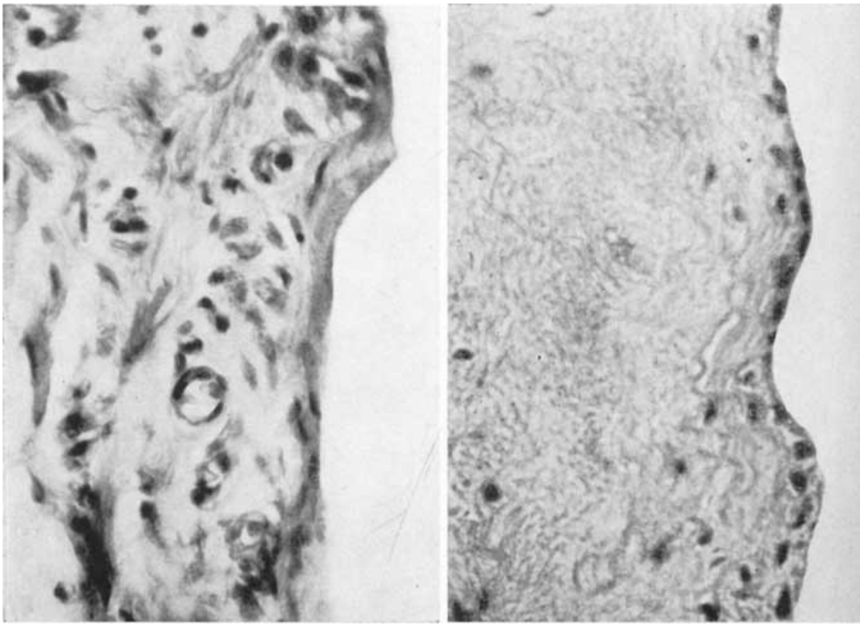


*Fig. 35: Margin of the cavity in the interspinous ligament of the LIV—LV space in a man of 46. Newly-formed connective tissue, numerous cells and blood vessels. Weigert-van Gieson, × 400.*

*Fig. 36: Margin of the cavity in the interspinous ligament of the LV—SI space in a man of 76. Mesothelial cell layer. Toluidine blue, × 400.*

*Discussion:* BAASTRUP stated that mechanical chafing destroys the interspinous ligaments in cases of »kissing spine». It will become clear from the foregoing that pronounced changes take place in the interspinous ligaments. In the lowest interspinous ligaments they set in at an early phase. To a great extent the changes are similar to those reported by various authors as occurring in the degeneration of other tendons and ligaments. The changes established in interspinous ligaments are thus degenerative by nature and surely play a role in the formation of the cavities found inside the ligaments. Thus it is not merely mechanical rubbing that is involved although mechanical factors must be of decisive importance in provoking degenerative changes.

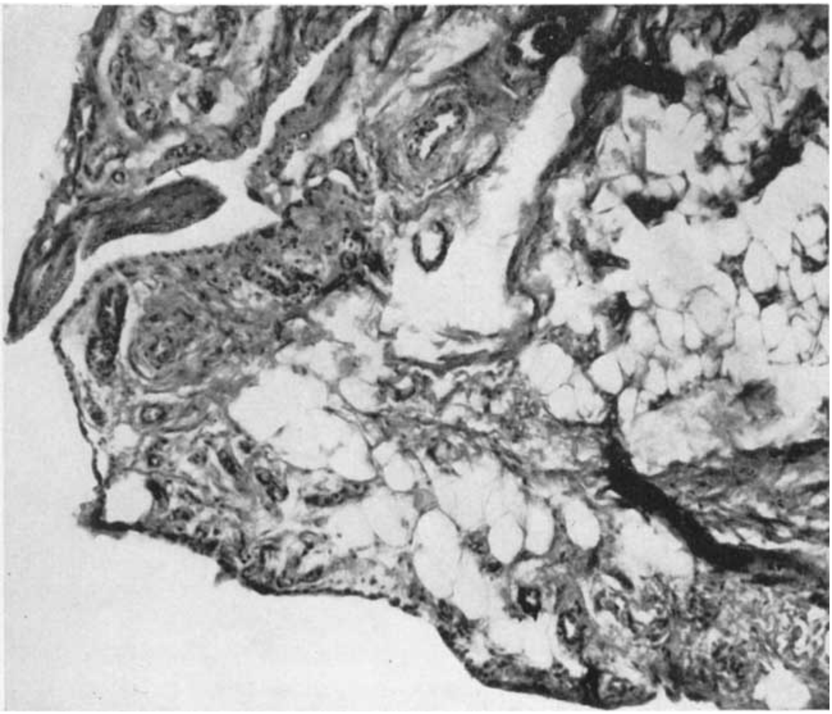


*Fig. 37: A projection invading the cavity inside the interspinous ligament of the LV—SI space. Note the mesothelial cover of fairly high cells and high vascular, cellular and fatty content in the stroma. Weigert-van Gieson, × 120. A man of 46.*

*Summary: Distinct histopathologic changes can be established before the 20th year of age in the lowest interspinous ligaments of some individuals. They become more common and more pronounced with age and can be stated also in the upper spaces. The principal and most frequent changes are fatty degeneration, breaking, fragmentation and necrotisation of fibre bundles, hyalinisation, calcification, proliferation of cells and blood vessels, accumulation of various mucopolysaccharides, metaplasia into fibrocartilage and degenerative changes in it. The cavities inside the interspinous ligaments may show features typical of joints under the microscope.*

