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ON SPONDYLOLYSIS AND SPONDYLOLISTHESIS

BY

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Among the numerous irregularities and defects occurring in the lumbosacral vertebrae, the ones due to defects in the lateral part of the vertebral arch were until recently perhaps the most disputed and obscure as to their etiology as well as their proper classification and clinical significance.

This condition involves a gap in the interarticular isthmus of the vertebral arch (the part located between the superior and inferior articular processes) and the consequences arising from this break in the continuity of the arch by slipping of the vertebral body and the transverse and superior articular processes anteriorly, while the inferior articular process, the posterior part of the arch and the spinous process remain in situ with regard to the vertebra below.

The nomenclature of the lesions here concerned has been rather confusing, varying from time to time and differing in the various countries. Spondylolysis generally means the simple presence of a gap in the interarticular portion of the vertebral arch without slipping. Some authors (*e.g., Meyer-Burgdorff*) who hold the undoubtedly correct though much disputed view that this involves a congenital defect, have wanted to emphasize this conception by designating this separation as lateral spina bifida—corresponding to the term posterior spina bifida for the failure of the arch to fuse posteriorly—and Meyer-Burgdorff will apply the term spondylolysis to cases in which a slipping of the vertebra has commenced. After this, the term spondylo-

listhesis should not be employed till the slipping had reached a more advanced stage.

It seems unnecessarily circumstantial and inconvenient to maintain such a distinction between the various stages of the

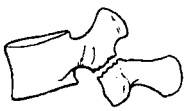


Fig. 1.
Site of spondylolysis. (After Glorieux & Roederer.)

affection, the more so as the linguistic objection—that no detachment (-lysis) takes place before the slipping has commenced —appears not to be correct. When the normal osseous connection between the anterior and posterior parts of the arch is replaced

Fig. 2.
Vertebra with spondylolysis. (After Glorieux & Roederer.)

by some other, less resistant, tissue, a "lysis" is really present. In the present work, therefore, the term

Spondylolysis will be employed for the demonstrated separation corresponding to the interarticular isthmus without any demonstrable slipping, whereas

Spondylolisthesis signifies this condition when slipping (more or less pronounced) has taken place.

A factor that may cause slipping in a stationary and symptom-free spondylolysis and thus produce an eventually symptom-giving spondylolisthesis, is the position of the sacrum. The wide physiological variation of the position of the sacrum naturally means a marked variability in the position of its proximal surface in relation to the longitudinal axis of the body; the more oblique this surface, the more will the fifth lumbar vertebra tend to slip downwards and ventrally. Something similar holds true, of course, of any higher point in the vertebral column.

A good many different measurements and designations have been given for the position of the sacrum, some of which will be employed here:

The *lumbosacral angle* means the angle formed between two lines drawn through the center of the sacrum and the fifth lumbar vertebra, respectively. The significance of this angle to the tendency of slipping depends not only on the size of the angle but also on the inclination of the sacrum, and thus on the inclination of the proximal surface of this bone.

The *promontory angle* means the angle between two lines drawn through the anterior surfaces of the two bones. The significance of this angle is the same as that of the lumbosacral.

The *sacrohorizontal angle* is the angle between the proximal surface of the sacrum and the horizontal plane in standing posture. This angle will give an accurate expression for the tendency to slipping of the fifth lumbar vertebra.

Brofeldt has mentioned this angle in pictures taken in standing as well as lying postures, and he was unable to find any difference in the angle in the various positions, whereas previous authors (*Müller & Zwerg*) state that only the angle measured in standing posture can be reckoned with. These two authors found the average value for this angle to be 27°, while other authors have found greatly divergent values. But measuring on a control material compared to patients with spondylolysis and spondylolisthesis has not revealed any convincing difference of this angle in the two groups.

Junghans, measuring the lumbosacral angle, found a difference of 10° in the two groups; but as this angle in the normal

material varied from 125° to 164°, the result is not convincing. It must be kept in mind, however—as will be pointed out later on—that in spondolylisthesis the pelvic inclination is reduced compensatorily, and hence measuring of this angle in patients with this affection is apt to give misleading results.

Friberg therefore compared the lumbosacral angle on pictures taken in standing position in cases of spondylolysis and spondylolisthesis and found only a difference of 6° between the two groups; but the number of patients suitable for measuring of this kind was too small to allow of any definite conclusion.

The extremes of the various angles in the lumbosacral region and of the various positions of the sacrum have been designated differently by various authors, and some of these designations are synonymes.

Undoubtedly the *horizontal sacrum* (*Brofeldt*) and the *acute sacrum* (*Scherb*) are quite identical, whereas the *arcuate sacrum* signifies a slightly deviating form, in which a marked lumbar lordosis through a gradually S-formed curvature continues in a strongly curving sacrum.

Common to all these forms is a very oblique proximal surface of the sacrum, that is, a very wide sacrohorizontal angle, so that in all these conditions there will be a marked tendency for the fifth lumbar vertebra to slip downwards and anteriorly over the sacrum if such slipping be possible.

Whitman therefore suggested to designate these various forms of oblique proximal surface of the sacrum by the term *prespondylolisthesis*. This term must be said to be unsuitable, however, because it is based on the presence of a single factor disposing to spondylolisthesis, and yet it links this name with a great many cases where a slipping could never arise, as the *conditio sine qua non* for the slipping—namely, the separation in the vertebral arch—is absent.

Still, the forward slipping of a vertebral body may occasionally be possible also without spondylolysis, but only in the relatively few cases where instead of spondylolysis we meet with a deformity or abnormality of the articular process or isthmus permitting the vertebra to slip.

Thus *Junghans* has described an affection which he designated as pseudospondylolisthesis, and which was associated with pain over the loins, pronounced lordosis of the lumbar spine and moderate ventral slipping of the vertebral body, always the fourth lumbar vertebra. The cause of this affection is to be found in an abnormally large angle between the root of the vertebral arch and the axis through the inferior articular processes of the same vertebra. If this angle approaches 180° instead of being merely a little over 90° as normally, the inferior articular process will not as usually with its almost angular hook hang on to the superior articular process of the fifth lumbar vertebra, but allow of a limited slipping over its articular surface, and the vertebra may thus become displaced anteriorly to some extent, although the isthmus is intact. Among 400 skeletons *Stewart* found this anomaly of the articular process in two cases.

The material on which the present studies are based originates from the Orthopedic Hospital, Copenhagen, 1926—1936, and from the Aarhus University Clinic of Surgery, the Municipal Hospital of Aarhus, 1936—1942, comprising altogether 27 cases. Of this total, 19 patients came from the Orthopedic Hospital (Nos. 1—19), and 8 from the Aarhus Clinic (Nos. 20—27). Some other patients from the Orthopedic Hospital, mostly patients admitted prior to 1926, on whom the diagnosis was made without roentgenography, were excluded from this account.

Some of the patients from the Orthopedic Hospital have received only ambulatory treatment, and on some of them the diagnosis was made on X-ray pictures they brought with them —pictures that are no longer available for revision. In those instances where such patients failed to turn up for the wanted reexamination with roentgenography, I have had to be content with the description of the roentgenograms given in the case records; and this description has not always been as complete as was desirable, for instance, with a view to the degree of the slipping and possibly other congenital anomalies.

Thus, roentgenograms which could be checked up were

available only in 20 of these cases, on which account the material naturally is somewhat incomplete with regard to a few points.

Most of the patients have been under observation through a considerable length of time. In two cases, however, the time since their admission has been too short for a real examination period. 7 patients have refused to return for reexamination. The remaining 18 have been under observation on an average for 5.2 years—from 1 to 24 years.

ETIOLOGY

Opinions have differed greatly as to the etiology of spondylolysis, three different views having been advocated: 1) that it is a congenital affection; 2) that the separation is a result of traumatic injury; and 3) that it is a matter of trophostatic changes in the vertebral arch.

The Congenital Etiology.

The frequency of spondylolysis is given by most authors as being about 5 %.

If spondylolysis be congenital one would expect fetuses and newborn children to show a similar incidence of spondylolysis, or two centers of ossification, instead of the normal one, on each side of the arch. Such double anlage of the centers of ossification are present normally in certain lower mammals and in whales (*Portmann*). Several authors have investigated this paragraph in man, but the results have been highly divergent.

Turner (cited after Thomson) states that occasionally several centers of ossification are seen. *Schwegel* (cited after Glorieux & Roederer) and, later, *Neugebauer* have found the ossification of the intercellular isthmus defective in the newborn. *Brailsford, Blume* and others have found the same anomaly associated with spondylolisthesis in infants. On the other hand, a good many authors have examined a large number of fetuses without finding two centers of ossification on either side of the vertebral arch. The technique employed in these investigations has varied

a little, but most often the vertebral column has been removed from the body, cleaned and roentgenographed. In this way, fine pictures of the centers of ossification in the vertebral body and arch are obtained.

Mall examined 60 fetuses under 100 days and found no double anlage at all. *Batts*, who examined 200 fetuses, from the 3' month to term, found in one case two centers of ossification in the arch of the third lumbar vertebra, in which spondylolysis occurs but seldom, but no double anlage in the fourth and fifth lumbar vertebrae, and he thinks, therefore, that it is not justified to conclude that spondylolysis is congenital. In his examination of 90 fetuses, from 6 weeks to term, *Hitchcock* found no double anlage, and the same result has been reported by *Willis*, *Junghans*, *Chandler* and *Hayek*.

From these figures it is evident that spondylolysis generally is not found in about 5 % of all persons, and the cited authors, together with many others who subscribe to their view, think, therefore, that it is safe to rule out a congenital origin of spondylolysis. To me, however, this conclusion appears not directly justifiable, as other things also have to be taken into consideration.

Relation to Other Congenital Defects in the Lumbosacral Region.

As is well known, many congenital defects or anomalies of the lower lumbar vertebrae and sacrum are common findings.

Posterior spina bifida, the congenital origin of which seems unquestionable, is found with a highly varying frequency.

Sacral spina bifida is found in 24 % of all cases (*Lübke*), and *Willis* states that it is frequent enough to be considered normal.

Vertebral spina bifida of the fifth vertebra is less common. According to *Friberg*, this condition was found by *Lübke* in 1.5 % of the cases, by *Willis* in 1.2 %, by *Køhler* in 10 %, by *Goljantsky* in 12.2 %, by *Heise* in 22 % and by *Brailsford* in 6 %.

Some authors have examined their spondylolisthesis material

for the presence of spina bifida. *Meyerding* found this affection in 35 % of his 207 cases, *Capener* in 15 of his 34 cases, and in his 280 patients with spondylolysis *Friberg* found spina bifida in 89 vertebrae in 80 patients (in some cases this affection involved more than one vertebra). This gives an incidence of 28.6 %. Finally, in the litterature, *Dellavalade* found a coincidence of the two affections in 30—40 % (cited after Friberg).

So, all these authors found the coincidence of the two lesions to be more frequent than the occurrence of spina bifida alone. It should further be noted that in many cases in Friberg's material the two defects were found in the same vertebrae and only in that one. Thus one patient with spondylolysis L. 2 and three patients with spondylolysis L. 3 all hâd spina bifida in the same vertebra and in this alone. As the frequeny of these affections decreases in the higher vertebrae, it seems more probable that also spondylolysis is of congenital origin.

On going through the roentgenograms of the *present material,* it was found that they were available only for 20 of the patients. In two cases the pictures were unsuitable for any decision as to the presence of other congenital defects. In the remaining 18 cases, sacral spina bifida was found in 8, or in 44.4 %.

No other demonstrable congenital abnormalities were found in this material.

It is further questionable whether it be justified from the materials reported so far to expect spondylolysis to be present in about 5 % of the population in general.

Most of the investigations which have given such results were carried out either on groups of people in whom some special conditions may very well have asserted themselves, or on materials collected in special clinics, in which the patients had been selected beforehand.

Thus *Shore* examined the skeletons of 82 Bantu negroes and found 5 of them (6.9 %) to show spondylolysis. In 200 skeletons of Indians ("American aborigines") *Congdon* found the lesion in 10 (that is 5 %). *Harbitz* examined 262 skeletons of Norwegians and Lapps—among others, from burial grounds—and found spondylolysis in 12 %; and in 296 skeletons of Lapps, *Schreiner* found spondylolysis in 12.8 %.

As to all these materials, it is quite possible that some hereditary factors in the races mentioned may have become accentuated through inbreeding, resulting in a higher frequency of the defect concerned.

Friberg tried to calculate the frequency of the lesion by estimating the percental occurrence of spondylolysis or spondylolisthesis in all the roentgenograms of the lumbosacral region kept on file in the Orthopedic Hospital in Stockholm; and he found it to be 6.3 %. But his material was highly selected indeed.

So it is very likely that in the general population the incidence of the lesion is much lower than the 5 % given by most authors.

It may be mentioned, however, that in an autopsy material, of which it is impossible to say whether it was selected, *Willis* found spondylolysis in 6 % of the cases, and in one-fourth of these the lesion was unilateral. The lamina involved were defective in their development, and no phenomena of regeneration were seen. From this he arrived at the conclusion that in these cases the spondylolysis was not of traumatic origin.

Systematic examination of a large control material might furnish the wanted information, but it would require a very thorough special roentgenography with pictures being taken, among others, in oblique diameters, in order to ensure that all the cases were diagnosed, and such an investigation would be very expensive—besides being quite impracticable under the present conditions.

The probability of a congenital etiology has been increasing to certainty, however, with the steadily increasing number of cases in whom the hereditary occurrence of the lesion has been demonstrated.

In earlier days some scattered instances were reported, in which several cases of spondylolysis or spondylolisthesis occurred in the same family (*Rouchet & Roudel, Keibel & Mall*).

Recently *Bakke* has observed a family in which all 5 children presented posterior spina bifida, and 2 of them showed also lateral spina bifida (spondylolysis), while the parents apparently were normal. In another family, the father showed spondylolysis, and all his 3 children showed posterior spina bifida. In one

family, the father and his two sons presented posterior spina bifida, while one of the sons showed also a unilateral spondylolysis.

Friberg has investigated the occurrence of these lesions through several generations of two families, with the following results:

Family I: A girl, 1 year old, presented spondylolysis in all the lumbar vertebrae and in the two lowest dorsal vertebrae, together with an increase in the distance between the body and the arch in the other dorsal vertebrae, without lysis being positively demonstrable here. In addition, the cervical spine showed small irregular vertebral bodies with spondylolysis and spina bifida. Further, spina bifida was also found in the fourth and fifth lumbar vertebrae.

The child was further suffering from bilateral congenital dislocation of the hip and bilateral subluxation of the knee and elbow.

The father showed unilateral spondylolysis, while the mother presented no abnormalities. Of the four grandparents only one was alive and presented no abnormality.

Family II: The 1' generation included one case of spondylolisthesis. Of the 10 members of the 2' generation, 5 had spondylolisthesis; 1 was dead. One of these patients was married to a man with spondylolisthesis. The 3' generation comprised 44 members, 40 of whom were examined. Of these 40 persons, 9 were found to have spondylolisthesis; and 7 out of these 9 were children of the two parents who both presented this lesion.

In this family, then, altogether 24.6 % of the members had spondylolisthesis.

The view about a congenital etiology of spondylolysis and spondylolisthesis thus finds support in the following points:

1. The occasional occurrence of a double anlage of ossification centers in each side of the vertebral arch has been demonstrated.
2. The occurrence of the lesion increases in frequency with the coincidence of other congenital defects.

3. The presence of hereditary factors has been proved through genetic investigations.

The fact that several authors have failed to find any double anlage of ossification centers in the arch even in fairly large materials of fetuses and newborn is readily explained by the hereditary nature of the lesion.

It must be considered more likely that the frequency of the lesion in the general mixed population is less than the 5 % given by most authors.

Theories about Traumatic Etiology.

The traumatic origin of spondylolysis has been discussed and asserted by numerous authors, and a brief review of the theories advanced to this effect will be appropriated here.

The traumatic injuries to be taken into consideration may consist in: 1) a single severe traumatic injury adequate for the production of a fracture of the character here involved; 2) frequent minor injuries as suffered under daily physical exertion or, under some particular circumstances, resulting from altered static conditions—but the discussion of these cases will be postponed till later.

The fracture may arise either as 1) an extension fracture, 2) a flexion fracture, or 3) a chisel fracture between the inferior particular process of the fourth lumbar vertebra and the superior articular process of the sacrum.

Extension Fracture.—On hyperextension of the lumbar spine, the vertebral body is tilted upwards while the spinous process is forced down against the underlying spinous process and is stopped here. Further extension of the spine will bring about a marked tension and eventually a fracture at the weakest spot (see Fig. 3), that is, in the interarticular isthmus, the relative weakness of which is increasing distally (*Bakke, Glorieux*).

Flexion Fracture.—In marked hyperflexion of the spine the mechanical conditions will depend on the simultaneous contraction of the musculature of the back. If the muscles of the back at the same time are strongly contracted, a possibly resulting

fracture will be located in the body of the vertebra, or a prolapse of the intervertebral disc will arise (*Glorieux*).

If the musculature of the back is relaxed or irregularly contracted the spine will be flexed, and the following injuries may arise: 1) compression fracture of the vertebral body; 2) rupture of the ligaments between the spinous processes; or, if the ligaments hold, 3) fracture of the vertebral arch.

Fig. 3.
Mechanism of the extension fracture. (After Glorieux & Roederer.)

Cases of this kind have been reported by *Bøhler* and *Glorieux*.

It is easy to understand that the trauma required for such a fracture must be quite considerable (in the case reported by Glorieux the patient fell from a height of 7 meters), and most often other fractures are present too. As a rule the patient is disabled at once, being unable to get up and walk, that is, presenting a picture entirely different from the usual features of spondylolisthesis.