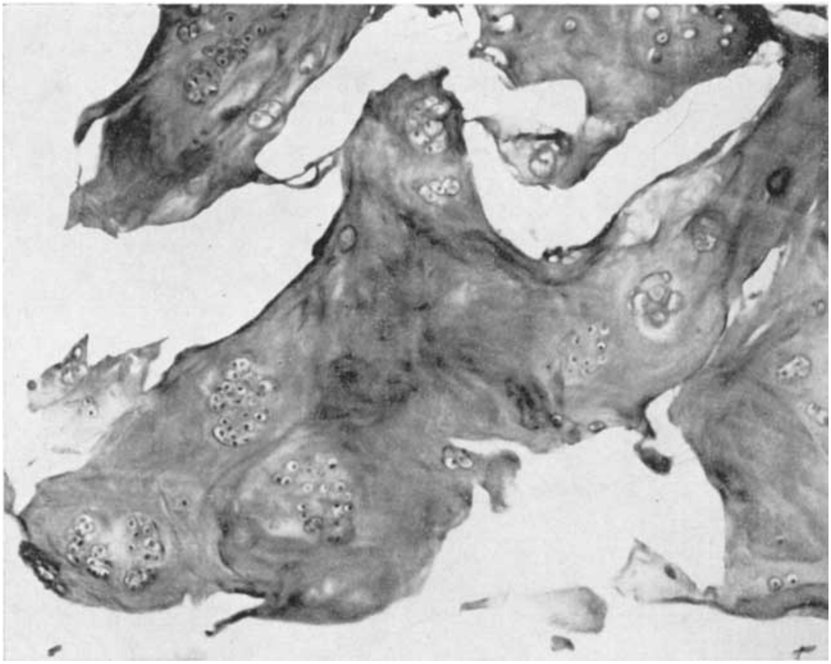


*Fig. 38: A projection invading the cavity in the interspinous ligament of the LV—SI space in a man of 61. Tissue resembling hyaline cartilage and containing large cell colonies. P.A.S. staining. P.A.S. is more strongly positive in areas which give no metachromatic reaction to toluidine blue, × 120.*

## VIII. RUPTURES IN THE INTERSPINOUS LIGAMENTS

### A. Macroscopy

*Earlier investigations:* In his article »Sprung Back» NEWMAN, in 1952, said that the supraspinous ligaments and also the interspinous ligaments sometimes rupture in serious traumas. Thus all his cases involved a direct and sudden stress. HACKETT (1957) mentioned relaxation of the supra- and interspinous ligaments as a causative agent of low back pain. Professor KALLIO has noted since autumn 1957 in connection with his operations for prolapse of the intervertebral discs that the interspinous ligament is often ruptured or relaxed in the same space. KÖHLER worked out a roentgenological method for the demonstration of these processes and introduced his technique preliminarily in 1959.

*Own investigations:* It was noted earlier that the interspinous ligaments of children are intact. This is not always the case with adults who relatively often have defects in certain parts of this ligament system. The ligaments must therefore have ruptured in one way or another.

The ruptures found in interspinous ligaments are of two types:

(1) complete ruptures with a fairly wide rent through the ligament. The opening is either empty or filled with fatty tissue.

(2) partial ruptures which show on either the right or the left of the ligament a rent which does not extend through the entire ligament but only through one layer to the cavity, almost always encountered in these cases, in the middle of the ligament. The other half of the ligament is intact, although generally much slacker than usual.

The author found such ruptures in a total of 39 subjects, i.e. in c. 21 per cent of the persons over 20 years of age. Approximately 7 per cent of these ruptures were complete, c. 14 per cent partial. All were observed macroscopically.

Ruptures in the interspinous ligaments have several special features which are characteristic of practically every case. One is their location in the interspinous spaces. All the ruptures observed by the present author were without exception localised in the lowest three lumbar interspinous ligaments. No ruptures were encountered above this level. The rupture often affected two spaces simultaneously. The ruptures established are distributed as follows by their localisation:

| | |
|---|---|
| LIII—LIV space | 1 |
| LIV—LV » | 7 |
| LV—SI » | 17 |
| LIII—LIV and LIV—LV spaces concurrently | 1 |
| LIII—LIV and LV—SI » » | 1 |
| LIII—LIV, LIV—LV and LV—SI spaces concurrently | 1 |
| LIV—LV and LV—SI » » | 11 |

Since one case showed a typical rupture concurrently in all three of the lowest lumbar spaces, and several cases had a rupture of two spaces, the total of ruptured interspinous ligaments was 54. Their distribution between the different spaces will be seen in Fig. 39.

The majority (c. 93 per cent) of the ruptures were localised in the two lowest spaces. In a little over 60 per cent of the cases one isolated rupture only was found in a single space. The rest of the cases mostly revealed a rupture in two spaces concurrently.

The rupture was typically and always localised at a certain site, the same place, in the interspinous ligament. This point of predilection was the medial portion of the ligament; the ventral and dorsal parts were usually intact. As has been stated previously, this part is composed of fibrous bundles which pass from the dorsal 1/3 of the inferior margin of the superior spinous process to the superior margin of the inferior spinous process, to its ventral 1/2. A typical rupture is thus always situated at this point. It is difficult to draw an accurate line between the different parts and the rupture may, depending on the case, extend slightly beyond the limits of the medial part. This never occurred to any considerable extent.

The ruptures were usually oval in form, with an antero-posterior axis, often slightly postero-superior — antero-inferior, i.e. the same as the main course of the fibre bundles. In some cases they were completely round. They were very well demarcated, sharply distinguished from the other parts of the ligament. The rents in the ligament could be empty or contain fat and loose connective tissue which filled them entirely or partially. The tissue right on the edges of the opening looked soft and flaccid to the naked eye.

In describing the changes in the interspinous ligaments with age it was noted how cavities often originate in the middle of the lowest interspinous

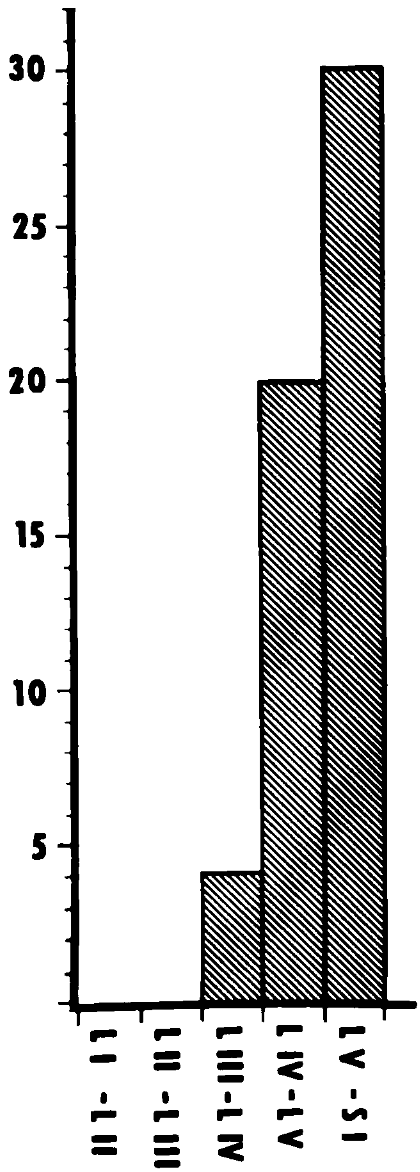



*Fig. 39: The number of ruptured interspinous ligaments established in the different interspinous spaces.*

ligaments in particular. The cases of rupture established here, both partial and complete, all displayed a minor or major cavity in the middle of the ligament. The cavity was either empty or filled with fatty tissue. A partial rupture in the ligament led to a larger cavity and, on the other side, depending on the case, there was either only a thin slack membrane or a slightly thicker layer of tendinous tissue. Complete ruptures revealed an even wider opening in the middle of the ligament.

In the chapter on the normal anatomy of the interspinous ligaments it was pointed out that a shallow pit may originate on the corresponding side of the ligament in a few cases in which certain transverse bands are associated with the lowest interspinous ligaments or when the point of attachment at the tip of the spinous process of the aponeurosis of the entire longissimus muscle participating in the formation of the ligament has shifted to the side. Such shallow pits are shown in Figs. 13 and 14. It is generally easy to distinguish these cases from the partial ruptures of the present series without danger of confusion. No fibrous bands joining the tips of the spinous processes can be established in the cases of rupture. These bundles are common in the variations of normal anatomy. The partial rupture is localised in a limited area, at a typical site, and is sharply demarcated as can be seen in the illustrations.

The youngest person in whom a partial rupture was established in the interspinous ligament was 24, and the youngest subject with a complete rupture was 36. The total of ruptures established was distributed by age groups as follows:

| | | | |
|---|---|---|---|
| 20—29 yrs | 1 | 60—69 yrs | 5 |
| 30—39 » | 8 | 70—79 » | 8 |
| 40—49 » | 8 | 80—89 » | 4 |
| 50—59 » | 5 | | |

The first case, an isolated one it is true, was found in a person of under 30; between 30 and 40 there was a peak after which the incidence was relatively even.

Eighteen of the ruptures were in female and 21 in male subjects. Since in the total material over 20 years of age 69 were women and 111 men, the relative incidence among women was slightly greater than among men, c. 26 against c. 19 per cent.

Analysis of the cases of rupture by occupational groups failed to establish any regular pattern. There was no distinct difference between heavy manual workers and light manual workers and intellectual workers. Three of the youngest women were a student, a domestic servant and a seamstress.

The three youngest men were a watchmaker, a labourer and a turner. The great majority of the women were ordinary housewives. In the male group a total of 5 were unskilled labourers and the others represented the most varied range of occupation such as carpenter, chaffeur, teacher, gardener etc.

Figs. 40—48 illustrate some complete and partial ruptures.

In some cases of rupture, the attention was drawn especially by the fact that the tendinous mass above the rupture, attached to the tip of the spinous process and continuing from there to form the most dorsal part of the interspinous ligament, moved very freely in relation to the tip. This pronounced instability was seen in a few cases. In a milder form it was more common in the rupture series as a whole.

*Discussion:* NEWMAN (1952) reported that the supra- and interspinous ligaments ruptured completely in the space between the spinous processes when subjected to trauma. In the ruptures noted by the present author the dorsal part of the interspinous ligament was always intact and only the medial part of the ligament was torn. The defects revealed roentgenologically in the »ligamentographs» of patients with back pain made by KÖHLER (1959) with contrast medium resemble those established in the present work.

*Fig. 40: Complete rupture in the interspinous ligament of the LV—SI space, seen from the left. A woman of 36. The ventral and dorsal part of the ligament are typically intact, the rupture in the medial part.*

*Fig. 41: Complete rupture in the interspinous ligament of the LIV—LV space, seen from the left. A woman of 42. The rupture is localised typically in the medial part of the ligament.*

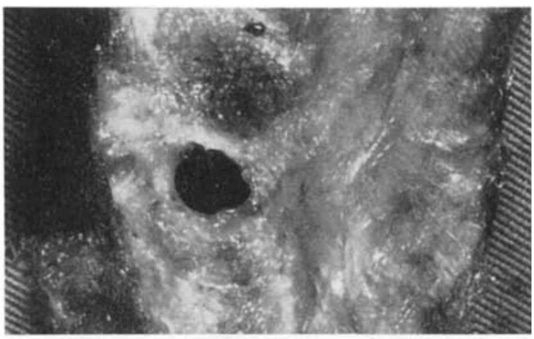


*Fig. 42: Complete rupture in the interspinous ligament of the LV—SI space, seen from the left. A woman of 50. The rupture has a typical localisation.*

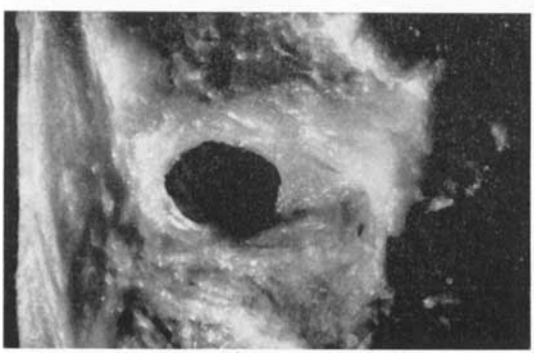


*Fig. 43: Complete rupture in the interspinous ligament of the LIV—LV space, seen from the right. A woman of 81.*

*Fig. 44: Complete rupture in the interspinous ligament of the LIV—LV space, seen from the right. A man of 50. The cavity in the middle of the ligament can also be seen.*

*Fig. 45: Partial rupture on the right side of the interspinous ligament of the LV—SI space in a man of 33. In the middle of the ligament a cavity, the other side intact.*

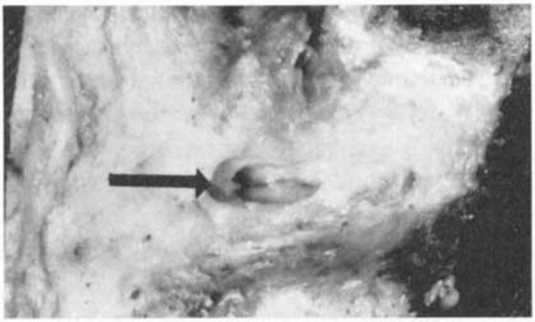


*Fig. 46: Partial rupture on the right side of the interspinous ligament of the LIV—LV space. The cavity inside the ligament filled with fat. A man of 39.*