Chisel Fracture.—Finally, Capener has advanced the theory that spondylolysis might arise traumatically in this way, that the inferior articular process of the fourth lumbar vertebra and the superior articular process af the sacrum through a powerful blow in the longitudinal axis of the spine may produce a fracture of the isthmus of the fifth lumbar vertebra, when these two processes push towards each other like opposing chisels. *Glorieux* and *Roederer* refute this theory with the argument that the two processes are not located in the same plane.

In the larger clinical materials reported so far, only some of the patients have been exposed to traumatic injuries, and often these have not been severe enough to produce a fracture.

Even in the case where the trauma has been severe enough

for this, it was most often preceded by symptoms suggesting that the trauma has merely accentuated the symptoms of a preexisting spondylolysis. This applies to *Meyerding*'s material comprising 583 cases, 47.7 % of which gave positive data of traumatic injury.

In *Friberg*'s material of 280 patients, 25 % gave a history of traumatic injury, but mostly of a chronic form (hard manual labor); only 2 of his patients gave a history of having suffered a traumatic injury adequate for the production of a fracture, and both these patients had additional fractures of the spinal column.

In the *present material* of 27 patients, 17 gave a history free from traumatic injury (Nos. 1, 2, 3, 6, 8, 9, 10, 14, 16, 17, 19, 20, 21, 24, 25 and 26).

In 2 patients the pain in the back was attributed to strenuous work (Nos. 11 and 13). (Overstrain on lifting in the case of No. 11, while No. 13 was a girl of 13 years who had delivered washing).

Altogether 8 patients gave a history of an acute adequate traumatic injury. In 4 of these cases (Nos. 4, 12, 15 and 27) it was a fall on the back or buttocks. All four patients had pain in the back, but they were not confined to bed for more than a couple of days at the most (1 patient), and this goes against the possibility of a fracture.

In 1 case (No. 18) the patient fell down from a ladder but caught a hold with his hands and was thus hanging by the hands. The pull on the vertebral column produced a transitory pain over the loins. Subsequently he suffered pain again over the loins on stumbling.

Another patient (No. 23) had had slight backache on strenuous work for 5—6 years, when one day he was hit in the back by an iron pipe that fell down from the first story of a house. On admission to the hospital examination revealed spondylolisthesis of the fourth lumbar vertebra with a slipping of 2 cm. Exostoses were found round the intervertebral space affected but nowhere else; and this indicates that the spondylolisthesis had been present for a considerable length of time prior to the injury.

The last two cases, then, involved presumably an aggravation of a preexisting spondylolisthesis.

In 2 cases (Nos. 5 and 7), in one of which the patient was run over by a farm waggon, while the other hurt his back in a runaway, the possibility of a fracture cannot be excluded with certainty. Still, in one of them the back symptoms and the deformity developed slowly during the following years, and the X-ray pictures showed the changes typical of spondylolisthesis.

When a traumatic injury produces a fracture of the interarticular isthmus, possibly combined with other fractures of the spinal column, it may become the site of a slipping and thus resemble spondylolisthesis. But this does not mean that all instances of spondylolisthesis are of traumatic origin; and if—or when—the spondylolysis is of congenital origin, the fracture is an entirely different lesion, possibly with a different and perhaps better prognosis as to healing than that of spondylolysis, which hardly ever undergoes osseous healing.

For the sake of completeness, it may be added that it has not been possible yet to produce an isolated fracture of the interarticular isthmus without this structure being injured beforehand (partial chiselling); but the fracture could be produced together with other fractures (*Azema, Gerlach*). In such experiments, however, the conditions will always be markedly non-physiological.

Trophostatic Etiology.

This involves the fact demonstrated by *Looser,* that bones with morbid changes (rickets, late rickets, osteomalacia) on exposure to very protracted influences may undergo transformation of the osseous tissue, which gradually is replaced by fibrous tissue or by cartilage. Roentgenographically this appears as an area of clearing in the bone (from 1 mm. til 1 cm. in width) while the bone at the same time becomes somewhat thicker. On healing of this process the area becomes sclerotic.

Meyer-Burgdorff claims that spondylolysis arises in this way. He bases this assertion on the case of a patient, 6 years old, who suffered a fracture of the twelfth dorsal vertebra, with kyphosis and increased compensatory lordosis, and in whom the

fourth lumbar vertebra showed spondylolysis. He asserts that it is possible roentgenologically to distinguish between four stages in the development of the affection, namely:

Stage I: Condensation of the marginal zone in the interarticular area (interpreted as a defensive reaction of the organism).

Stage II: Narrowing of the arcuate section with solution of the calcified areas into a cloudy deterioration. Parallel to this process of dissolution, a considerable rebuilding of bone takes place in the form of ossification or calcification of newformed osseous tissue in the adjacent parts of the arch.

Stage III: Separation, with irregular rough surfaces of bone (demonstrated on a museum specimen without clinical data).

Stage IV: Slipping, which is always acquired.

Meyer-Burgdorff has a material of 14 cases, but he gives clinical data only on the one case cited above, and he fails to state whether the other patients also presented altered static conditions.

Another case, reported by *Capener,* belongs to this category. This was a patient with tuberculous spondylolysis and gibbosity of the lumbar spine together with spondylolysis of the fifth lumbar vertebra, and in whom the altered static conditions are thought to have brought about a corrosion of the arch of the fifth lumbar vertebra through squeezing between the inferior articular process of the fourth lumbar vertebra and the superior articular process of the sacrum.

Gloricux & Roederer assert that this development is conceivable only in hunchbacks or in patients whose intervertebral disc has decreased considerably in height. The latter condition is often seen in spondylolisthesis but is generally regarded as a secondary phenomenon.

The altered or abnormal statical conditions in the vertebral column which together with the bone lesions mentioned by Looser or other similar processes might be able to induce spondylolisthesis must be either 1) habitual postural deformities such as increased lordosis, with or without a simultaneous sacrum horisontale, or 2) acquired postural deformities resulting from kyphoses (spondylitis, fractures, rickets) or other lesions—*e.g.,* contracture of the hip—which all give the sacrum an abnormal

position (with a very oblique proximal surface) and thus may increase the tendency of the overlying vertebrae to slipping and thereby augment the strain on the alveolar processes and ligaments.

It is certain, however, that such abnormal statics are far from present in all cases of spondylolysis. No doubt, however, it is a secondary compensatory phenomenon when, in spondylolisthesis with marked slipping, the longitudinal axis of the sacrum is nearly vertical.

These facts make it highly improbable that spondylolysis should originate in the manner just mentioned in nearly every instance.

In the above two cases of patients with fracture and with tuberculous spondylitis, respectively, it is quite conceivable that the atrophy of the bone may have disposed the vertebra to form such a transformation zone. Besides, I think, it is only in rare cases that one is able with certainty to exclude the possibility that a patient with spondylolysis may at some previous juncture have had one of the bone lesions that Looser considers disposing to this affection. But it would be a rather far-fetched standpoint to assume that these conditions may have been present even in a fairly large percentage of the patients with spondylolysis.

GENERAL CLINICAL ASPECTS OF SPONDYLOLYSIS

Classification in Stages.

Spondylolysis, as mentioned, signifies the state of the morbid condition prior to the commencement of slipping.

Spondylolisthesis consists in a ventral slipping of the vertebral body plus the superior articular processes and the transverse processus parellel to the upper surface of the underlying vertebra. At the same time, or prior to this slipping, the intervertebral space between the two vertebrae is often decreased.

This slipping can be measured in millimeters or centimeters, recording either the width of the gap in the intervertebral isthmus, or the extent to which the anterior or posterior margin of the slipping vertebra is displaced anteriorly in proportion to

the underlying vertebra; or the displacement may be given in fractions of the anteroposterior diameter of the vertebral body.

Accordingly, the development of the lesion may be divided into different stages. To me the following classification appears preferable:

Spondylolysis: No slipping.

Stage I: The vertebral body has not yet slipped forward to the extent of one-half of its width (anteroposterior diameter).

Stage II: The vertebra has slipped forwards by more than one—half of its width. At this juncture, the slipping vertebral body will usually begin to tilt over the anterior margin of the underlying vertebra.

Stage III: The vertebra has slipped forwards so far that its entire width is in a plane anterior to the underlying vertebra.

Stage IV (also designated as spondyloloptosis): The vertebra has not only slipped entirely in front of the underlying vertebra but has also sunk down on the anterior surface of the latter.

Meyerding has suggested a slightly different classification which does not include the tilting of the slipping vertebra over the margin of the underlying nor its sinking in front of this vertebra.

Distribution of the Writer's Material in the Different Stages.

Employing the above classification, the patients in the present material are found to be distributed as shown in Table 1.

TABLE 1

Distribution of the Writer's Material in Stages.

Spondylolysis	4	patients
Stage I	6	„
Stage I—II	1	„
Stage II	12	„
Stage III	0	„
Stage IV	2	„
"Considerable slipping"	1	„
No data on this point	1	„
Total	27	„

Thus nearly 50 % of these patients presented Stage II, that is, a slipping corresponding to more than one-half of the width of the vertebra, while 11 presented slighter degrees (including 4 instances of spondylolysis), and 2 showed a more marked degree.

On comparison of this with the distribution of *Meyerding's* and *Friberg's* materials, there is found to be a considerable difference in the distribution of my material and the others—as shown in Table 2. Of course, due allowance has to be made for the difference in the principles of classification adopted: Meyerding's spondylolysis + Stage I + Stage II corresponds to my spondylolysis + Stage I, while Meyerding's Stage III corresponds to my Stage II.

TABLE 2

Comparison of the Classification and Distribution of the Patients in the Material investigated by Meyerding, by Friberg and by the Writer.

Meyerding's classification	Meyerding's material	Friberg's material	Writer's classification	Present material
Spondylolysis + Stage I and II	395	157	Spondylolysis + Stage I + Stage I—II	11
Stage III	29	34	Stage II	12
Stage IV	18	18	Stage III	0
			Stage IV	2
No data	141		No data	2
Total...	583	209		27

In Meyerding's and Friberg's material a greater majority of the patients fall in the classes of the relatively slight stages, while a slipping exceeding one half of the vertebral width was seen only in 29 of Meyerding's 583 patients (*i.e.*, about 5%, and a little more frequently in Friberg's material (about 16 %), whereas the corresponding group in my material comprises about 50 % of the patients.

The only reasonable explanation of this difference appears

to be that the diagnosis was made more often or, rather, more early in the first two materials than in my material, undoubtedly because most of the cases in my material come from an orthopedic hospital, to which the patients are referred only at a relatively late juncture of the lesion. Thus, of the 8 patients in this material who came from a general surgical clinic to which the patients are admitted directly from the practising physicians, 4 presented spondylolysis, 2 showed Stage I, and in 1 the lesion was characterized as Stage I—II; and no patient in this group showed the more advanced stages.

The relation of the traumatic injury to the degree of spondylolisthesis has been investigated by various authors. *Meyerding,* for instance, has analyzed his material of 583 patients, making comparison between the entire material and that part of the material in which the history of the patient gave positive data about traumatic injury; and he found the percental distribution of the various stages to be the same in the total material as in the group with a history of traumatic injury.

On going through the *present material* with a view to this point, all the patients with a positive history of acute traumatic injury were found to present Stage I (2 patients) or Stage II (6 patients), while the 2 patients who showed Stage IV had no traumatic injury in their history.

Nor does a comparison between the stages of the lesion and the occupation of the patients offer any suggestion of connection between these two aspects. The two patients who presented the most advanced lesion (Stage IV) were both occupied with housework.

Localization of the Lesion in the Vertebral Column.

The localization of the lesion in the present material is quite in keeping with the findings in the large materials reported in the literature. A comparison of the present material with Meyerding's and Friberg's materials with a view to this feature is given in Table 3.

TABLE 3

Localization of Spondylolysis in the Vertebral Column in Meyerding's, Friberg's and the Writer's Materials, given as Percental Incidence.

	Meyerding's material in %	Friberg's material in %	Present material in %
5' lumbar vertebra	82.1	65.4	83.3
4' „ „	11.3	28.4	16.7
3' „ „	0.5	0.41	
2' „ „	0.3	0.14	
1' „ „		0.04	

In this material of 27 patients, bilateral spondylolysis was in 20 cases localized to L V, in 4 cases to L IV. In addition, 1 patient had bilateral spondylolysis localized to L V and unilateral spondylolysis of the right side of L IV; and 1 patient had unilateral spondylolysis limited to the left side of L V. Further, in 1 case the localization of the lesion was not given in the record and no X-ray picture was available.

The *age distribution* in this material differs a little from the one observed in the larger materials in the literature.

TABLE 4

Age Distribution of Patients in Meyerding's, Friberg's and the Writer's Materials.

Age (in years)	Present material (27 cases) No.	%	Meyerding's material (583 cases) in %	Friberg's material (280 cases) in %
1— 9				1.07
10—19	3	11.1	6	13.02
20—29	11	40.7	15.3	17.2
30—39	7	25.9	25	23.9
40—49	2	7.4	24.9	25.7
50—59	3	11.1	19.2	14.6
60—69	1	3.7	7.2	
70—79			2.2	5
80—89			0.2	

Thus, as seen in Table 4, the majority of the present patients are ten years younger than the majority in Meyerding's and Friberg's materials. Correspondingly, in Meyerding's material the average age of the male patients is 40.3 years, of the female, 43.5 years, while in my material the average age for all the patients (both sexes) is 31.6 years.

Spondylolysis has also been observed in the very young. Thus, *Friberg* mentions the case of a child 11 months old with multiple spondylolysis. *Kleinberg* had a patient 17 months old; and many authors have observed this lesion in patients about 10 years old. In the writer's material the youngest patient was 12 years old.

Sex Distribution.

In the earliest reports on spondylolisthesis the patients were all women (Lambl), as the diagnosis was made only when the deformity was an obstruction to parturition. But the large clinical materials from more recent times have shown the lesion occurs in men too—and even appears to be more frequent in these.

Thus, Meyerding's material includes 400 men and 183 women, Friberg's material 193 men and 97 women, and Willis' 54 men and 3 women—that is a male preponderance exceeding two-thirds.

The small material here presented includes 10 men and 17 women.

In skeleton materials we should expect to find the actual sex distribution, irrespective of the clinical symptoms that bring a patient to seek medical advice. Most of the authors who have examined skeleton materials have failed to give the sex of the skeletons, but

Junghaus found 13 men and 16 women, and
Shore found 4 men and 1 woman,

the addition of which gives an equal number of men and women. These figures are too small, however, to be decisive.

The male preponderance found in the clinical materials may

presumably be due to the circumstance that the harder labor of the men and their greater risk of exposure to traumatic injury will more often induce the symptoms of an existing spondylosis in this sex than in the female. Friberg's analysis of that part of his material in which the history of the patients was negative as to traumatic injury shows the male preponderance here to be a little lesser than in the total material. This may be taken to indicate that traumatic injury as well as the character of the daily work plays some role as to making spondylolysis symptomatic.

Parturitions in the Material.

In spondylolisthesis, especially when it involves the fifth lumbar vertebra—in particular, when the lesion develops into spondyloloptosis—the displacement of the vertebral body down on the anterior surface of the sacrum will naturally narrow the true pelvis considerably, as the conjugate diameter is greatly decreased.

In women this may form an insurmountable obstruction to parturition. This is the reason why the lesion in earlier times was diagnosed only in women, and the first reports on this affection were given by obstetricians.

Of the 17 women in this material 8 have never borne children. In one of these patients (No. 4, Stage II) induced abortion was performed.

Of the remaining female patients, 6 have been delivered from 1 to 4 times, all way of the vagina (Nos. 3, 7, 10, 16, 21 and 25). Of these six patients, 1 had spondylolysis, 1 presented Stage I of spondylisthesis, 3 presented Stage II, and 1 Stage IV (nevertheless, she has given birth to 4 children without any difficulty).

In the cases of 3 female patients no data are available as to pregnancy and parturition.

PATHOLOGIC-ANATOMICAL CHANGES

Normally the *interarticular isthmus* is subject to considerable variation. For one thing, it varies in the different parts of the vertebral column, being as a rule thicker and more robust proximally in the spine than distally. But even in the lumbar spine, where spondylolysis occurs most frequently, this structure is highly variable.

Roentgenographically this part of the vertebral arch is brought into view by taking the picture in oblique diameters — in the lumbar part most often by elevating one side of the pelvis about 30°. The optimal rotation is not constant, however, but has to be found in each individual case.

In such pictures the superior and inferior articular processes of a vertebra will be seen to be connected by a bony bridge— the isthmus itself. Its thickness may vary within wide limits (from about 1 cm. to a few mm.).

Separation will appear as a breach in the continuity of this bridge.

Macroscopically the separation appears most often as a linear slit; but it may be of irregular form—*e.g.,* V-formed, curving, or quite irregular. Often there is no sclerosis of the margins of the slit; but sometimes processes of regeneration are seen in the form of sclerosis or exostoses.

Generally the separation takes an oblique course—from above posteriorly and down anteriorly—and, at the same time, from the side posteriorly towards the middle anteriorly; in bilateral spondylolysis, in other words, as the pages of an open book which, instead of being held in ordinary reading position, has its upper margin turned in towards the chest of the reader.

For this reason, as will be pointed out later, the direct roentgenographic presentation of the gap will seldom be possible in frontal view, and often not in lateral projection, but best in that projection, where the gap is hit by the rays.

Microscopic examination of the gap, as reported by some authors, has shown some features that were interpreted as evidence of an acquired pseudarthrosis (*Zwerg* and *Meyer-Burg-*

dorff), whereas other authors have interpreted their findings as indicating a congenital separation (*Schmorl, Junghans, Willis* and *Hammerbeck*).