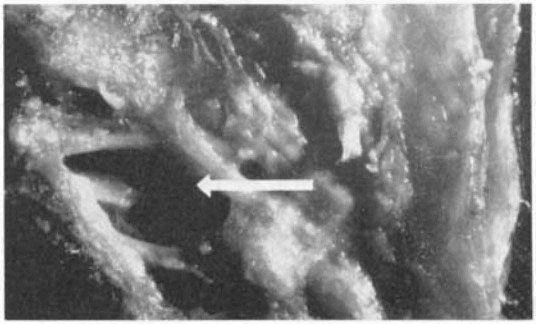


*Fig. 47: Partial rupture on the left side of the interspinous ligament of the LV—SI space in a man of 71. The transverse fibre bundles departing from the superior spinous process pass to the ventral surface of the aponeurosis of the longissimus.*

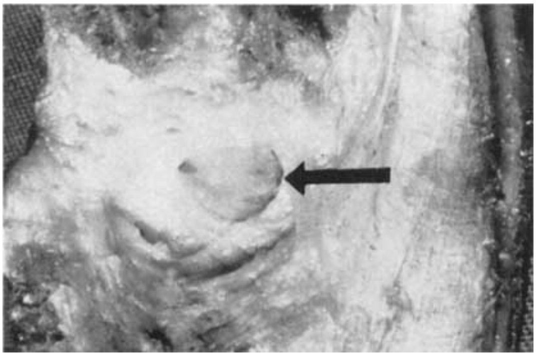


*Fig. 48: Partial rupture on the left side of the interspinous ligament of the LV—SI space in a woman of 63.*

The ruptures found in the interspinous ligaments were oval or round gaps, their edges always rounded. Had the ruptures originated post mortem the margins of the defects should be very sharp, which they were not.

The distribution of the ruptures in the different interspinous spaces is interesting. 55.6 per cent were in the LV-SI space and 92.6 per cent in the two lowest lumbar spaces. It was mentioned in connection with the supraspinous ligament (pp. 20) that in 95 per cent of the present series this ligament ended in LIV or above it. This and the ruptures of the interspinous ligaments obviously have something in common.

Ruptures of the interspinous ligaments have been localised in the area of the medial portion of the ligament where the fibre bundles pass obliquely between two bony surfaces of different vertebrae. The spinous processes move further apart on ventral flexion of the spine as there is no supraspinous ligament in the lowest lumbar spaces to restrict the movement. If the fibre bundles of the longissimus, which constitute the dorsal part of the interspinous ligament, are capable of moving relative to the tip of the spinous process as the microscopic picture suggests they do, the medial part of the interspinous ligament is subjected to tension and because of its structure is incapable of stretching or otherwise giving way. On the other hand, all the cases of rupture displayed in the middle of the ruptured ligament a minor or major cavity on gross examination, and this must surely have weakened the ligament. These factors have an obvious role in the origin of the ruptures, but the explanation for them cannot be mechanical only.

*Summary: Ruptures occur during life in the lowest interspinous ligaments. They were established in 21 per cent of the subjects over 20 years of age. All the ruptures were localised without an exception in the lowest three lumbar spaces, and*

*the majority, 92.6 per cent, in the lowest two. The ruptures were localised in the area of the medial portion of the ligament, the dorsal and ventral part were intact. Concurrently with the ruptures, pronounced instability was sometimes observed between the tendons attached to the spinous process of the vertebra above the rupture and the spinous process. The youngest person in whom a rupture was established was 24, and the peak incidence of ruptures was reached by the age group 30—40.*

## B. Histopathologic changes

*Earlier investigations:* The present author has found no reports in the literature on the histopathology of ruptures of the interspinous ligaments.

There are reports of the changes occurring in pathologic ruptures of different tendons. SCHAER (1936) described degenerations of different degrees in the tendinous tissue in ruptures of the tendon of the supraspinatus muscle in the shoulder. The forms of this degeneration have already been discussed. He also described morphologically cyst-like necrotic foci which were found on the margin of the rupture close to the bone. Several other investigators (FLEISCHER—HANSEN 1941, BJÖRKROTH 1943, DEPALMA 1952, DAVIDSSON 1956, ORELL 1958) demonstrated microscopically various changes in the ruptures of different tendons. Examples are loosening and fragmentation of the structure of the fibre bundles, breaking and necrotisation in the collagenous fibres, changes in stainability, calcification, proliferation of cell elements and blood vessels.

*Own investigations:* Microscopic examination revealed changes of different degrees in the ruptured interspinous ligaments. Breaking and necrotisation of fibre bundles, hyalinisation, fatty degeneration, calcification, proliferation of cell elements and blood vessels were established in all these cases in a milder or more marked degree. In general, all the degenerative changes reviewed in the preceding chapter were demonstrable in pronounced form in ruptured interspinous ligaments.

However, in addition to the degenerative changes observed with age even in externally intact interspinous ligaments, specific changes were also established in some of the ruptured ligaments. The most common was the occurrence of cyst-like degeneration foci in the ligament close to its place of attachment to the bone. The cysts could be situated in the fibrocartilaginous or tendinous part beside the place of attachment and were usually seen in the area of the medial part of the ligament. Mostly, they were filled with a homogeneous or somewhat scaly-looking, structureless mass which had as it were pushed aside the morphologically still preserved collagenous bundles in the environment (Fig. 49). Partly preserved collagenous bundles could be established here and there in the middle of the necrotic mass on the edge of the cyst (Fig. 50). On the other hand, in places a major rupture in the ligament could be seen in the region of a large cyst formation (Fig. 51).

The stainability of the cysts varied to some extent. They usually stained faintly yellow with Weigert-van Gieson while the homogenised part of the ligament immediately around them stained a stronger red than the other tendinous bundles. Inside the same cyst the stainability varied notably, some parts staining yellowish and others remaining practically unstained. Some cysts in their entirety did not stain at all. The formations did not react to resorcin-fuchsin.