Thus, *Junghans* found the gap to be filled irregularly with fibrillary connective tissue, which was torn in several places, with small hemorrhages in the resulting crevices; here and there some areas of beginning calcification. In one specimen, a small piece of spongy bone was embedded in about the middle of the gap. *Schmorl* found in 3 cases some flakes of rudimentary cartilage in the gap. From their findings, these two authors concluded that spondylolysis is of congenital origin.

Glorieux & Roederer arrived at the conclusion that the origin of the lesion cannot be decided from the microscopic findings, and that these have to be interpreted as indicating that spondylolysis may be of traumatic origin as well as congenital.

As will be pointed out later, spondylolysis may undoubtedly remain symptom-free for many years and give no demonstrable secondary changes in the bones, ligaments or other tissues.

It is only when the back of the patient through some occasional causal circumstance (overstrain, traumatic injury, etc.) becomes insufficient that the first subjective symptoms make their appearance, and they are gradually accompanied by the secondary changes. These may consist in the slipping, or in local secondary changes in the vertebrae involved, intervertebral discs, ligaments, etc., or in the posture of the spine and pelvis.

Among the local secondary changes, some are so constant that several authors have claimed them to constitute the primary conditions required for the development of any spondylolisthesis.

Changes in the Intervertebral Disc.

Gradually, as the intervertebral space is narrowed and the disc degenerates, the adjacent vertebral surfaces will become traumatized, and if the slipping proceeds at the same time, the ligaments along the edges of the vertebrae will be exposed to an increased traction that will produce an osseous reaction in the form of sclerosis or marginal exostoses.

These bony changes may be circular, extending round the entire body of the vertebra, but usually they are more pronounced at the anterior margin.

As the slipping progresses, the osteophytes at the anterior margins may gradually attain enormous dimensions. Thus, when the vertebral body is slipping entirely down on the anterior surface of the sacrum, a large osteophyte is formed here, which —as a sort of console—serves to form a support under the steadily slipping vertebral body (see Fig. 13).

These osseous changes are subject to wide variations; they may develop into enormous structures, but, on the other hand, they may also be entirely absent (Fig. 15).

The slipping, especially in Stage II, is often associated with an impression in, or erosion of the inferior surface of the slipping vertebra, resulting from the pressure of this structure against the anterior margin of the sacrum. Gradually, as the vertebra keep slipping, the site of this pressure—and hence the impression —will shift further posteriorly on the vertebra. When the slipping has reached Stage III the vertebral body will most often be markedly wedge-shaped, much higher anteriorly than posteriorly, its lower posterior corner being worn off to a varying extent (Figs. 19, 23 and 25).

These changes in the fifth lumbar vertebra are often accompanied by changes in the sacrum, the anterior margin of the latter being flattened (Fig. 27) in some instances. Most often, however, the hypertrophic processes on the sacrum are in considerable preponderance, as mentioned, with production of large console-like exostoses which form a sort of support for the slipping vertebra (*Meyerding, Glorieux & Roederer*).

The *changes in the posterior arch* are far less pronounced. Exostoses may be seen round the small joints, between the articular processes, but often they are normal phenomena. The spinous process of the slipping vertebra remains in situ, but the spinous process of the overlying vertebra will move forwards with the body and, in some instances, be tilted upwards as the slipping vertebra begins to dip. A groove will thus be formed, corresponding to the row of spinous processes; and, in the

absence of spina bifida, the spinous process of the slipping vertebra may be felt or even seen to project distally to this groove (Fig. 13).

The Spinal Canal.

Meyerding has presented a sketch showing that the spinal canal in spondylolisthesis forms a sharp bend and is narrowed rather considerably anteroposteriorly, but he fails to mention how this has been demonstrated, and in the text he does not even mention the spinal canal at all. *Glorieux* & *Roederer* think this is not the case, and other authors have subscribed to this

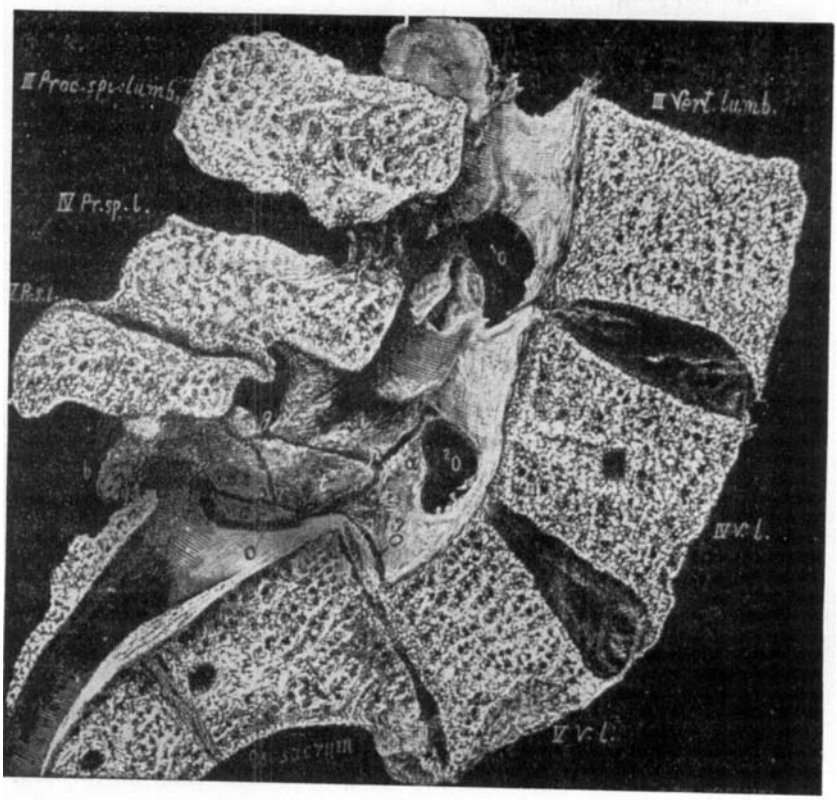


Fig. 4.

view, but no particular investigation into this point appears to have been carried out.

Junghans has presented some pictures of longitudinal sec-

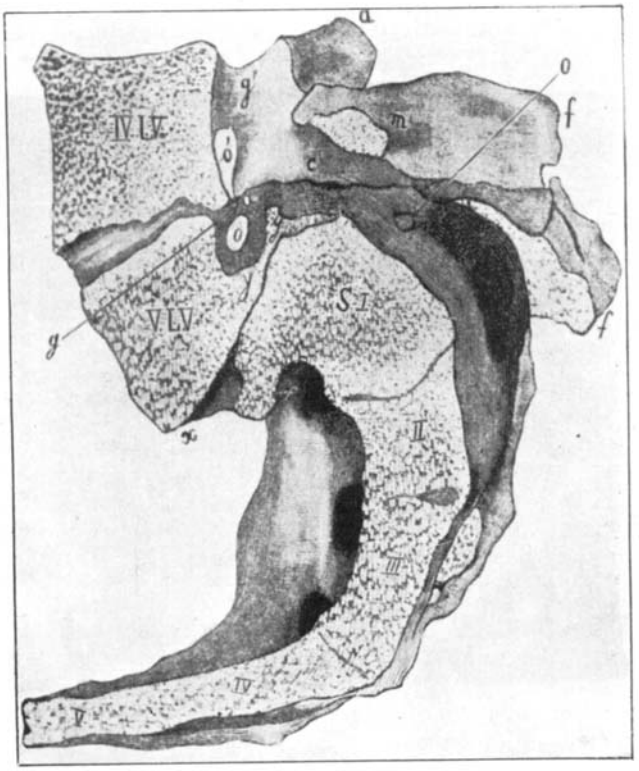


Fig. 5.

Figs. 4 and 5.

Sagittal section through the lumbosacral spinal column (after Neugebauer) with slipping of ½ and 1 vertebral width, respectively. The anterior wall of the spinal canal is stair-formed. The posterior wall is almost regular. The canal is not narrowed.

tion through vertebral columns with spondylolisthesis of the fifth lumbar vertebra, where the slipping amounted to nearly one-half of the vertebral width. Also *Neugebauer* has presented

some pictures of such cases, with slipping of ½ and 1 vertebral width, besides an instance of spondyloloptosis (Figs. 4, 5 and 6).

In these cases the anterior wall of the spinal canal is markedly staircase-formed. The posterior wall is quite smooth without any step formation, and the anteroposterior diameter here is rather increased (Figs. 4 and 5) except in the picture of

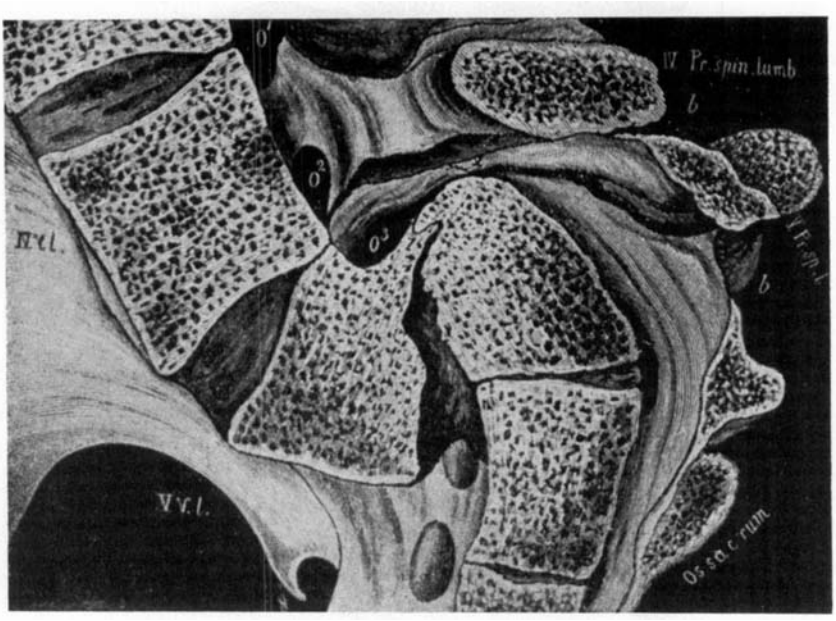


Fig. 6.

Section through a spondyloloptic spinal column (after Neugebauer). No console formation on the sacrum. Anterior wall of the spinal canal markedly stair-formed. Some narrowing of the interval between the upper posterior edge of the sacrum and the spinal process of the 4' lumbar vertebra.

spondyloloptosis, which shows some narrowing of the passage between the posterior superior margin of the sacrum and the spinous process of the fourth lumbar vertebra (Fig. 6). But the canal is not narrowed too much to accomodate the branches of the cauda equina.

In order to examine the form of the spinal canal, I have

performed extradural myelography on 5 patients with spondylolisthesis after a method that will be mentioned in Jydsk Medicinsk Selskabs Forhandlinger, Nordisk Medicin 1943.

For this purpose Perabrodil is injected through the hiatus sacralis and the roentgenogram is taken immediately after. The contrast substance is then seen to be distributed in the extra-

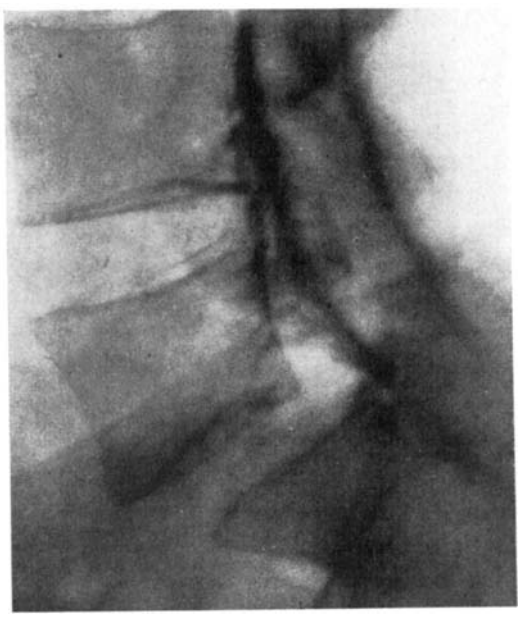


Fig. 7.
Patient No. 7. Spondylolisthesis of the 5' lumbar vertebra, Stage I.
Extradural myelography, lateral view.
The contrast substance is seen to line the anterior wall along the posterior longitudinal ligament, which is detached from the posterior surface of the slipping vertebra. The anterior as well as the posterior wall of the spinal are quite regular in outline.

dural space, being located anteriorly just back of the posterior longitudinal ligament, and anteriorly just in front of the ligamentum flavum and the arches of the vertebrae.

One patient with spondylolysis (No. 26) showed no abnormality on myelography; no sign of prolapse of vertebral discs.

In two patients with spondylolisthesis, involving respectively the fourth and fifth lumbar vertebra (Nos. 21 and 27), corresponding conditions were seen (Figs. 7, 8 and 9).

The slipping of the vertebra is quite plain. The contrast follows the anterior wall of the spinal canal along the posterior surface of the vertebra beneath the spondylolisthesis, and then

Fig. 8.

Patient No. 21. Spondylolisthesis of the 4' lumbar vertebra, Stage I. Extradural myeolography (lateral view).

The contrast substance is seen along the posterior longitudinal ligament of the anterior wall of the spinal canal, which here is curving slightly forwards. The anteroposterior diameter of the spinal canal is increased.

it forms a slight curve (Fig. 8) or proceeds without any irregularity whatever (Fig. 7) up to the lower margin of the vertebra above the spondolisthesis. The posterior wall of the spinal canal appears perfectly normal and regular (this is seen best in Fig. 7).

In one patient (Fig. 9) the contrast substance had difficulty in passing the site of the spondylolisthesis, and only a small

amount of it reached a higher level. Instead of ascending, some of the contrast substance flowed out along the nerve-roots. Presumably this difficulty in the distribution of the contrast substance is due to fibrous changes in the tissue resulting from irritation.

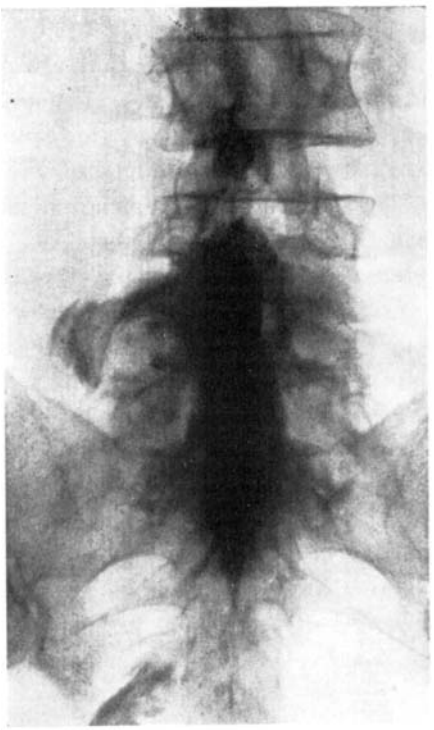


Fig. 9.
Patient No. 21. Spondylolisthesis of the 4' lumbar vertebra, Stage I. Extradural myeolography (frontal view).
The contrast substance has had difficulty in passing the site of the spondylolisthesis; instead of passing it has made its way out to the side along the nerve roots.

These pictures show, then, that in spondylolisthesis the posterior longitudinal ligament becomes detached from the posterior surface of the slipping vertebral body—also from its lower margin—and that there is no narrowing of the spinal

canal, at any rate not in the early stages of the lesion. On the contrary, its anteroposterior diameter is rather increased.

I have not yet had any occasion to perform extradural myelography on patients with more advanced stages of spondylolisthesis.

According to the myelograms of the longitudinal sections of vertebral column presented by *Neugebauer,* it can be established that the anterior wall of the spinal canal always will form a bend corresponding to the intervertebral space distal to the slipping vertebra, the anterior wall of the canal at this level being pulled forwards. This irregularity of the anterior wall will be smoothed by the posterior longitudinal ligament, which becomes detached from the slipping vertebra. In the milder stages the diameter of the spinal canal is rather increased, while in the later stages it may become more narrow; but not even in Stage IV, as a rule, is the canal narrowed so much that it cannot accomodate the cauda equina adequately.

The *intervertebral foramina* are not affected by spondylolysis or spondylolisthesis. Being situated close to the vertebral body, anteriorly to the superior articular processes as well as the transverse, the foramina are far removed from the site of the lesion and they accompany the slipping body in its forward shifting (the foramina are seen in Fig. 4). So the spinal nerves will not be compressed directly, and, far from being stretched, they will become more relaxed than normally as the vertebra slips forwards.

Organic Nervous Changes.

In keeping with these findings, organic nervous changes are rare in spondylolisthesis. Their presence has even been denied by some authors (*Meyer-Burgdorff, Burns, Guilleminet, Turner, Wollesen*). Other authors claim that nervous changes are frequent. Thus *Asbury* found nervous changes in two-thirds of his material comprising 27 patients. A review of his work shows, however, that these findings are somewhat vague and confusing.

In his material, *Asbury* includes 3 cases of verified fracture of the body of the fifth lumbar vertebra with subluxation of the entire vertebra—that is, of the posterior vertebral arch too—and in 5 cases no defect of the vertebral arch could be demonstrated roentgenographically. He emphasizes several times that the nervous symptoms are found preferably in cases where the entire vertebra (the posterior arch included) is dislocated, and not in the cases where the arch has remained in situ—*i.e.*, not in true spondylolysis. In other words, in several of his cases the lesion seems more likely to have consisted in a severe fracture or total dislocation of the fifth lumbar vertebra.

A review of the recorded neurological symptoms shows the following features:

The symptoms were present in 16 of the 27 patients. Of these 16 patients, 8 can hardly be reckoned as having organic nerve lesions, as they presented merely subjective symptoms in the form of pains and paresthesias, but no sensory disturbances or paresis.

8 patients showed also objective signs:

1 had sensory disturbances ("saddle anesthesia").

2 had a sensation of stiffness over the posterior aspects of the legs, without sensory disturbances.

4 had a relative paresis of one or more muscles, but no complete paralysis of any muscle. The author fails, however, to show that this was not a defect in the musculature. Finally,

2 patients showed absence of the Achilles tendon reflex, and

4 showed decreased patellar and Achilles tendon reflexes on both sides.

4 showed a positive Laseque sign, the presence of which is not sufficient by itself for a diagnosis of organic nerve lesion.

As *Asbury* fails to state whether it be the same patients who presented several of these symptoms, but merely says that the symptoms were found mostly in patients with dislocation of the entire vertebra, his account affords no proof that organic nerve lesions may be so common in true spondylolisthesis as claimed by him.

Heinrich & Krupp found signs of organic nervous changes in their four cases and think that such symptoms would be found more frequently on systematic neurological examination of these patients by a specialist. At the same time, however, they call attention to the fact that many of the cases reported in the literature may hardly have been clear-cut instances of spondylolisthesis but rather cases of traumatic injury, presumably with fracture or total dislocation of the vertebrae; and they

emphasize that such a pronounced lesion of the cauda as riding-breeches anesthesia and sphincter disturbances are seen but seldom.

Other authors have reported a few cases in which massive paralysis was observed.

In 1893 *Lane* reported a case of this kind, although, judging from his description of the operation, the lesion was undoubtedly a disc prolapse. In 1915 *Ryerson* reported a case in which the patient had spastic paraplegia. No information was given about roentgenography, and the clinical findings were rather against a true spondylolisthesis (the spinous process of the fifth lumbar vertebra—that is, the posterior arch too—was very movable forwards). In discussing this case, *Nutter* raised the objection that injury to the cauda equina at the level of the fifth lumbar vertebra, cannot give spastic paraplegia.

Among the larger materials in the literature, *Friberg* found sensory disturbances in areas of the lower extremities in 8 out of 302 cases, but no instance of disorder of the sphincter or sexual functions. *Meyerding* states that paralysis is a rare phenomenon, being present in less than 2 % of his material of 583 patients.

In the *present material,* objective neurological symptoms were demonstrated in 3 of the 27 patients. Of these 3 patients, one presented impairment of sensibility from the feet to the waistline, where the sensibility was rather accentuated, and absence of Achilles tendon reflex on one side. Another patient presented irregular impairment of sensibility in the peroneal region on both sides, in the trochanter region on one side, and on the medial aspect of the right femur. In these two patients, whose spondylolisthesis was located in the fifth lumbar vertebra, the neurological phenomena were thus referable chiefly to nerves arising from a higher segment. In the third patient the neurological symptoms were limited to paralysis of the bladder (disturbance of the sphincter ?) and "riding-breeches paresthesia"—that is, typical signs of a caudal affection.

In the first of these patients (No. 2), with spondylolisthesis of the fifth lumbar vertebra, Stage II, and sacral spina bifida, the impairment

of sensibility involved both lower extremities from the feet up to about the waistline, where the sensibility seemed rather accentuated. The knee-jerks were lively and equal. The right Achilles tendon reflex was normal, the left apparently absent. Plantar reflexes normal, sense of localization and posture normal. No ataxia. Musculature well developed, perhaps a little soft; tonus rather slight. Conclusion: Condition very uncertain. There is a possibility of muscular dystrophy, but the affection is probably of organic nature, perhaps with an admixture of hysterical element. The possibility that the lesion may be due to a displacement of the lumbar plexus produced by dislocation of the vertebra, possibly in connection with trophic disturbances, cannot be excluded.

(Examination by neurological specialist.)

The second of these patients (No. 15), with spondylolisthesis of the fifth lumbar vertebra (Stage II), showed hypesthesia in the left trochanteric and peroneal regions, round the right external malleolus, on a part of the dorsal surface of the right foot and on the medial aspect of the right thigh. The reflexes were normal.

The third patient (No. 20) was admitted for difficulty in urination. She presented spondylolisthesis of the fifth lumbar vertebra (Stage II), and sacral spina bifida. The bladder was found to be slightly trabecular. Cystometry showed tension at 500 cc. but there was no particular increase in pressure—neither at this degree of filling nor on attempt at urination (paralysis of the bladder). Tests for sensibility showed analgesia for pin-prick on the right side of the vulva from the mons Veneris to the anus, on the right side of the introitus, on the right major and minor labia and on the adjacent part of the right femur. Slight hypesthesia in the corresponding region on the left side. Reflexes and sensibility otherwise normal. Lumbar puncture: Clear fluid; pressure 90 mm. water; cells 9/3; albumin 10: globulin 1; Wassermann negative. Presumably the neurological changes are due to disturbances of innervation brought about by the osseous malformation in the lumbar region.

(Examination by neurological specialist.)

Of the remaining patients, 3 have had tingling paresthesias of the legs without organic neurological changes (Nos. 11, 18 and 19). One of these patients was examined by a neurological specialist. In 14 patients the reflexes and sensibility were found to be normal. The remaining 7 patients were not examined as to reflexes and sensibility.

Five of the patients were examined by a neurological specialist, three with negative result.

The possibility that the neurological affections may be due to a complicating disc prolapse has been discussed by *Gold-*

thwait, but this has never been demonstrated, and myelography has not been performed. In the three patients in this material on whom extradural myelography was performed, no signs of any disc prolapse were found.

Obviously the possibility suggets itself that the columnar dislocation may give rise to an irritative arachnoiditis or a chronic irritative inflammation of the extradural tissue that may be the cause of the usually slight organic nervous changes encountered sometimes. This possibility is suggested by the aforementioned obstruction to the passage of the contrast substance and extradural myelography beyond the spondylolisthetic vertebra (cf. remarks concerning Fig. 9 p. 30).

Lumbar puncture with examination of the spinal fluid appeared to have been carried out on such patients but seldom. In the present material lumbar puncture was performed on 2 patients (Nos. 2 and 27) and showed no pathological changes.

COMPLAINTS IN SPONDYLOLYSIS AND SPONDYLOLISTHESIS

Both spondylolysis and spondylolisthesis may be symptom-free through a considerable lenght of time. The onset of insufficiency of the back, spontaneous or resulting from acute or chronic overstrain or from traumatic injury, is associated with symptoms that may be due to 1) overstretching of ligaments, or originate 2) from the joints or intervertebral discs, or 3) from the musculature, or result 4) from nervous injury.

Often, however, the slipping has progressed to a considerable extent without giving any pain, or there has been merely a very slight discomfort, to which the patient has paid no particular attention for a good long time.

When the complaints have become so pronounced that the patient seeks medical advice and the lesion is diagnosed, this first examination often reveals a considerable degree of slipping; and sometimes it is only on thorough questioning that the lesion

is established as having been present for a long time. In some cases, however, no previous symptoms can be demonstrated.

As instances, the following cases may be cited:

No. 4: About 7 years ago the patient fell down two steps, landing on her buttocks. No symptoms during the following years. Now she has had backache for some months, but it was accidentally that she discovered a deformity of her back. There is spondylolisthesis of the fifth lumbar vertebra, Stage II, with slipping of about three-quarters of the vertebral width and beginning tilting of the vertebral body.

No. 20: Difficulty in urination for the last 5 years. No complaint concerning the back. Spondylolisthesis of the fifth lumbar vertebra (Stage II).

No. 23: From 5 to 6 years pain over the loins on physical exertion, but no notice taken of this complaint. Then the patient was hit in the back by an iron rod that fell from a height of one story on which account he was hospitalized. Examination revealed spondylolisthesis of the fourth lumbar vertebra, Stage I—II. Exostoses are present on the affected vertebrae—and only on these—indicating that the slipping is of no recent date.

No. 24: This patient is a man of 68 years, who was admitted for ureteral colic. X-ray examination reveals accidentally a bilateral spondylolysis of the fifth lumbar vertebra, involving also the right side of the fourth lumbar vertebra. On thorough enquiry it is learned that in youth he has had attacks of severe pain over the loins, for which he went to the doctor a couple of times. After this, however, he went through with his military service. Since then, he has had a little pain over the loins now and then but has never consulted a physician for it.

Pain over the loins is the complaint which most often brings the patient to the doctor (present in 24 of these 27 patients).

This pain is subject to great variation in character and intensity; most often it is induced by work or overstrain, in particular, lifting a heavy load. Not infrequently the pain is induced by stooping. As a rule, the pain subsides on rest and confinement to bed, but it may be present at night too, and disturb the sleep. The pain may be so severe that it renders the patient unable to work. Thus, three of the patients in this material were granted disablement benefit, while two others are known to have applied for this benefit but have been refused it.

In some cases the *pain may be of radiating character.*

In 13 patients the pain radiated down in one or both lower

extremities, most often on the posterior aspect of the thigh, but sometimes extending down in the legs. In one patient the pain radiated out in the buttocks alone; in one patient it radiated not only down in the legs, but also out on one side of the abdomen.

In one patient the pain had the character of chilling of the legs (No. 19); in another it appeared in the form of paresthesias (No. 18) without being accompanied by any demonstrable sign of organic nerve lesion.

In some patients the pain commences or flares up as sudden lancinating pain of very brief or somewhat longer duration, often induced by some particular movement or a slight blow (*e.g.*, tripping or stepping off the curb accidentally).

Tiredness or weakness was the chief complaint in 7 cases, while loss of ability to lift a moderate load was an almost constant phenomenon in this material.

Complete absence of pain was recorded in 3 cases (Nos. 4, 20 and 24). These patients have just been mentioned.

Obviously the complaints of these patients are quite atypical and not different from the symptoms produced by any of the causes that induce the symptom complex of lumbago-sciatica. If in such a patient the symptoms persist through a considerable length of time or keep on recurring, the possibility of this lesion has to be considered. On the other hand, the lesion may be symptom-free for a good many years, or the symptoms may be present and subside again even in cases with a very considerable deformity.

STATIC CHANGES IN SPONDYLOLISTHESIS

Under this heading the posture of the vertebral column and pelvis are considered together with the condition of the musculature.

As long as the functional capacity of the back is sufficient, spondylolysis is not associated with static changes in the vertebral column and pelvis other than the physiological variations. When insufficiency of the back begins to assert itself, the spon-

dylolysis will give symptoms, and the various complaints will set in, producing or, perhaps, being produced by 1) changes in the musculature and 2) changes in the posture of the vertebral column and pelvis developing under the slipping of the vertebral body.

The slipping of the vertebral body will by way of reflexes give rise to defensive reactions on the part of the organism in the form of 1) muscular spasms, and 2) static changes.

The muscular spasms will try to stabilize and fix the elastic or sliding part of the vertebral column. Their possible significance to the complaints will be discussed later on.

It will be appropriate here first to mention the static changes.

While the forward slipping of the vertebral body is still in its first stage, the changes in the posture of the vertebral column will not be pronounced. When, on the other hand, the slipping passes into the second or third stage, in which the slipping vertebra commences to tilt down and later sink down in front of the underlying vertebra the changes in the spinal posture will become demonstrable clinically.

Let us imagine, for the present, that we are dealing with an instance of spondylolisthesis of the fifth lumbar vertebra (cf. Figs. 10, 11, 12 and 13).

When this vertebra begins to tilt down anteriorly, its support from the sacrum will be diminished considerably, and its superior surface will be standing in a more oblique plane. The fourth lumbar vertebra will have to take part in this movement, and this will tend to tip the trunk forwards. But the organism tries to counteract this tendency by means of an *increased lordosis* in the overlying part of the lumbar spine.

When, nevertheless, these patients with advanced spondylolisthesis present *no pronounced lordosis,* it is because the organism performs an additional compensatory reaction, namely: a reduction in the *inclination of the pelvis.* This reaction consists in elevation of the anterior part of the pelvis, obviously to establish a better support of the fifth lumbar vertebra on the sacrum by making the superior surface of the sacrum more horizontal, that is, by diminishing the sacrohorizontal angle (or by increasing the lumbosacral and promontory angle).

This movement of the pelvis will also place the sacrum in a more vertical plane, and in pronounced cases the sacrum may even get to stand quite vertical.

In order to preserve the erect posture on standing, the hip-joints will have to be extended somewhat.

In addition, the forward and downward slipping of the fifth lumbar vertebra—and thus of the entire spinal column above this vertebra—on the oblique superior surface of the sacrum will bring about a *shortening of the trunk* (Figs. 10 and 11). This shortening does not become particularly pronounced and clinically demonstrable, however, till the vertebra has passed in front of the sacrum and begins to sink a little, down on the anterior surface of the sacrum. Then the *costal margin approaches the iliac crest, reaching sometimes this level or even descending below it, medially to the iliac crest* (Fig. 11).

With this shortening, the skin and subcutaneous tissue of the trunk will become too abundant, producing some *oblique transversal folds of the skin* in both flanks, practically parallel with the direction of the ribs, and more pronounced if the patient is obese (Fig. 10).

As mentioned before, there will also be formed a *groove proximal to the spinous process of the fifth lumbar vertebra,* which sometimes may be seen or felt projecting. This groove is formed as the spinous process of the fourth lumbar vertebra accompanies its body in the tilting, while the fifth spinal process remains at its original place.

Behavior of the Musculature.

The first stages of spondylolisthesis are accompanied by spasms of varying parts of the musculature of the back, which is associated with variable pain and tenderness that are not pathognomonic of the lesion but merely expressions of insufficiency of the back.

In the later stages, when the vertebra commences to tilt and sink down in front of the sacrum and the shortening of the trunk becomes pronounced, the distance between the origin and

the insertion of the truncopelvic muscles—*i.e.*, largely, the deep muscles of the back, the abdominal muscles and the iliopsoas—will become shorter than before, the musculature will be shorter and hence thicker. This, together with the forward displacement of the entire spine in relation to the pelvis will bring about that the *deep muscles of the back present the appearance of thick protruding muscular bellies* on both sides of a distinct furrow corresponding to the row of spinous processes (Fig. 10 and 12).

As to the abdominal muscles, corresponding changes will hardly be demonstrable clinically. Also the iliopsoas is bound to be shortened considerably.

The reduction in the pelvic inclination will diminish the real shortening of the muscles of the back and increase the shortening of the iliopsoas.

Presumably this total shortening of the musculature is contributable to the impairment of the muscular power and sensation of weakness of the back which these patients commonly complain of.

Clinically, the back of such a patient will then present the following features:

The inclination of the pelvis is diminished, the sacrum standing more vertically, and the iliac crests being more horizontal than normally (Figs. 10, 12 and 13). These features are seen more distinctly when the patient is inspected from the side.

The lumbar lordosis is moderately pronounced, but its typical feature is that it commences at a higher level and is shorter than normally (Figs. 12 and 13). Superiorly, the lumbar lordosis turns into a dorsal kyphosis which perhaps is more pronounced than normally. Inferiorly, where the lordosis commences, there is sometimes a visible and palpable groove, distally to which the spinous process of the slipping vertebra is projecting.

The musculature of the back looks vigorous and bulges strongly. Transversal or oblique folds of the skin are seen in the flank. The trunk is short and the costal margin is lowered to or below the level of the iliac crests. The gluteal muscles sometimes

appear flattened, probably on account of the anterior elevation of the pelvis (Figs. 10, 11, 12 and 13). There may be direct or indirect tenderness of the spine and musculature, depending on the present state of the lesion.

The mobility of the spine will be reduced and sometimes painful; most often the movements of the spine will take place in the upper part of the lumbar spine and in the dorsal spine,

Fig. 10.

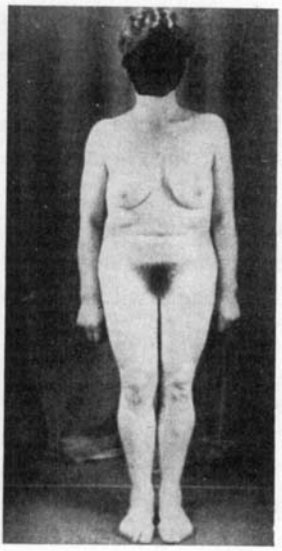


Fig. 11.

Fig. 12.

Figs. 10, 11 and 12.
Patient No. 9. Spondylolisthesis of the 5' lumbar vertebra. Stage IV. Note the elevated lumbar lordosis, the almost vertical sacrum, the slight flattening of the buttocks, the short trunk with the costal margin reaching down to the iliac crests, and oblique transversal furrows in the lumbar region. (Scar after Albee's operation.)

while the lower part of the lumbar spine will be fixed in a variable degree depending on the immediate state of the lesion.

Most often the capacity for lifting a load will be lowered considerably.

This entire presentation of the development of the lesion was

based on the supposition that it involved spondylolysis of the fifth lumbar vertebra and that it was this vertebra which was slipping in relation to the sacrum. This, as mentioned, is the most frequent form of the lesion, and it is this localization that gives the most pronounced slipping and the most typical static changes. It was also presupposed that the slipping was due to a

Fig. 13.
Spondylolisthesis of the 5' lumbar vertebra with slipping of 2 cm. (after Rydén).
Note the vertical sacrum, the high lumbar lordosis, which is limited below by the projecting spinous process of the slipping vertebra.

bilateral spondylolysis and that the lesion progressed symmetrically.

When spondylolysis is located in the fourth lumbar vertebra or at a higher level in the spine, the local pathologic-anatomical changes are quite of the same character as here described. It has been found, however, that the slipping of the fourth lumbar vertebra or a higher vertebra seldom reaches such marked degrees as when the lesion is located in the fifth vertebra. Hence

the entirely clinical changes will usually be far less pronounced, if they be demonstrable at all, in cases of spondylolisthesis located above the fifth lumbar vertebra. In cases of this kind the diagnosis can be made only by roentgenography.

Cases associated with Scoliosis.

When the spondylolysis is unilateral, or if in a bilateral lesion the slipping is asymmetrical, the clinical picture will be different from the one presented above and also more complicated. The local secondary changes will be of the same nature, but the clinical features will turn out differently.