New features emerged on histochemical examination. The cysts did not stain metachromatically with toluidine blue but retained an intense blue colour. The contrast emerged sharply and clearly in the area of fibrocartilage especially; the environment was markedly metachromatic, but

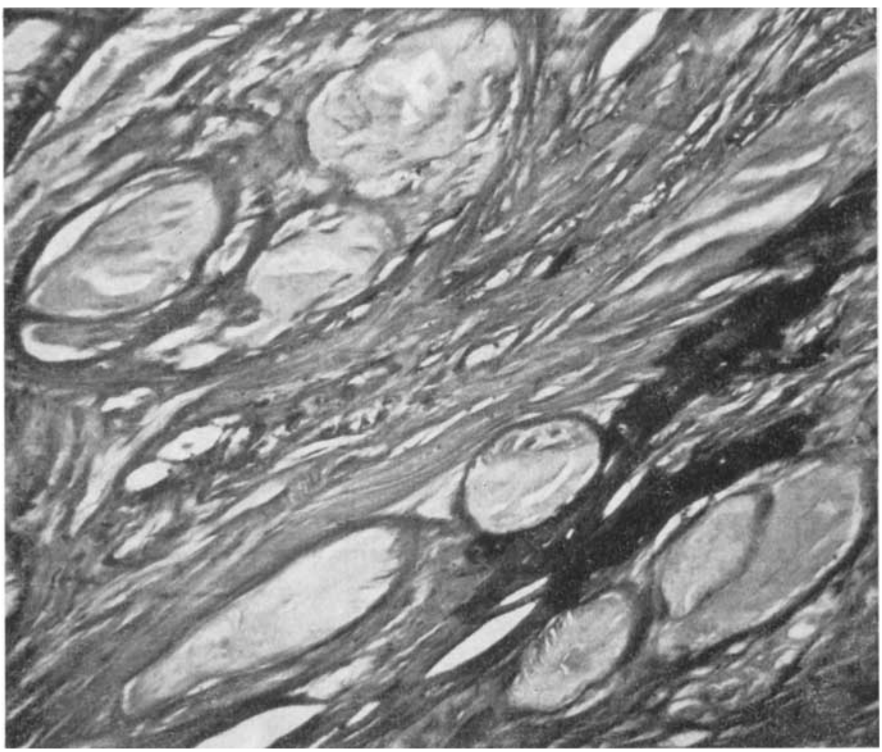


*Fig. 49: Degeneration foci in th: interspinous ligament of the LV—SI space in a man of 35. A partial rupture in the ligament. Calcification around the cysts. Weigert-van Gieson, × 120.*

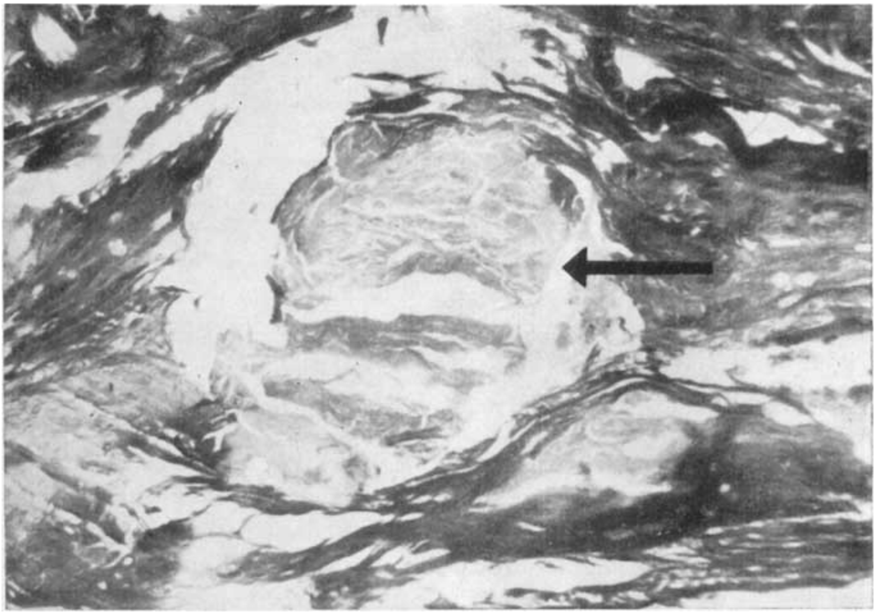


*Fig. 50: Large degeneration focus (arrow) in the interspinous ligament of the LIV—LV space in a man of 76. Complete rupture in the ligament. Alcian blue, × 120.*

*Fig. 51: Large necrotic area close to the bone in the interspinous ligament of the LV—SI space with a partial rupture. A woman of 63. Alcian blue, ×120.*

the cysts stained an intense bright blue. Alcian blue, on the other hand, stained the cysts bluish green and the differences were not as clear in a fibrocartilaginous area since the environment also to a great extent stained the same colour, although the cysts generally coloured more faintly. The same variation in stainability of the cysts that was noted with Weigert-van Gieson was observed with both the methods mentioned above.

Some of the preparations were treated with testicular hyaluronidase prior to staining. The result was a less intense colour in the metachromatic places but in the cyst formations no difference from the controls kept in saline solution. Both, however, showed in places a slight paling of the blue colour in the cysts.

In P.A.S. staining the cyst formations gave a very strong positive reaction which was not affected by diastase treatment.

Hence it is probable that hyaluronic acid and chondroitin sulphuric acids did not affect the picture here. Nor was the P.A.S. positivity caused by glycogen. The variations in stainability indicated that there might be substances differing slightly from one another in different parts of one cyst and in the different cysts. The paling of the colour in some places in the cysts in both the hyaluronidase-treated and the control preparations might warrant the assumption that a part of the cystic contents was water soluble.

The literature contains detailed information on a few mucopolysaccharide substances only, and the agent inside the cysts could not be identified with any of them. The cysts contained mucopolysaccharides as they turned bluish-green when stained with Alcian blue, but two additional properties of the cystic substances were the absence of matachromasia and the presence of P.A.S. positivity. The disappearance of metachromasia in mucopolysaccharides might be caused by the loss of the acid groups on binding with proteins or by the disintegration of the molecular structure of polysaccharides (PEARSE 1960). Desulphation alone might also increase the intensity of the P.A.S. reaction and reduce metachromasia (MCMANUS 1954). An unhomogeneous degeneration mass might consequently be involved in cysts containing mucopolysaccharides which differ from known acid mucopolysaccharides in the number of acid groups or sulphate groups or molecular structure.