In its slipping, the vertebra will not only slide forwards, but it will also rotate round an eccentric axis, which passes approximately through the articular processes of the fixed side; and the narrowing of the intervertebral space will be more pronounced on the side where the slipping proceeds. These two factors will result in a rotation scoliosis of the spine with the convexity on the side where the slipping has taken place.

This form of the lesion was first described by *Glorieux*, who called it "scoliose listhesique".

This form of scoliosis is found in unilateral spondylolysis and sometimes, in a relatively mild degree, in bilateral spondylolysis with asymmetrical slipping. It is said to be particularly pronounced, however, in patients who besides the spondylolysis have also a unilateral sacralization, and in such cases it is not always possible to decide which of the two lesions is the cause of the scoliosis.

Cause of the Pain.

Any attempt to give the cause of the pain in these patients is bound to be somewhat speculative. As organic nervous changes have been found only in rare instances, it is evident that generally the pain cannot be due to organic nervous lesions arising from pressure. Nor is there any reason to assume that the pain arises from joints or ligaments. If so, we should hardly ever see

any advanced stage of spondylolisthesis, which must have taken many years for its development, to remain symptom-free until shortly before the medical examination on which the diagnosis is made—and this is very often the case (cf. the case of No. 3).

To me it seems more likely that the pain is muscular.

From other deformities of the spine we are well acquainted with the fact that severe changes—*e.g.*, kyphoscoliosis—will remain quite symptom-free as long as the spine is well balanced, *i.e.*, as long as the deformity is compensated by corresponding changes in other parts of the spine, and that pain makes its appearance first when the balance is disturbed and the back thus becomes insufficient.

Similarly, the spondylolisthetic spine is being compensated gradually, as the slipping progresses slowly, by the postural changes mentioned above, and pain does not set in till the deformity is no longer compensated and the musculature therefore tries to establish and maintain the balance which is otherwise dependent on the static conditions. This state may make its appearance spontaneously because of the steadily progressing slipping or it may be induced by a more accidental cause such as traumatic injury or overstrain, hard or unaccustomed labor, etc.

X-RAY DIAGNOSIS

The final and exact diagnosis of spondylolisthesis must invariably be made by X-ray examination.

In order to make this complete, the pictures have to be taken in 1) the frontal plane, 2) the sagittal plane, and 3) in both oblique diameters.

In the lateral view and, especially, in the frontal view, the aforementioned oblique course of the separation will most often make the separation invisible, unless the slipping is rather considerable, as the gap otherwise is concealed by overprojection. The pictures taken in the oblique diameters serve to present the separation itself. If this is not directly visible in the ordinary

frontal and lateral projections, a thorough analysis of the pictures will sometimes raise a justified suspicion to the effect that spondylolysis is present anyhow—or even a relatively slight degree of spondylolisthesis.

Glorieux & Roederer have given an excellent presentation of the analysis of the normal X-ray picture of the lumbar vertebrae

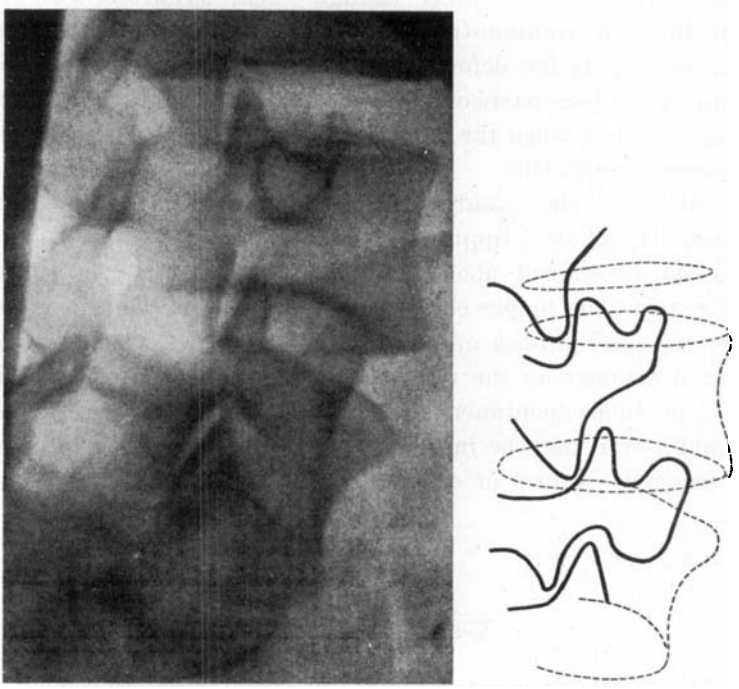


Fig. 14 a. *Fig. 14 b.*

Figs. 14 a and 14 b.
Normal articular processes and interarticular isthmus in oblique projection.

and of the demonstration of the changes appearing in the lines in relatively slight spondylolisthesis.

The aspects that are of particular interest in this lesion will be reviewed here.

On analysis of the X-ray picture of a normal fifth lumbar

vertebra in *frontal projection,* it is possible to follow the lines produced by the various parts of the vertebra, and when we are familiar with the normal relation of these lines and their merging, it is sometimes possible also in this projection to demonstrate

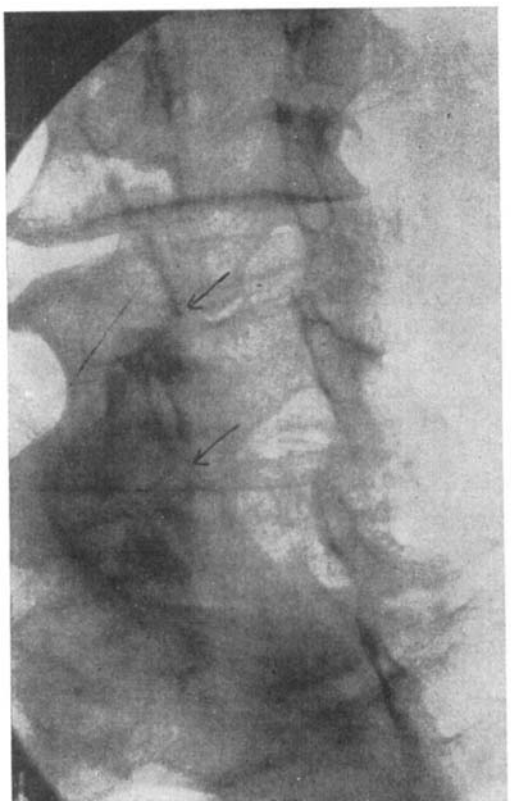


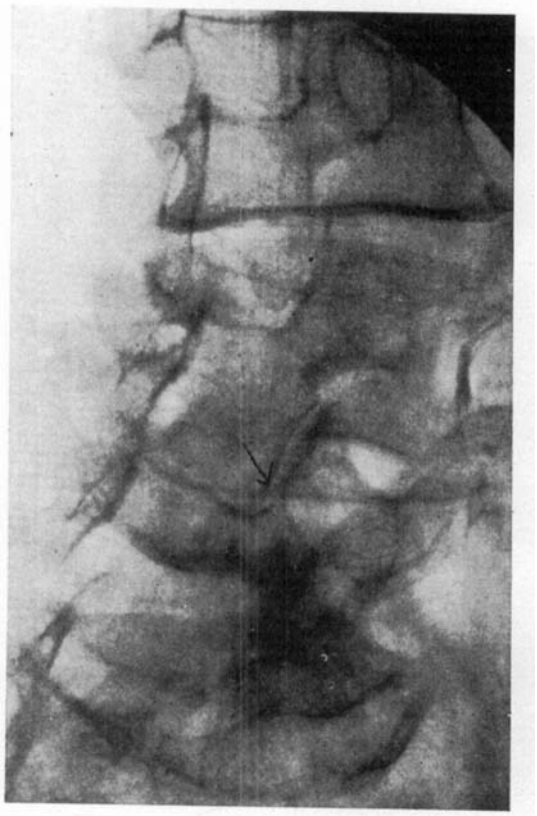
Fig. 15 a. *Fig. 15 b.*

Figs. 15 a and 15 b.
Patient No. 24. Picture taken from the right side. Spondylolysis of the 4' and 5' lumbar verbrae. Oblique projection.

even small dislocations corresponding to the isthmus. The picture must be taken with the projection exactly in the midline, and the central ray must be precisely parallel with the intervertebral

space. When these requirements are met, the upper margin of the projection of the spinous process will always be distal to the proximal articular surface of the vertebra.

Only in abnormal vertebrae—in fracture, destruction by



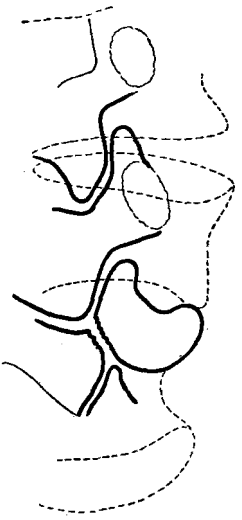


Fig. 16 a. *Fig. 16 b.*

Figs. 16 a and 16 b.
Patient No. 24. Picture taken from the left side.
Spondylolysis of the 5' lumbar vertebra.

metastasis of a malignant tumor or spondylitis, osteomalacia and spondylolisthesis—will the upper margin of the spinous process be in a plane with the proximal articular surface of the vertebra.

When then the aspects of the posterior vertebral arch are analyzed, starting with the upper margin of the spinous process, two lines may be traced. The proximal line, which is formed by the upper margin of the arch is curved, with the convexity downwards, arises from the spinous process and runs up to the

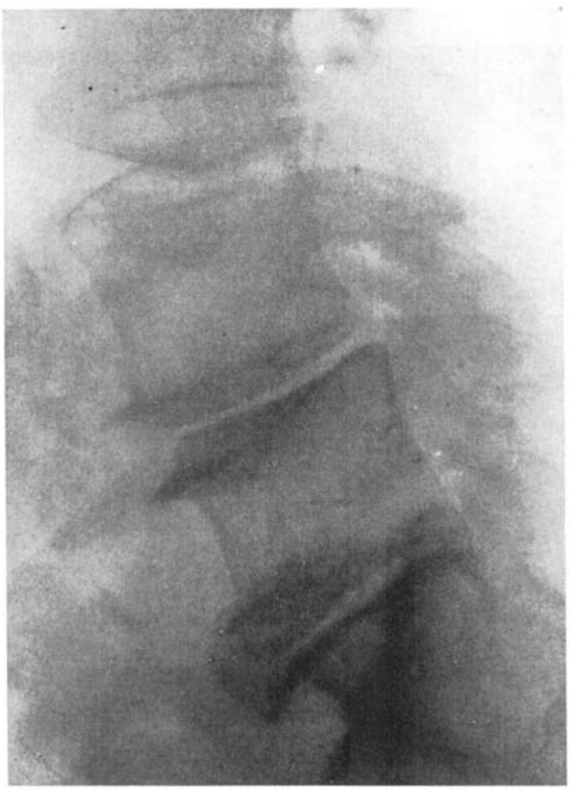


Fig. 17.
Patient No. 24. Bilateral spondylolysis of the 5' lumbar vertebra and unilateral spondylolysis of the 4' lumbar vertebra, on the right side with narrowing of the 4' and 5' intervertebral spaces, but not of those higher up.

side, to the medial border of the superior articular process, pointing towards the tip of this process.

The more distal line, which usually is more conspicuous than

the proximal, is formed by that crest on the posterior surface of the arch which arises from the attachment of the ligaments here. It runs downwards, curving laterally, and then turns proximally into the medial border of the articular surface of the superior articular process. In *spondylolysis and spondylolisthesis this line* is broken.

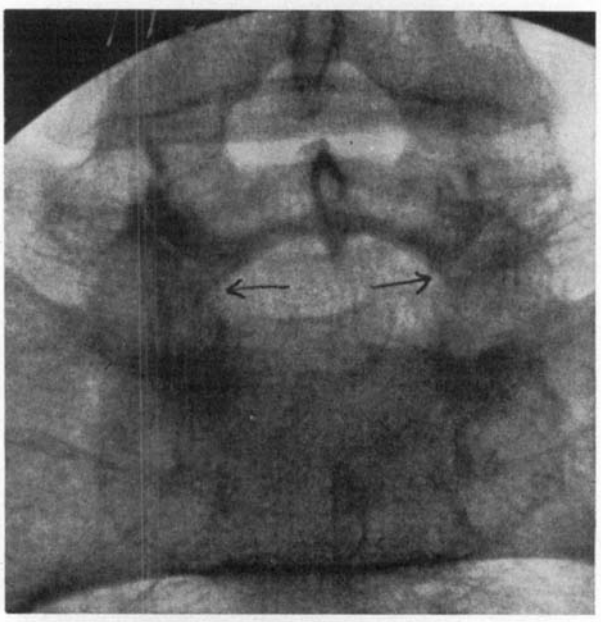


Fig. 18.
Patient No. 25. Spondylolysis of the 5' lumbar vertebra. Frontal view with distinctly visible gap in the isthmus. Sacral spina bifida.

Sometimes, especially in the more severe degrees of spondylolisthesis, the separation can be seen also in the frontal projection as a break in the continuity of the arch (Figs. 18 and 24).

In Stages II, III and IV—especially in cases where the vertebra has not only slipped forwards but also commenced to tip down over the anterior margin of the underlying vertebra—the slipping vertebra will sometimes present a frontal view of its

proximal surface, which *Glorieux* & *Roederer* have compared to a "chapeau de gendarme" (Fig. 24).

In the *lateral projection* the picture will far from always show the separation in the spondylolysis, as this is concealed by the surface of the gap. In spondylolisthesis, however, the gap will often be visible, and the degree of the slipping may be measurable by the width of the gap in millimeters or centimeters (Figs. 19 and 20).

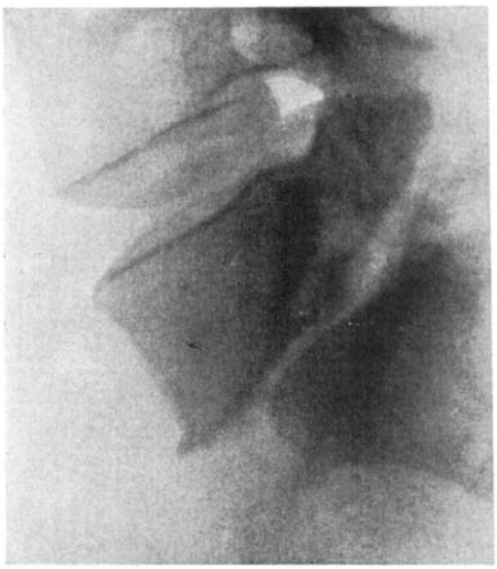


Fig. 19.
Patient No. 18. Spondylolisthesis of the 5' lumbar vertebra, Stage I.
Separation distinctly visible.
Narrowing of the intervertebral space.
Excavation of the distal surface of the 5' lumbar vertebra.
Moderate exostoses and beginning console formation.

At the same time, the slipping vertebral body will be displaced in relation to the underlying, and the slipping can be measured here too and be given either in linear measure or in fractions of the width of a vertebral body (cf. Figs. 23, 25, 26 and 27). In addition, exostoses will sometimes be seen round the underlying intervertebral space, in some cases going on to true

console formation for the support of the slipping vertebra (Figs. 17, 19 and 23); and the intervertebral space is often narrowed (Figs. 17, 19, 23, 25, 26 and 27).

So the pictures in oblique projections, which usually are required in spondylolysis and slight degrees of spondylolisthesis, are always necessary in order to exclude the presence of a spon-

Fig. 20.
Patient No. 21. Spondylolisthesis of the 4' lumbar vertebra, Stage I.
Separation distinctly visible.
No narrowing of the intervertebral space; no exostoses.
(See also Fig. 8.)

dylolysis. As mentioned already, the optimal degree of rotation for these pictures could not be given, as it varies with the individual conditions, but if the picture is to be satisfactory, it must show the joint slit in the small joints of the spine.

On analysis of the picture, one will then see the lines formed by the superior articular process continuing the line between the inferior articular processes after passing through a narrow area, the so-called interarticular isthmus. In spondylolysis and spondylolisthesis there will be a visible break in the continuity of these contours corresponding to the separation of the isthmus

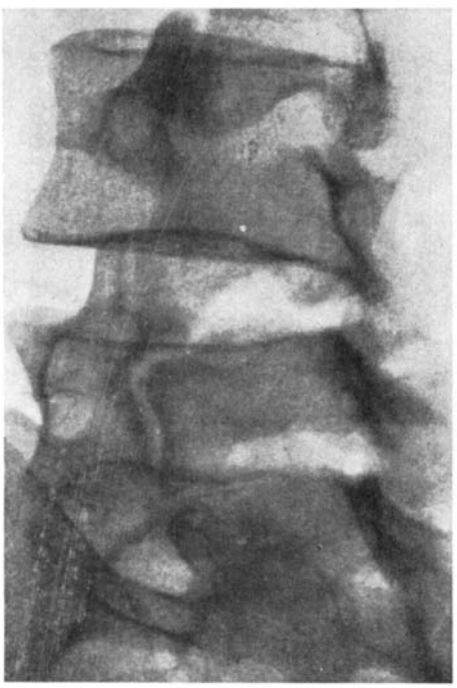


Fig. 21 a.

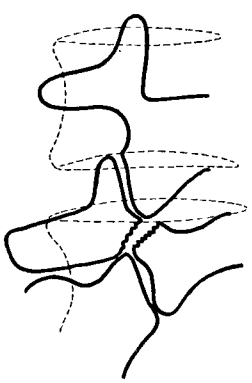


Fig. 21 b.

Figs. 21 a and 21 b.
Patient No. 27. Spondylolylisthesis of the 5' lumbar vertebra, Stage I. Oblique projection, right side.

(Figs. 14 A and B, 15 A and B, 16 A and B, 21 A and B, and 22 A and B).

As far as the fifth lumbar vertebra is concerned, these features may be difficult to ascertain, especially in severe cases, because of overprojection of the iliac crests.

TREATMENT

Several of these patients require no treatment at all, as the symptoms are either quite insignificant, or the diagnosis is made as an accidental finding on X-ray examination for some other

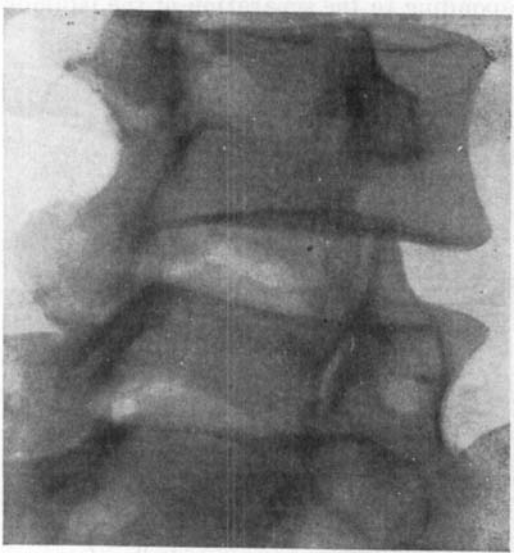


Fig. 22 a.

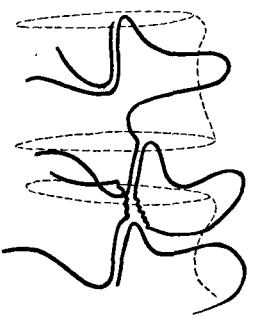


Fig. 22 b.

Patient No. 27. Spondylolylisthesis of the 5' lumbar vertebra, Stage I. Oblique projection, left side.

lesion. Such patients must then be kept under observation, and treatment is to be instituted if this condition gets worse.

In the present material of 27 patients, there was no reason to institute any treatment in 7 cases (Nos. 3, 13, 20, 23, 24, 25 and 26). One patient (No. 6) refused to submit to treatment. 5 of the patients have been reexamined, and only one of these showed a slight aggravation of the condition. 3 of the patients have not returned for reexamination or replied on enquiry about their state of health.

Of the first-mentioned 7 patients, 3 had spondylolysis without slipping of the fifth lumbar vertebra (Nos. 24, 25 and 26); one of these had also

unilateral spondylolysis of the fourth lumbar vertebra (No. 24). Of the remaining four, who all presented spondylolisthesis, 1 showed a transition between Stage I and II (No. 23), 2 showed Stage II (Nos. 13 and 20), and 1 had spondyloloptosis, Stage IV (No. 3). The last-mentioned patient was provided with an abdominal belt because of the pendulous abdomen, but

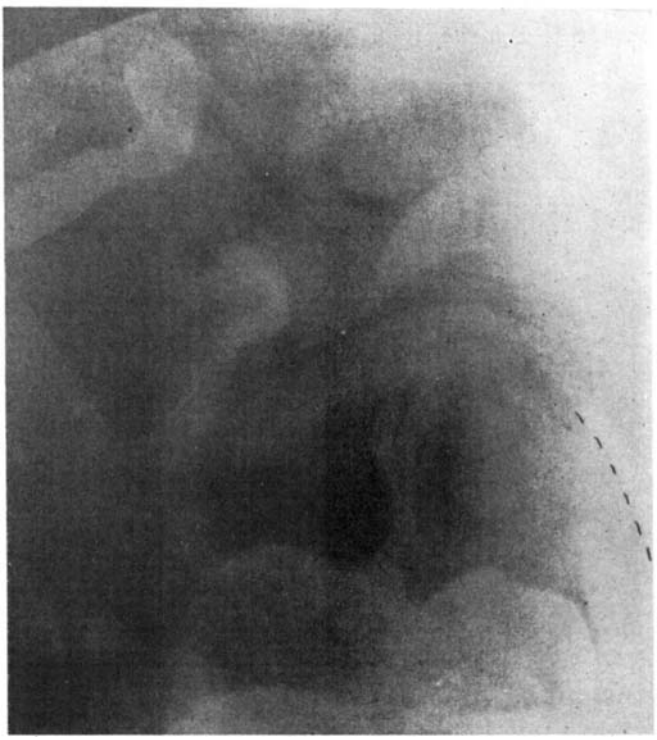


Fig. 23.
Patient No. 20. Spondylolisthesis of the 5' lumbar vertebra, Stage II.
Lateral view.
Excavation of the posterior distal corner of the 5' lumbar vertebra.
Narrowing of the intervertebral space.
Considerable console formation on the anterior surface of the sacrum.

otherwise she received no treatment. She has been under observation for 11 years and is perfectly free from pain while tending to her own work as housewife. She has had altogether 4 children, two of them during the observation period.

Of one patient (No. 6), it is merely known that she presented "some slipping of the fifth lumbar vertebra". Her symptoms were so severe that

operative treatment was advised. She refused to submit to such treatment in this hospital but declared that she wanted it performed in the local hospital, near home. She failed to enter this hospital, however, and she has not replied on enquiry about her health.

Of the aforementioned 7 patients who presented no indication for treatment, then, 3 had spondylolysis, 1 had spon-

Fig. 24.
Patient No. 20. Spondylolisthesis of the 5' lumbar vertebra, Stage II.
Frontal view.
Full view of the proximal surface of the 5' lumbar vertebra—presenting the form of a "chapeau de gendarme" (Glorieux & Roederer).
Separation of the arch visible. (→).

dylolisthesis, Stage I—II, while 2 showed Stage II and in 1 the lesion had advanced to Stage IV. This shows that the severity of the symptoms is not dependent on the degree of the slipping.

On Attempts at Reposition.

In cases requiring treatment it seems obvious to consider the possibility of a reduction of the displacement by reposition.

Indeed such treatment has been attempted by various authors, usually without success.

Friberg has reported an interesting case in which such reposition was performed successfully by Watson Jones, Liverpool. This patient was a girl, 12 years old, with spondylolisthesis of

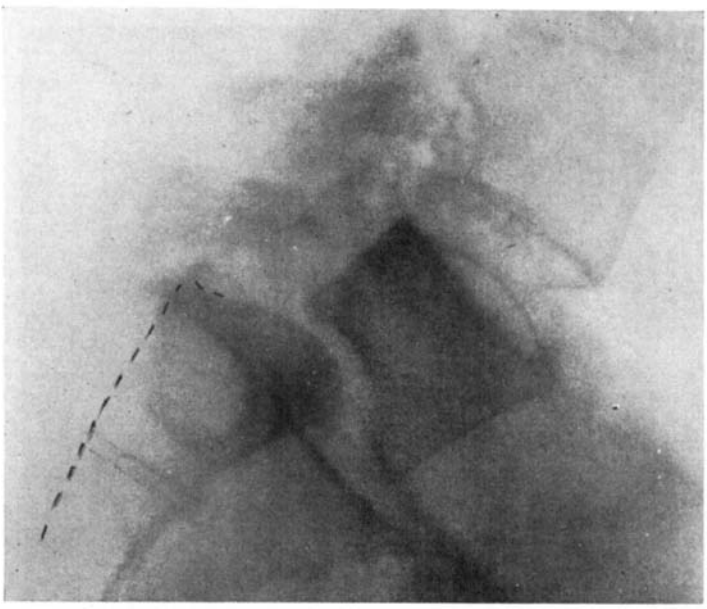


Fig. 25.
Patient No. 1. Spondylolisthesis of the 5' lumbar vertebra, Stage II.
Slipping more than ½ vertebral width.
Narrowing of the intervertebral space.
Excavation of the distal surface of the 5' lumbar vertebral and rounding of the anterior edge of the sacrum. No exostoses.

the fifth lumbar vertebra, with the slipping amounting to ½ vertebral width. She had had symptoms for 9 months. The reposition was performed successfully under ether anesthesia, with the hips being flexed, strong upward traction on the thighs and downward traction on the lumbar region. Three weeks later, the position was fixed by means of an Albee graft.

Friberg has attempted reposition himself in two cases, but unsuccessfully. One patient was a boy of 13 years, whose symp-

tom had lasted hardly one year and in whom the fifth lumbar vertebra had slipped 2 cm. There was a flat excavation in the distal surface of this vertebral body. He was put in a plaster cast covering only the pelvis, and adhesive extension with 5 kg. was applied to each leg for three months. The attempt at re-

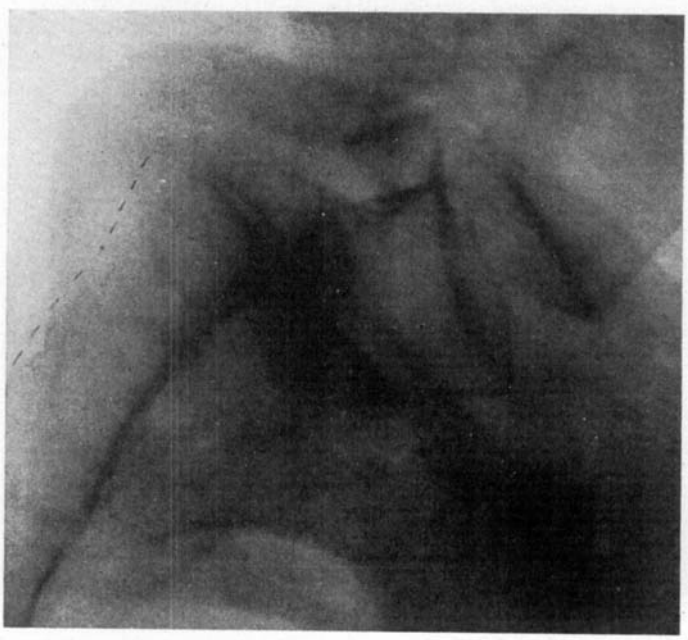


Fig. 26.
Patient No. 1. Spondylolisthesis of the 5' lumbar verbra, Stage III. Same patient as Fig. 25, after an observation period of 9 years.

position failed, and operative treatment had to be resorted to subsequently.

The other patient was a boy, 15 years old, who had had symptoms for 1½ years and showed spondylolisthesis of the fifth lumbar vertebra, which had slipped half its length. The vertebral body was diminished in height, and the same applied to the intervertebral space; the proximal surface of the sacrum had undergone some sclerosis. Reposition was attempted with wire extension, 10 kg. on each leg (to the inferior end of the

femur) for 4 weeks; but it was unsuccessful, and the patient was submitted to operation later.

A few other authors have reported successful reposition in a few cases (*Glorieux, Ryden*). *Brailsford* obtained a satisfactory result in an acute case, and *Bowmann* obtained the same

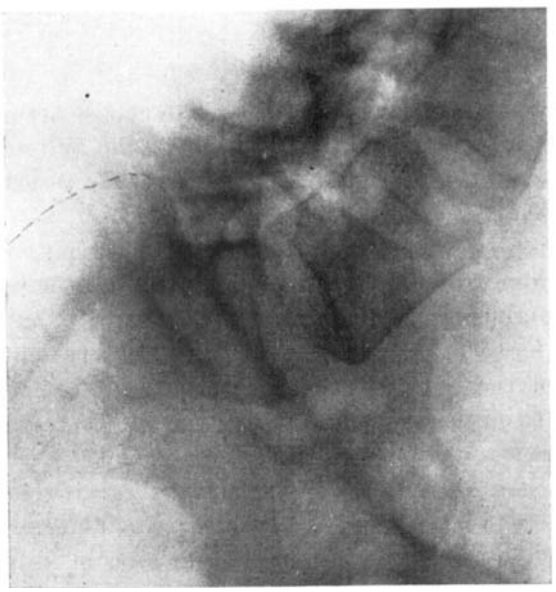


Fig. 27.
Patient No. 3. Spondylolopthosis of the 5' lumbar vertebra. No console formation.

in a few cases of traumatic origin (cited after *Glorieux* & *Roederer*).

Gourdon employs systematically reducing extension as introduction for treatment with corset, among other reasons, for relaxation of muscular contractures, but he fails to report whether this measure resulted in reposition (4 cases). (See below.)

It is generally acknowledged (*Glorieux* & *Roederer*, and others) that reposition of the slipping may be expected only in cases where its onset has been acute or following traumatic injury, and in which the secondary phenomena have not reached

any particularly advanced stage such as shrinkage of ligaments, exostoses, degeneration of the intervertebral disc, etc. X-ray examination will give the required information about some of these changes.

In the present material no attempt was made at reposition.

As to treatment, then, one will have to choose between orthopedic and surgical treatment. As a rule, one will try first to carry through an orthopedic treatment and only resort to operation if orthopedic measures prove insufficient.

According to *Glorieux & Roederer,* the tendency to operative treatment appears to be greater among American surgeons than among the European. Still, *Meyerding* operated on 99 of his 583 patients, and in *Friberg's* material of 280 patients 47 were operated on, that is, about the same proportion in operated and non-operated patients in the two materials. In the present material, 6 out of 27 patients were operated on.

In the choice between orthopedic and surgical treatment the decisive factor is not primarily the degree of deformity but the severity of the symptoms. As mentioned, even in its late stages the disease may often give but very mild symptoms, while milder degrees of the lesions may be accompanied by severe symptoms.

Besides considering the general condition of the patient, regard has to be taken also to his social standing and work. Heavy manual work suggests operative treatment, while lighter or sedentary work is more compatible with the continual employment of a corset (*Meyerding*).

Also cosmetic considerations may play a role, as, for instance, women of higher social standing will be more inconvenienced by wearing a corset continually than will women belonging to the broader population.

Further, the disposition of the treating physician may readily influence the choice of treatment, as an all-round surgeon most often will be lacking the general orthopedic view, which does not reckon so much with the time it will take to carry through the

orthopedic treatment. Besides, an orthopedist will naturally look upon the continued use of a corset as less inconveniencing than will a general surgeon. Probably it will be quite practicable in most cases first to try orthopedic treatment to see if this may lead to a satisfactory result.

Orthopedic Treatment.

The orthopedic treatment most commonly employed—and which was used in this material too—consists in application of a stiff (leather) corset, without any preceding attempt at reposition. If necessary the patient is kept in bed for a shorter or longer period, on which regimen the muscular contractures and pain most often will subside.

When the patient is free from pain, he is first put in a Sayres plaster corset, which the patient wears for some months. If the symptoms disappear under this treatment, and if the patient is able to do his work while he wears this corset, a permanent corset is made, which is to be worn only in the daytime and taken off at night.

A few authors employ systematically a more complicated regimen.

Thus, *Gourdon* obtained an excellent result on treating 4 relatively mild cases after the following principles:

1' seance: By steadily increasing the extension of the lower extremities for 10—14 days, an attempt is made to stretch the posterior lumbar and lumbosacral ligaments; muscular contractures are abolished at the same time.

2' seance: An attempt is made at slow reposition of the deformity by vertical extension of the pelvis, which is carried out by means of two broad belts, one of which is placed over the abdomen, fixing the lumbar spine, while the other is placed under the pelvis, exerting a vertical and forward traction.

3' seance: Fixation of the spondylolisthesis in the obtained position by means of a plaster corset, sometimes reinforced by splints, for 4—6 months. Then application of the permanent corset.

Gourdon fails to state whether reposition was obtained by this treatment, but it seems doubtful that it may be possible by means of a corset to retain such a reposition of the fourth or fifth lumbar vertebra.

In the present material, *corset treatment alone* was employed in 12 cases (Nos. 1, 4, 7, 10, 11, 12, 15, 17, 18, 19, 22 and 27).

In addition, corset treatment was employed also in 5 cases in which operative treatment had to be given subsequently (Nos. 2, 5, 8, 16 and 21).

Of the 12 patients who were given corset treatment alone, 1 (No. 27) is still under preliminary tentative treatment, the result of which cannot yet be decided.

2 patients have been characterized as recovered.

One of them (No. 22), who had spondylolysis of the fifth lumbar vertebra, has been reexamined after two years. He is no longer wearing the corset, and he is able to do all his work (on a farm) without any inconvenience.

The other patient (No. 7) had spondylolisthesis of the fifth lumbar vertebra, Stage II. He has now been under observation for six years. He had ceased his occupation and is now a newspaper reporter. He has no symptoms when he wears a corset.

1 patient has improved considerably.

This patient (No. 4) had spondylolisthesis of the fifth lumbar vertebra, Stage II, with slipping of three-fourths of the vertebral width. She has been under observation for 9 years. She is doing her own housework, besides taking care of a chicken farm, and she is able to lift some loads (washing) without inconvenience, but occasionally—for instance on stumbling—she has a brief attack of lancinating pain in the back. During the observation period a slipping of the vertebra has increased distinctly, from Stage II to Stage III (Figs. 25 and 26).

In 3 patients the condition is unchanged.

One of these patients (No. 1), with spondylolisthesis of the fifth lumbar vertebra, Stage II, has been under observation for 14 years. She wears her corset and is able to do her housework though with moderate discomfort.

Two patients (Nos. 15 and 18), with spondylolisthesis of the fifth lumbar vertebra, were greatly disabled on their admission to the hospital, and they are not better now under the corset treatment. They are both

receiving disablement benefit and have ceased working. They were advised to submit to operative treatment but refused.

In addition, one patient (No. 14), with spondylolisthesis of the fourth lumbar vertebra, Stage I, has refused to return for reexamination after two years, and on enquiry she has given merely insufficient information about her state of health. Finally, 4 other patients (Nos. 10, 11, 12 and 17) have failed to return for the wanted reexamination.

Thus, treatment with corset has been employed in altogether 17 cases, in 5 of which it has proved efficient. In 5 other cases operative treatment was given subsequently; this was further advised in two cases but refused. In 4 cases no information has been available about the result of the treatment; and in one case this treatment has been instituted just recently.