Besides definite cyst-like formations some fibre bundles of homogeneous appearance stained in the same way as the cysts described above but were not of typical cyst morphology. In these regions the tissues revealed numerous fissure formations (Fig. 52). Foci of degeneration of this type or in the form of a cyst were established in c. 55 per cent of the cases of

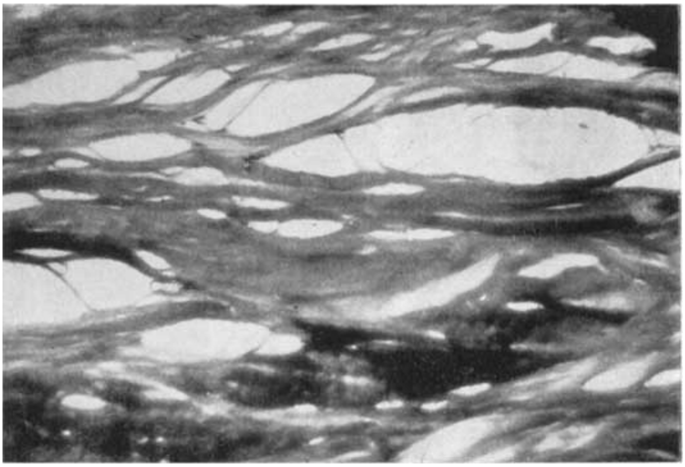


*Fig. 52: Markedly fissured area in the middle of metachromatic fibrocartilage. A great number of the bundles are homogeneous, some stain bright blue (dark ones). Toluidine blue, × 120. A man of 35.*

rupture. In some the cysts were very profuse, in others there were only a few.

One case of rupture showed a slightly different process in the ligament (Figs. 53 and 54). It too had islets in the ligament close to its place of attachment to bone. They contained a greyish, necrotic and necrobiotic mass containing calcium salts and staining faintly with Weigert-van Gieson. In the centre of this mass, here and there, were a few cells and round granules which retained sharply nucleic colours and were thus basophilic. The surrounding tendinous tissue displayed an actively degenerative process in which the attention was drawn above all to the high cell content and the vacuoles of different size in the areas of degeneration. On histochemical stainings the mass itself stained very poorly in places and metachromatically elsewhere. It was impossible to decide on the basis of one case whether the degeneration was more significant in the ruptures of the interspinous ligaments.

In reporting on the macroscopic examination of ruptures of the interspinous ligaments it was stated that some cases of rupture showed pronounced mobility and instability between the tendinous masses passing across the tip of the spinous process of the fourth or fifth lumbar vertebra and the tip itself. Microscopically, they showed very great changes. Some cases had large cyst-like necroses in the middle of the tendinous bundles (Fig. 55) or in the fibrocartilaginous part near the bone (Fig. 56). In their

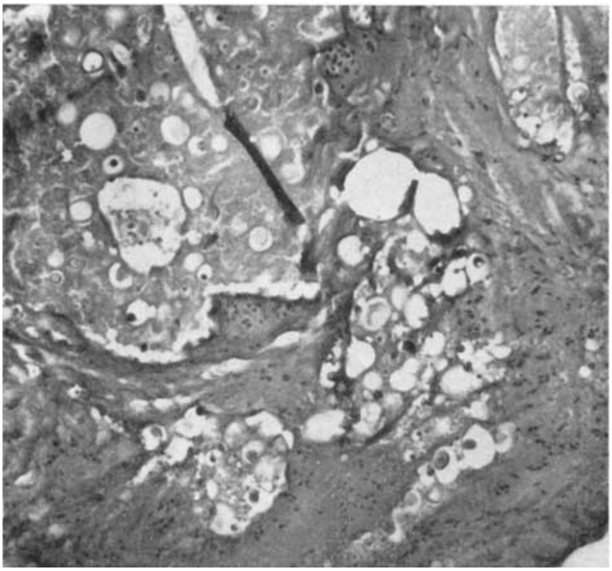


*Fig. 53: A site of degeneration with complete rupture in the interspinous ligament of the LV—SI space in a woman of 41. Weigert-van Gieson, × 120.*

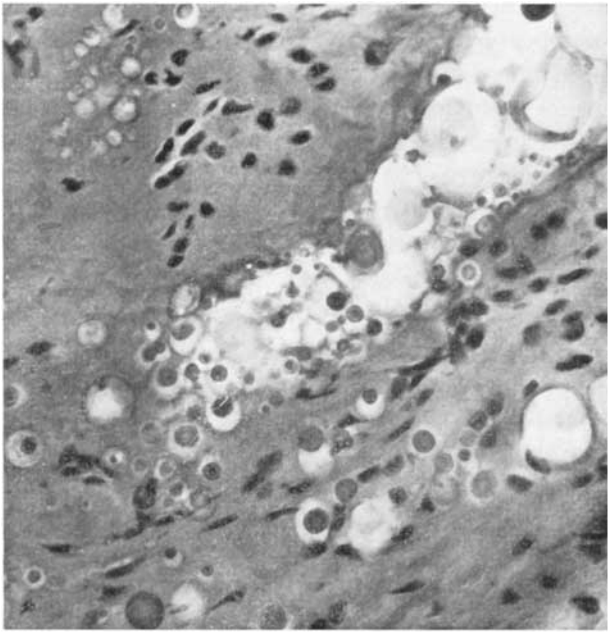


*Fig. 54: Magnification of the area of the lower edge of Fig. 53. Deg eneration in progress in the tendinous tissue. Necrotic mass, a great number of different cells and basophilic granules, × 400.*

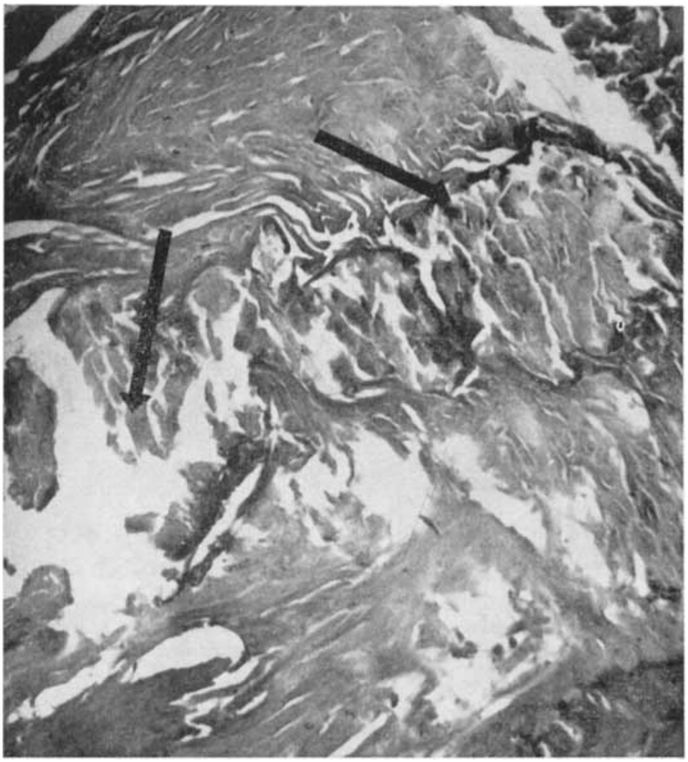


*Fig. 55: Cross (horizontal) section of the tendinous masses at the tip of the spinous process of the fifth lumbar vertebra in a man of 67. Complete rupture in the interspinous ligament of the LV—SI space and pronounced instability at the tip of the spinous process involved. Extensive, partly cystic necrosis (arrows) near which the tendinous tissue is completely destroyed. Weigert-van Gieson, × 120.*

vicinity the tendinous bundles were torn apart and from the bone. In other cases, again, there were large ruptures in the middle of the tendinous bundles, in the loose connective tissue between them (Fig. 57), causing marked instability. The tendinous bundles continuing from here ventro-caudally to form the most dorsal part of the interspinous ligament were thus torn out of their environment. The necrotic regions, very extensive in these cases, were not confined to the cases of rupture. They seemed to be very common, especially when of smaller proportions, in other cases after the 30th year of age.

*Discussion:* The rupture of interspinous ligaments always occurred in tissues showing varying degrees of degeneration, but never in completely healthy tissues. The most interesting of the degenerative changes is the

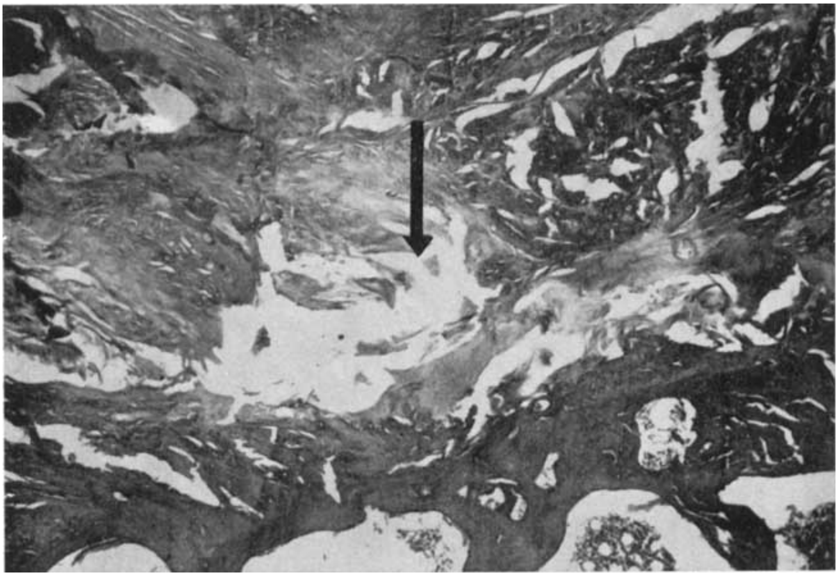


*Fig. 56: Cross (horizontal) section of the tip of the spinous process of the fifth lumbar vertebra. Extensive area of necrosis and partial disintegration in the tendinous tissue. A man of 73 with complete rupture in the interspinous ligament of the LV—SI space and instability at the tip of the spinous process. Weigert-van Gieson, × 40.*

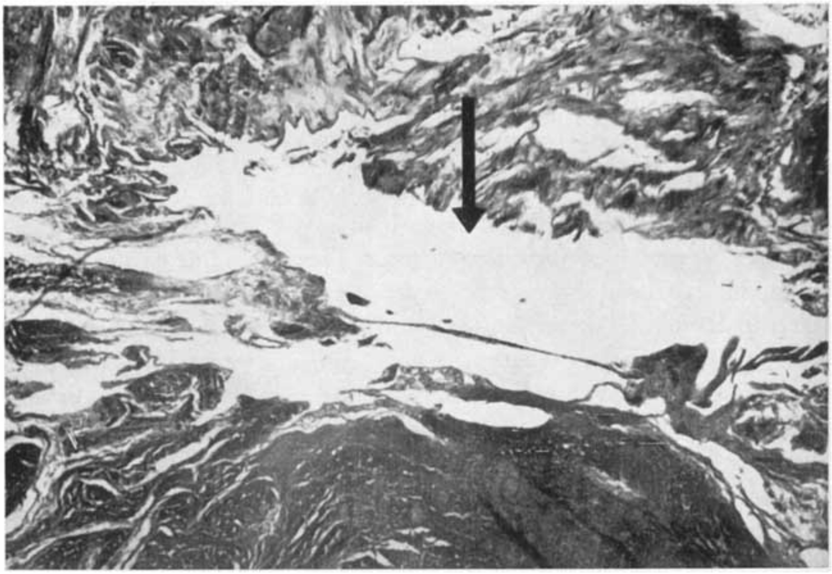


*Fig. 57: Large rupture in the loose connective tissue between the tendinous bundles at the tip of the fifth lumbar spinous process. A woman of 42 with a rupture in the interspinous ligament of the LV—SI space. Weigert-van Gieson, × 40.*

cystic degeneration reviewed. It has morphological features similar to those seen in ruptures of the tendon of the supraspinatus in the shoulder reported by SCHAER (1936). The changes are also in some respects similar to those occurring in the ruptures of different tendons reported by many investigators.

Ruptures of the interspinous ligaments consequently always involved a degenerative component, and the final rupture is caused by mechanical strain.

*Summary: Degenerative changes of different degree were established in all cases of rupture of the interspinous ligaments. Consequently, the ruptures occurred in degenerated tissue. The most notable change was the cyst-like degeneration in which cysts composed of structureless mass containing mucopolysaccharides occurred in the ligament close to the place of attachment to the bone. In the cases showing instability in relation to the tip of the spinous process, ruptures and necroses were established in the tendinous masses at the tips of the spinous processes above the ruptures.*

# IX. GENERAL DISCUSSION AND CONCLUSIONS

The principal movement of the lumbar spine is forward and backward bending. FICK (1911) and BROMAN (1922) state backward bending from the intermediate position to be 90°, ventral flexion 25° and rotation 5°. The fourth and the fifth lumbar vertebra usually move most. The roentgenologically established total values are somewhat smaller in living people (ALLBROOK 1957), but the last two or three lumbar vertebrae always move most during extension and flexion. ALLBROOK reported by way of an example a case in which the total movement in the lumbar spine is 83° distributed as follows between the different vertebrae: LI 11°, LII 12°, LIII 18°, LIV 24° and LV 18°. In most cases, however, the fifth lumbar vertebra moves the most.