A numerical expression for the efficiency of the orthopedic treatment—*i.e.*, chiefly treatment with corset—in spondylolisthesis is hardly obtainable from the literature except in *Friberg*'s material. Here a satisfactory result—*i.e.*, absence of inconvenience on the performance of any kind of work (less than half of these patients) or absence of inconvenience only on performance of lighter work (over one-half of the patients)—was recorded for the men in 56 % of such cases, for the women in 84 %.

Surgical Treatment.

The following conditions will furnish indications for surgical treatment:

1. Severe degree of the subjective symptoms.

If the complaints are pronounced or somewhat disabling and not yielding to orthopedic treatment, they will constitute an indication for surgical treatment.

2. In cases where the slipping continues, after observation for some length of time, this feature will add to the indications for operative treatment, as it may be possible by this treatment to prevent further slipping.

3. Cases associated with scoliosis—*i.e.*, cases with asymmetrical slipping—constitute a particular indication for operative treatment, especially if the scoliosis develops rather rapidly. If this form of the lesion is allowed to develop to a more pronounced degree, the deformity will be particularly inconveniencing with regard to the working capacity as well as to cosmetic aspects.

In every case, however, the indication for operative treatment has to be considered individually, in particular with a view to the occupation of the patient, but also with regard to his social standing.

Naturally, here as well as in any other disease, the general condition of the patient may constitute a contraindication for operative treatment or influence the weight of other indications. As to the age of the patient, youth is no contraindication. On the contrary, it is important in children and young persons as far as possible to prevent the deformity from developing to more severe degrees.

Wilson has operated on a boy of 9 years. *Guilleminet* on a child of 11 years. *Hellstrøm* on a child of 13 years, and *Friberg*'s material includes one patient of 13 years and 2 of 14 years who were operated on.

The *present material* includes no child who was submitted to operative treatment. The youngest patient was 12 years old when she (No. 1) was admitted to the hospital, and she has now been under observation for 24 years. During this period the slipping has progressed from Stage II to Stage IV, and a slight scoliosis has developed. Operation was advised at her first examination, but this was refused.

The next youngest patient on admission to the hospital (No. 13) was then 13 years old and presented spondylolisthesis of the fifth lumbar vertebra, Stage II. The symptoms were only few and slight. Operative treatment was advised but refused. The patient has not returned for the wanted reexamination.

Methods of Operation.

The operative treatment aims to afford support of the spinal column in such a way that additional slipping is prevented and the symptoms of insufficiency cease.

Numerous methods for operative treatment have been devised and employed; fundamentally they may be divided into two groups: 1) operations aimed against the anterior slipping part of the vertebra, *i.e.*, against the body, transverse processes or superior articular processes; and 2) measures aimed against the posterior part of the vertebra, *i.e.*, against the inferior articular processes, the arch, or the spinous process.

The most rational will be at the operations to try to form a support for that part of the vertebra which is slipping, but this has been carried out only in relatively few cases—because of the technical conditions that make the access to these parts of the vertebra more difficult.

Operations aiming to form support for the slipping vertebra have been performed *from the front* in a limited number of cases and after different methods that can be divided into two groups: 1) insertion of a graft through the body of the fifth lumbar vertebra, the intervertebral space and down in the sacrum; 2) removal of the intervertebral disc together with the adjacent parts of the fifth lumbar vertebra and the sacrum and filling of the defect with suitable pieces of bone in order to obtain osseous healing.

The first method has been carried out transperitoneally by *Burns* (as the first) in 3 cases and by *Jenkins* in 2 cases. These authors drilled a hole down through the body of the fifth lumbar vertebra, through the intervertebral disc and down in the sacrum, whereafter they placed a tibial graft in the hole. In these cases the result is said to have been good. In one of Burns' patients the result was an osseous ankylosis between the two vertebrae, corresponding to the graft; in the other the graft had undergone partial absorption. The third patient was just operated upon.

In 3 cases *Mercer* performed the transperitoneal operation and chiselled a quadrangular groove in the body of the fifth lumbar vertebra and sacrum, with removal of the corresponding part of the intervertebral disc and inserted a bone graft from the iliac crest, fixing the graft to the sacrum by means of a

screw. One patient died after the operation; one recovered and became fully able to work; and in the third patient the primary result is good (personal communication to Friberg).

The *second group of operations* has been performed transperitoneally by *Friberg* in 4 cases, and by *Speed* in 1 case. In some cases the transplant was fixed to the sacrum by means of a screw; in others the transplant was not fixed by any particular measure. Of Friberg's 4 patients one died after the operation; one recovered and is able to work, one improved but has pain on physical exertion; and one is free from subjective symptoms. None of these patients showed osseous ankylosis after 1½ years.

In addition, *Chaklin,* Moscow, has performed the same operation extraperitoneally in 6 cases (cited after Glorieux & Roederer). After the operation he secured a strong lumbar kyphosis, in which position he kept the patients for some weeks, in order to keep the transplant firmly in situ, and with this technique he obtained osseous ankylosis between the two vertebrae and a good primary result. None of these patients died.

From the literature, thus, 13 patients have been collected who were operated on transperitoneally after these methods; and 2 of them died after the operation. In addition, there are 6 patients who were operated on extraperitoneally by Chaklin without any fatal result. So, in comparison to the posterior osteosynthesis, the case mortality for this group has been rather high.

Burns claims that the method is very easy and less shocking than the Albee operation. *Mercer* advises against this operation on obese patients, in cases with complete dislocation of the vertebra (Stages III and IV) and in cases showing osseous healing or tendency hereto (pronounced exostoses or console formation). *Friberg* states that it is not settled yet when the operation is to be carried through from the front, while we know when it should *not* be done—namely, in the great majority of cases.

The *second group of operating methods,* likewise aimed against the projecting part of the slipping vertebra, consists in the insertion of a bilateral graft between the ilium and the lateral surface of the vertebral body or the transverse process of this vertebra.

Zahradnicêk (cited after *Glorieux* & *Roederer*, who fail to give the publication) has employed this technique for support of the slipping vertebra in one case. An incision was made parallel with the iliac crest and the ala of the ilium was laid bare posteriorly. A hole was drilled through the ala pointing obliquely and medially. A tibial graft was passed through this hole, extending to the anterior and lateral surfaces of the fifth lumbar vertebra. In addition, an Albee graft was inserted in the back. After this, the patient was free from pain.

Similar methods have been employed by other authors who introduced the bridge into the divided transverse processes.

Campbell, Lance & Aureausseau tried first a slow reposition for 3 weeks and then they placed the patient in a plaster bed—in order to make him accustomed to the plaster cast. At the operation the iliocostal muscles are dissected out, and also the transverse process and 6 cm. of the iliac crest medially and posteriorly. The musculature is pulled to the side, and thick grafts are chiselled out of the lateral part of the iliac crest in such a way that they remain connected with the medial part of the crest. The grafts are turned up against the divided and roughened transverse processes of the fifth lumbar vertebra, sometimes those of the fourth vertebra too.

This operation is performed on both sides; and it has been employed in 2 cases. Subsequent X-ray examination showed that the grafts formed no union with the transverse processes of the fifth lumbar vertebra, whereas there was good fixation of the fourth lumbar vertebra.

After *Mathieu—Demirleau's method* a hole is drilled in the ala ossis ilii and a tibial graft is inserted in the hole, extending to the divided transverse processes of the fifth lumbar vertebra, sometimes of the fourth lumbar vertebra too. The operation has been performed in one case, and here an Albee graft was inserted too.

As yet, these methods have not been employed sufficiently often to allow of an estimation of their effectivity; besides, re-examinations after a sufficiently long observation period are still wanting.

Glorieux & Roederer raise these objections to the methods mentioned that the transverse processes of the fifth lumbar vertebra often are small and thus afford but poor support for the bridge, that in pronounced spondylolisthesis the transverse processes are displaced so far forward that they are accessible only with difficulty, and that the iliac crest affords only a poor material for the bridge.

Operations aimed against the Posterior Part of the Slipping Vertebra.

Theoretically these operations will be less well-founded than operations on the anterior part of the vertebra, as the fixation will be placed rather far from the slipping vertebra and transferred hereto but indirectly through the overlying vertebrae. On the other hand, the posterior parts of the vertebra are more easily accessible, and the technique of the operation is therefore easier. Besides, as is well known, the case mortality with this kind of operation is very low.

Thus, of the 144 patients in Meyerding's, Friberg's and the present material, on whom posterior osteosynthesis was performed, none died.

If the fixation merely connects the inferior and superior articular processes with the corresponding articular processes of the adjacent vertebrae, no fixation of the spondylolysis will take place at all, as this does not prevent further separation. On the other hand, an arthrodesis of this kind (it forms a part of Hibbs' operation) may be useful by contributing to an effective ankylosis of this part of the spine.

In order to secure an effective fixation, a solid osseous block must be formed between the spinous process—and, if possible, the arch—of the slipping vertebra and several vertebrae above as well as below the slipping.

The method most commonly employed for this purpose—and also other lesions of the spine besides spondylolisthesis—has been

Albee's operation, with insertion of a tibial graft in the divided spinous processes.

In spondylolisthesis, however, this method appears not always to have given quite satisfactory results (according to *Azema*) in 30 % of the cases reported in the literature, and it has been modified, therefore, in various ways, especially by American surgeons.

Furthermore, the particular conditions encountered just in spondylolisthesis have caused some particular difficulties in the employment of this method. Thus, in sacral spina bifida, which is a common phenomenon, it is necessary to place the graft rather laterally on the sacrum. Owing to the sometimes increased lordosis, it has been difficult in such cases to adjust the graft, and it has been necessary sometimes to excise it with a suitable curvature, or it has been necessary to fracture its lower part, or employ several thin and flexible osteoperiosteal grafts, which can be formed precisely after the conditions present, instead of a thick and rigid graft.

Some authors have modified the principles of the method. *Meyerding* thus employs two lateral grafts. After chiselling a thin layer of the sides and spinous processes and arch he places one graft on each side as close to the arch as possible and fills all interstices, especially in the lumbosacral angle and at the end of the grafts with spongy osseous tissue. In Meyerding's material of 583 patients, 99 were operated on after this method, and the results are reported to have been "gratifying".

Hibbs has operated on 23 spondylolisthesis patients after his own method, which, with various modifications, now consists in resection of the spinous processes at the base. A graft is chiselled out from each lamina and turned up on each articular process, superior as well as inferior, and then these grafts are turned respectively up and down, being brought into flat contact with the corresponding grafts on the adjacent vertebrae; and finally, in some cases an arthrodesis is performed that covers all the small joint. As the last step of the operation, the resected spinous processes are turned down over the bared base of the spinous process of the underlying vertebra.

Among the 147 patients, suffering from various lesions, who were operated on after this method, 66.9 % were cured, 12.5 %

improved, and 20.8 % remained unchanged after an observation period of 1½—14 years. There was no fatal outcome of the operation.

Also Hibbs' method has been modified, among others, by *Lee,* who with a special chisel removes some slivers from the arch of the last three lumbar vertebrae and from the posterior surface of the sacrum. These slivers are turned up over the adjacent vertebra. The spinous processes are resected and divided into small pieces, which are distributed in the lumbosacral angle, in the midline as well as laterally. Superficially hereto, small tibial grafts are now transplanted, and most superficially some large and very wide tibial grafts. The grafts are fixed by means of chrome catgut sutures in the fascia.

With this technique Lee has operated on 35 patients suffering from various lesions, with a good result in 32. Of these patients 7 had spondylolisthesis, and all were cured.

Widerøe has given a similar but less extensive modification of Hibbs' method.

Further, *Bentzon* has given a method which as yet has been

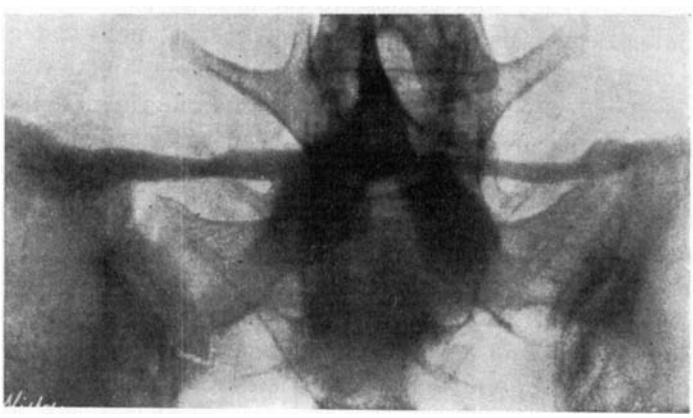


Fig. 28.

Spondyloloptosis of the 5' lumbar verbra and sacral spina bifida. Operation after Bentzon's method, with transverse graft between the two iliac crests, passing through the interval between the spinous processes of the 3' and 4' lumbar verbrae. At one end of the graft, two Looser zones are seen.

mentioned but briefly in the literature, and which I have been permitted to outline after his personal communication.

This method was employed for the first time in 1937 in a patient in whom an Albee graft was impracticable on account of a combination of severe spondylolisthesis (Stage IV) with pronounced sacral spina bifida, so that the dura was uncovered over the greater part of the sacrum.

The method consists in the application of a tibial graft resting with its two ends on the iliac crests near the posterior superior iliac spines and supporting the spinal column by passing through a perforation between the spinous processes of the third and fourth lumbar vertebrae (see Fig. 28).

The technique of this operation is briefly described as follows:

A transverse, upwards convex, incision is made between the two posterior superior iliac spines. The spinous processes of the third and fourth lumbar vertebrae are laid bare and a hole is made between them by removal of a part of the interspinal ligament; if necessary, a little of the edges of the spinous processes is nipped off.

Then the iliac crests are bared at the posterior superior spines and, by means of blunt probe, a channel is formed straight through the erectors of the spine in such a way that the three points—the posterior superior iliac spines and the hole between the spinous processes of the third and fourth lumbar vertebra—as far as possible fall in a straight line.

A pliable lead probe is now inserted and adjusted to fit, whereafter it is used as pattern for the graft that is to be cut out of the tibia.

The tibial graft is inserted. If necessary, a groove is cut in the edge of the iliac crest for accomodation of the graft, which is then fixed at the ends by means of bone sutures with fishgut.

After-treatment in plaster cast.

This operation has been performed on 3 men, respectively 19, 17 and 17 years old, all with spondylolisthesis of the fifth lumbar vertebra. In one the lesion had reached Stage II (slipping of a little more than one-half vertebral width); in the two others it had gone on to Stage IV (spondyloloptosis). One of

these patients had ostepsathyrosis with blue sclerae, diffuse lime atrophy and a past history of many fractures.

One year after the operation the last-mentioned patient had improved considerably, but, owing to this general morbid condition, he was not yet able to work.

The two other patients have now been under observation respectively 2½ and 2 years; they are both free from pain. One, who formerly was farming and presented spondylolisthesis (Stage IV), together with sacral spina bifida, has changed occupation, being a tailor now; he is still using corset. The other is doing office work and playing tennis without any inconvenience; he has commenced to do without the corset in the evening and on Sundays.

Theoretically one would perhaps be afraid that such a long elastic bridge would not give sufficiently solid support to the vertebral column. In these three patients, however, the result has been satisfactory.

That this bridge is subject to considerable tension is evident from the fact that in one of the patients, two years after the operation, two Looser zones have formed close to one end of the bridge (see Fig. 28). In one of the other patients a similar clearing in the bridge was seen half a year after the operation (corresponding to the passage of the graft between the spinous processes). This rarefication healed subsequently. The effectivity of the graft appears not to be influenced by these clearings.

In the *present material,* 6 of the 27 patients were treated operatively, all after Albee's method, in a few cases with slight modifications (Nos. 2, 5, 8, 9, 16 and 21). Two of these patients were operated on in another hospital, one of them without preliminary corset treatment.

Of these patients, 2 can be characterized as cured (Nos. 2 and 8), as they have now been under observation for respectively 10 and 5 years, feeling perfectly well and being able to do ordinary farm work.

In 3 patients the condition has improved after the operation (Nos. 5, 9 and 21). Two of them (Nos. 5 and 9), with an observation period of 1 and 4 years respectively, have had to change

their occupation but are able to attend to lighter work with moderate inconvenience. One (No. 21), with an observation period of 1½ years, is able to do lighter housework without any pain, but now and then she has a little tiredness of the back after exertion. X-ray examination shows that the bridge has broken; she is still wearing a leather corset.

In 1 patient (No. 16) the condition has remained unchanged after the operation, with an observation period of 1 year.

Considering the question as to which method of operation may be preferable, it is difficult on the basis of the present material to furnish evidence of the advantage of one method to the other, as a majority of the patients were operated on after Albee's method, and the patients operated on after the other methods have either been too few to give any clear idea of the results, or the available information about the condition has been too uncertain.

As to patients submitted to Albee's operation the results have been fairly satisfactory, in particular when estimated after the data given *by Friberg*, which are more thorough and comprehensive than those furnished by other authors. In these cases the patients are either free from inconvenience at the performance of any work (nearly one-half of the patients operated on in this way) or only at relatively light work (a little over one-half of the patients). Thus a relatively satisfactory result was obtained in 77.4 % of the male patients, in 92.3 % of the females. But this statistical account includes also a few patients who were operated on after other methods.

If the present small material is grouped in a similar way, the therapeutic results will turn out somewhat similar, 2 of the 6 operated patients being cured, 3 have moderate inconvenience on relatively slight work, and 1 showing no change.

As to the patients who were operated on after *Meyerding*'s method, this author merely states that the result was satisfactory, and the results after *Hibbs'* method are given as 66.9 %

cured, 12.5 % improved, and 20.8 % unchanged. *Lee* has had good results in about 90 % of his operated cases. As to the other methods, the number of patients has been too small for any statistical account.

For the operations aimed against the slipping vertebra from the front, the considerably higher case mortality has to be taken into account too.