Changes in lumbar lordosis originating in the routine work and duties of daily life (KEEGAN 1953) thus affect most strongly the lowest lumbar vertebrae. Their spinous processes sometimes move further apart causing traction and tension in the fibres of the dorsal and central portions of the lowest interspinous ligaments, sometimes again press against one another and subject the soft parts between the bony surfaces, i.e. the central parts of the interspinous ligaments, to heavy friction and wear.

Mechanical friction certainly plays a role in the origin of the cavities established inside the interspinous ligaments, partly in that it destroys tendinous bundles, partly through degenerative changes caused by circulatory disturbances. Heavy strain may also cause sclerosis and chondrogenesis, and it is possible that cartilage has a poorer nutrition than the tendinous tissue. But other factors also are probably involved. General degenerative changes in the connective tissue set in at the same ages at which the cavities and degeneration appear in the interspinous ligaments. Atherosclerosis also commences at these ages. It is an established fact that for instance thyroid hormone, thyrotropin, growth hormone and cortisone have an appreciable effect on connective tissue and its metabolism. Well known also is the significance of vitamin C for the metabolism of connective tissue. Hormones and vitamins may thus have a role of their own, in addition to the part played by general degenerative and mechanical factors, in the formation of cavities. It is impossible on the basis of the present series to apportion the significance of each of these factors in individual cases.

The ruptures of the interspinous ligaments always occurred in degenerated tissue. The metabolic factors mentioned may be accessory causes of the degenerative changes, but they cannot alone explain the localisation of the ruptures solely in the lowest interspinous ligaments of the lumbar spine. Mechanical strain, partly the friction of the spinous processes against one another but even more direct traction and tension bearing on the fibre bundles of the medial part of the ligament, is probably directly or indirectly the decisive cause of the origination of the ruptures. Heavy mechanical strain may cause degenerative changes via ischemia. On the other hand, tissue in such a condition may to some extent be more sensitive to the changes caused by different metabolic factors. The final cause of the rupture is direct mechanical strain on a ligament weakened by degenerative processes.

Of all the ruptures in the interspinous ligaments in the present series, 92.6 per cent were localised in the lowest two lumbar interspinous ligaments. In 95 per cent of the material the supraspinous ligament ended in LIV or above it. It must be noted, further, that the majority of cases of prolapse of the disc are also localised in the lowest two lumbar spaces. There may be some causal connection between these two circumstances. The prolapse usually occurs in the dorsal part of the disc, and hence from the purely mechanical point of view the giving way of the most posterior parts of the spine should be of considerable, even decisive, significance as a precondition for the prolapse. Suggestions and observations to this effect have been put forward by NEWMAN (1952) and HACKETT (1957) and by Professor KALLIO in connection with his operations.

## X. SUMMARY

The aim of this investigation of human cadavers was to establish the structure of the supraspinous and interspinous ligaments of the lumbar region of the human spine and the changes occurring in them during life.

The total series comprised 306 cadavers. There were 13 embryos and fetuses, 101 children under 10 and 192 distributed fairly evenly between all age classes up to 90. The child material was used principally to find out whether there are congenital defects in the supraspinous and the interspinous ligaments in the region of the lumbar spine in children with normal bones. The answer was in the negative for the present material; in other words, both ligament systems are intact in children.

It was found that the supraspinous ligament was composed of three layers, the superficial, central and deep layer. In children all these parts consisted of tendinous tissue, but soon after the 20th year of age incipient metaplasia into fibrocartilage could be demonstrated in the central and deep layer and this was pronounced by middle age. Gradual ossification occurred in the ligament concurrently. It appeared, contrary to earlier opinion, that supraspinous ligament did not extend to the sacrum but ended in LIV in 73, in LIII in 22 and LV in 5 per cent of the cases. The lowest spaces had only the tendinous raphe of the aponeurosis of the longissimus without fibres directly connecting the tips of the spinous processes.

The principal course of the fibre bundles in the interspinous ligaments was postero-superior — antero-inferior. The interspinous ligaments of the upper part of the lumbar spine differed in structure from the ligaments of the lowest two spaces because the fibre bundles from the supraspinous ligament participate in the formation of the interspinous ligaments and this ligament does not exist in the lowest spaces. Three parts were distinguished in the interspinous ligaments in the lowest spaces: dorsal, medial and ventral. The dorsal part comprised the fibre bundles of the longissimus which move ventrally across the tip of the spinous processes; the medial part was made up of fibre bundles passing obliquely from the

lower margin of the superior spinous process to the upper margin of the inferior spinous process. Microscopically, the ligament was composed chiefly of collagenous bundles, with a very few elastic fibres.

By the 20th year of age changes began to appear gradually in the ligaments, first in the lowest two interspinous ligaments, later also higher up. Metaplasia of the tendinous tissue into fibrocartilage takes place in the medial and dorsal part of the ligament at the site of attachment to the bone. Breaking of the fibre bundles, fragmentation, disappearance of stainability, destruction of tendinous tissue and, finally, cavity formation which is most common in the LIV-LV space, occur in the middle of the ligament. A cavity in this space was established on gross examination in 75 per cent of persons between 31 and 40; it was more common in older subjects in whom the cavities often became ultimately formations reminiscent of true joints. In addition to the degenerative changes listed, with histochemical staining methods it was possible to establish accumulation of various mucopolysaccharides in the areas of degeneration. Fatty degeneration and calcification were also common findings.

The investigation showed that ruptures occur in the lowest interspinous ligaments during life. One or more ruptures were established in the interspinous ligaments in a total of 21 per cent of the subjects aged over 20. They were all localised in the lowest three lumbar interspinous ligaments, the majority (92.6 per cent) in the lowest two. The ruptures were always in the area of the medial part of the ligament. The youngest subject in whom a rupture was established was 24. Concurrently with ruptures there was sometimes pronounced instability between the tendons attaching to the spinous process of the vertebra above the rupture and the spinous process itself. Microscopic examination demonstrated in all the ruptured ligaments various degenerative changes of which cyst-like degeneration was the most prominent. This degeneration revealed cyst-like pouches in the ligament close to the place of attachment to the bone. They were composed of a structureless, P.A.S.-positive mass which on Alcian blue staining gave a mucopolysaccharide colour but did not stain metachromatically with toluidine blue.

The degenerative changes appearing early in the interspinous ligaments and the cavity formations developing inside them and the ligament ruptures were attributed partly to a very heavy local mechanical strain caused by anatomic factors, partly to certain other, more general factors affecting the organism as a whole.

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