Numerically, then, the results obtained by operative treatment are only a little better than those of orthopedic treatment. It must be kept in mind, however, that the operative results have been obtained in the more severe cases where orthopedic treatment was of no avail. So the conclusion appears to be that the method of choice in a given case is the one that gives the best prospect of a solid bony ankylosis of the part of the spinal column involved.

In my estimation, *Meyerding's modification of Albee's method* will as a rule offer most advantages, as it seems to combine a fairly simple technique with the prospect of the formation of a solid block that is more vigorous than the simple Albee graft and also deeper, *i.e.*, near the slipping vertebra.

SUMMARY

The present material comprises 27 patients from the Orthopedic Hospital, Copenhagen, and the Aarhus University Clinic of Surgery, the Municipal Hospital of Aarhus.

For 20 of these patients the observation period has been from 1 to 24 years (averaging 5.2 years).

The nomenclature is discussed. In this work the term "spondylolysis" is employed to designate the separation in the interarticular isthmus without slipping of the vertebra, while "spondylolisthesis" designates a condition in which slipping has taken place in a greater or lesser degree.

Spondylolysis is taken to be of congenital origin because double centers of ossification have been demonstrated on each side of the vertebral arch, and because the lesion occurs more frequently together with other congenital defects in the lumbar sacral region. Finally, also because the presence of hereditary factors has been demonstrated.

The frequency of the lesion is considered to be lower than the approximately 5 % given by most authors, because this figure results from materials in which heredity presumably may have played an increased role. This view finds support in the fact that some authors have not been able to demonstrate the double centers of ossification in a fairly large number of fetuses.

Fracture of the interarticular isthmus (traumatic spondylolysis) has been observed together with other fractures of the spinal column, but extremely seldom as the only fracture.

The theory about a trophostatic etiology can hardly be of any practical significance.

In the present material the appearance of the lesion is divided into the following stages:

Spondylolysis.

Stage I: Slipping less than one-half vertebral width.

Stage II: Slipping more than one-half vertebral width.

Stage III: Slipping more than the vertebral width.

Stage IV: Additional sinking of the vertebra in front of the underlying vertebra.

About 50 % of the patients presented Stage II—*i.e.*, in comparison to the materials of Meyerding and Friberg, the present material is made up of more advanced cases.

No connection can be demonstrated between a history of traumatic injury, the occupation of the patient and the stage of the lesion.

The location of the lesion in the vertebral column is the same here as in other materials, but on an average the patients are 10 years younger here than in other materials.

As to sex distribution, male patients are generally in majority, but in this material there are more women. Presumably the general male preponderance is due to the harder work and more common exposure to traumatic injury that may activate an otherwise symptom-free spondylolysis.

In the present material 6 of the patients have gone through parturition; one of them, with Stage IV has even given birth to 4 children without any complication.

The pathologic-anatomical aspects of the lesion are reviewed.

The primary lesion is a congenital defect in the interarticular isthmus. Secondarily the intervertebral space is narrowed and the disc undergoes degeneration; exostoses are formed along the margins of the vertebrae, increasing to console formation under the slipping vertebra, atrophy of the slipping vertebra through wear and also of the anterior margin of the underlying vertebra; besides, occasionally exostoses round the small joints of the spinal column corresponding to the spondylolysis.

The width of the spinal canal is reviewed by means of sagittal sections of the spinal column taken from the literature and by extradural myelography performed on 3 patients in the pre-

sent material. The spinal canal is demonstrated not to be narrowed in the lighter stages of the lesion, and to be narrowed but little in the more severe stages. The intervertebral foramina are not affected by spondylolisthesis.

The writer arrives at the conclusion that in spondylolisthesis the appearance of organic changes in the nerves are rare and, furthermore, localized but seldom to the segments affected by the slipping vertebra. Neurological changes in higher segments are presumably due to local secondary changes in the form of arachnoiditis, inflammation of the extradural tissue, or possibly prolapse of an intervertebral disc.

The complaints of these patients are reviewed. It is emphasized that spondylolysis and spondylolisthesis are free from symptoms in several cases. The symptoms do not differ decisively from the symptom complex of ordinary lumbago sciatica.

In discussing the static changes it is emphasized that the tendency to lordosis for compensation for the forward slipping of the spinal column in turn is compensated by a diminution in the inclination of the pelvis, which puts its stamp on the clinical findings. Thus, in the more advanced stages, the sacrum is found to be vertical, and the iliac crests horizontal; and there is a slight lordosis in the lumbar region, the lower limit of which lies at a higher level than normally. A groove is formed above the spinous process of the slipping vertebra, as the spinous process of the overlying vertebra takes part in the forward slipping and tilts upwards, more or less.

The interpretation of the X-ray picture is reviewed, and it is emphasized in particular that photos taken in oblique projection, presenting the articular processes and the interarticular isthmus, are required for the diagnosis of spondylolysis and the slighter degrees of spondylolisthesis.

The treatment is discussed. It is pointed out that several of these patients require no particular treatment. Reposition of the slipping vertebra is considered impracticable in most cases. The orthopedic treatment in the form of a corset, which is sufficient in a little more than one-third of the cases, is advisable as tentative treatment before any operation is performed.

The various methods for operative treatment are reviewed, and the writer arrives at the conclusion that the method of choice is the one that combines the simplest technique with the best prospect of resulting in a solid osseous ankylosis of the section of the spinal column involved.

ZUSAMMENFASSUNG

Das vorliegende Material umfasst 27 Patienten aus dem Orthopädischen Krankenhaus in Kopenhagen und aus der chirurgischen Universitätsklinik am städtischen Krankenhaus in Aarhus.

Die Observationsdauer betrug für 20 dieser Patienten von 1 bis 24 Jahre (durchschnittlich 5,2 Jahre).

Die Terminologie wird erörtert. In dieser Arbeit wird der Ausdruck »Spondylolysis« zur Bezeichnung einer Lockerung im Isthmus interarticularis ohne Verschiebung des Wirbels verwendet, während »Spondylolisthesis« einen Befund bezeichnet, bei dem eine mehr oder weniger ausgesprochene Verschiebung stattgefunden hat.

Es wird angenommen, dass die Spondylolysis kongenitalen Ursprungs ist, weil auf jeder Seite des Wirbelbogens doppelte Ossifikationskerne nachgewiesen wurden, weil die Läsion häufiger in Verbindung mit anderen kongenitalen Defekten der Lumbosakralregion vorkommt und weil schliesslich auch das Vorhandensein erblicher Faktoren nachgewiesen wurde.

Die Häufigkeit der Läsion wird für niedriger gehalten als die annährend 5 %, welche von den meisten Autoren angegeben werden, weil diese Ziffer aus Materialen stammt, in dem Heredität vermutlich eine grössere Rolle gespielt hat. Diese Ansicht findet eine Stütze in dem Umstand, dass einige Autoren nicht in der Lage waren, die doppelten Ossifikationskerne bei einer einigermassen grossen Zahl von Föten nachzuweisen.

Eine Fraktur des Isthmus interarticularis (eine traumatische Spondylolysis) ist in Verbindung mit anderen Frakturen

der Columna beobachtet worden, als einzige Fraktur jedoch äusserst selten.

Die Theorie einer trophostatischen Ätiologie dürfte kaum praktische Bedeutung haben.

Im vorliegenden Material ist das Vorkommen der Läsion in die folgenden Stadien eingeteilt:

Spondylolysis.

Stadium I: Verschiebung geringer als eine halbe Wirbelbreite.

Stadium II: Verschiebung grösser als eine halbe Wirbelbreite.

Stadium III: Verschiebung grösser als eine Wirbelbreite.

Stadium IV: Weiteres Abgleiten des Wirbels an der Vorderseite des darunterliegende Wirbels.

Etwa 50 % der Patienten zeigten Stadium II, d. h. das vorliegende Material besteht im Verhältnis zu dem von Meyerding und Friberg aus mehr vorgeschrittenen Fällen.

Zwischen einer traumatischen Schädigung in der Anamnese, der Beschäftigung des Patienten und dem Stadium der Läsion lässt sich kein Zusammenhang nachweisen.

Der Sitz der Läsion in der Wirbelsäule ist hier derselbe wie im Material anderer Autoren, doch sind hier die Patienten durchschnittlich 10 Jahre jünger als in dem Material anderer.

Hinsichtlich der Geschlechterverteilung sind die männlichen Patienten im allgemeinen in der Mehrzahl, im vorliegenden Material finden sich jedoch mehr Frauen. Vermutlich ist das allgemeine männliche Übergewicht auf die härtere Arbeit zurückzuführen und darauf, dass Männer mehr traumatischen Schädigungen ausgesetzt sind, die eine sonst symptomfreie Spondylolysis aktivieren können.

Im vorliegenden Material haben 6 Patientinnen Geburten durchgemacht; eine dieser Patientinnen mit Stadium IV hat sogar ohne jede Komplikation 4 Kinder geboren.

Das pathologisch-anatomische Bild der Krankheit wird besprochen.

Die primäre Läsion ist ein kongenitaler Defekt im Isthmus

interarticularis. Sekundär ist der Intervertebralraum verengt und die Zwischenwirbelscheibe degeneriert; es haben sich an den Rändern der Wirbel Exostosen gebildet, die unter dem verschobenen Wirbel zu konsolartigen Gebilden anwachsen: durch Abnutzung entsteht eine Atrophie des verschobenen Wirbels und ebenso des vorderen Randes des darunterliegenden Wirbels: ausserdem gehen die Exostosen bisweilen um die kleinen Gelenke der Wirbelsäule herum, soweit die Spondylolysis reicht.

Die Breite des Spinalkanals wird vermittelst sagittaler Sektionen der Wirbelsäule untersucht, wie sie sich in der Literatur finden, und durch extradurale Myelographie, die an 3 Patienten des vorliegenden Materials ausgeführt wurde. Es wurde nachgewiesen, dass der Spinalkanal in den leichteren Stadien der Läsion nicht verengt ist, und dass er in den ernsteren Stadien etwas, aber nur wenig verengt ist. Die Foramina intervertebralia werden von der Spondylolisthesis nicht in Mitleidenschaft gezogen.

Verfasser kommt zu dem Schluss, dass bei der Spondylolisthesis organische Veränderungen der Nerven nur selten vorkommen und dass dieselben ausserdem nur selten auf die Segmente lokalisiert sind, die von den verschobenen Wirbel beeinträchtigt werden können. Neurologische Veränderungen der höher gelegenen Segmente sind vermutlich einer Arachnoiditis, einer Entzündung des extraduralen Gewebes oder möglicherweise eines Prolapsus einer Zwischenwirbelscheibe zuzuschreiben.

Die Beschwerden dieser Patienten werden besprochen. Es wird ausdrücklich hervorgehoben, dass Spondylolysis und Spondylolisthesis in einzelnen Fällen symptomfrei sind. Die Symptome unterscheiden sich nicht wesentlich gewöhnlichen Lumbago Ischiassymptomenkomplex.

Bei der Erörterung der statischen Veränderungen wird hervorgehoben, dass die Tendenz zur Lordose als Kompensation der Verschiebung der Wirbelsäule nach vorn ihrerseits durch eine Verminderung der Beckenneigung kompensiert wird, was dem klinischen Befund das Gepräge gibt. So steht in den mehr vor-

geschrittenen Stadien das Sacrum vertikal und die Cristae iliacae horizontal; und es besteht eine leichte Lordose in der Lumbalregion, deren untere Grenze höher liegt als normal. Ober dem Processus spinosus des verschobenen Wirbels bildet sich ein Grübschen, da der Processus spinosus des darüberliegenden Wirbels an der Verschiebung nach vorn teilhat und mehr oder weniger nach oben gekippt ist.

Die Auswertung des Röntgenbildes wird besprochen, und es wird besonders hervorgehoben, dass für die Diagnose der Spondylolysis und der leichteren Grade der Spondylolisthesis Aufnahmen in Schrägprojektion erforderlich sind, welche die Processus articulares und den Isthmus interarticularis erkennen lassen.

Die Behandlung wird besprochen und es wird hervorgehoben dass viele dieser Patienten keiner besonderen Behandlung bedürfen. Eine Reposition des verschobenen Wirbels wird in den meisten Fällen als unausführbar angesehen. Die orthopädische Behandlung in Form eines Korsetts, die in etwas mehr als einem Drittel der Fälle ausreichend ist, kann als versuchsweise Behandlung anempfohlen werden, bevor eine Operation ausgeführt wird.

Die verschiedenen Methoden einer operativen Behandlung werden besprochen, und Verfasser kommt zu dem Ergebnis, dass diejenige die Methode der Wahl ist, welche die einfachste Technik mit der besten Aussicht verbindet, eine solide ossöse Ankylosierung des betroffenen Abschnitts der Wirbelsäule herbeizu führen.

RÉSUMÉ

Les observations publiées ici portent sur 27 malades de l'Hôpital Orthopédique de Copenhague et de la Clinique de Chirurgie de l'Université, à l'Hôpital Municipal d'Aarhus.

Pour 20 de ces malades la durée de la période d'observation a varié entre 1 et 24 ans (en moyenne 5,2 années).

La terminologie est discutée. Dans ce travail, le terme »spondylolysis« est employé pour désigner le relâchement de l'isthme interarticulaire sans glissement de la vertèbre, tandis que celui de »spondylolisthésis« désigne un état dans lequel il y a glissement plus ou moins prononcé de la vertèbre.

Il est supposé que la spondylolysis est d'origine congénitale, étant donné que l'on a trouvé de chaque côté de l'arc vertébral un double noyau d'ossification et du fait également que, souvent, cette lésion se manifeste simultanément avec d'autres défectuosités congénitales de la région lombaire sacrée. Cette supposition s'appuie en outre aussi sur la constatation d'autres facteurs héréditaires.

La fréquence de cette lésion est estimée comme étant inférieure au pourcentage approximatif de 5 % indiqué par la plupart des auteurs, car ce chiffre résulte de l'observation de malades chez lesquels l'hérédité joue vraisemblablement un grand rôle. Ce point de vue s'appuie sur le fait que plusieurs auteurs n'ont pas été en mesure de trouver les doubles noyaux d'ossification en examinant un nombre assez important de fétus.

Une fracture de l'isthme interarticulaire (spondylolysis traumatique) a été observée simultanément avec d'autres fractures de la colonne vertébrale, mais très rarement comme fracture unique.

La théorie de l'étiologie trophostatique n'a guère d'importance pratique.

Les présents cas ont été répartis en groupes d'après le stade de la lésion :

Spondylolysis.

Stade I : Glissement inférieur à une demi-largeur de vertèbre.

Stade II : Glissement supérieur à une demi-largeur de vertèbre.

Stade III : Glissement supérieur à une largeur de vertèbre.

Sade IV : Glissement prononcé de la vertèbre sur la partie antérieure de la vertèbre sous-jacente.

La moitié des cas rentre dans le stade II, c'est-à-dire que,

comparé à celui de Meyerding et Friberg, le matériel d'observation examiné ici est constitué par des cas plus avancés.

Aucun rapport n'a pu être établi entre l'anamnèse de la lésion traumatique, l'occupation du malade et le stade de la lésion.

La localisation de la lésion dans la colonne vertébrale est la même ici que dans les autres observations, mais les malades sont en moyenne de 10 ans plus jeunes que dans les autres observations publiées.

Si l'on envisage la répartition par sexe de cette maladie, on constate que les hommes sont en majorité, toutefois dans la présente documentation les femmes sont en plus grand nombre. Il est vraisemblable que la prépondérance générale du sexe mâle est due au fait que les hommes ont un travail plus dur et sont plus exposés aux lésions traumatiques susceptibles d'activer une spondylolysis qui, autrement, ne présentait aucun symptôme.

Dans le présent matériel d'observation, 6 malades ont accouché; l'une d'entre elles, au stade IV a même donné naissance, sans complications, à quatre enfants.

Les aspects anatomo-pathologiques de la maladie sont examinés.

La lésion primaire est une défectuosité congénitale de l'isthme interarticulaire. Secondairement, l'espace intervertébral est rétréci et le disque dégénère; des exostoses se forment le long des bords de la vertèbre, se développant en forme de console sous la vertèbre déplacée; l'usure conditionne l'atrophie de la vertèbre déplacée et également des bords antérieurs de la vertèbre sous-jacente; en outre, des exostoses apparaissent occasionnellement sur les petites articulations de la colonne vertébrale, aussi loin que va la spondylolysis.

La largeur du canal rachidien a été examinée au moyen des sections sagittales de la colonne vertébrale extraites de la littérature, ainsi que par des myélographies extradurales pratiquées sur 3 malades faisant partie de la présente documentation. Il a été observé que le canal céphalo-rachidien n'est pas

rétréci dans les premiers stades de la maladie et que, dans les cas plus graves, il se rétrécit, mais seulement à un très léger degré. Les trous conjugaisons ne sont pas affectés par la spondylolisthésis.

L'auteur conclut que les modifications organiques des nerfs sont rares et que, d'autre part, dans ces rares cas, elles sont localisées dans les segments atteints par le glissement des vertèbres. Des altérations neurologiques dans les segments situés plus haut sont probablements dues à des modifications locales secondaires sous forme d'arachnoiditis, d'inflammation du tissu extradural ou peut-être du prolapsus du disque intervertébral.

Les plaintes des malades sont examinées. Il est relevé que dans plusieurs cas la spondylolysis et la spondylolisthésis ne présentent aucun symptôme. Les symptômes ne diffèrent pas d'une manière décisive du complexe de symptômes du lumbago sciatique ordinaire.

Dans la discussion des modifications statiques, il est relevé que la tendance à la lordose pour compenser une déviation de la colonne vertébrale en avant est à son tour compensée par une diminution de l'inclinaison du pelvis qui met son empreinte sur les trouvailles cliniques. C'est ainsi que dans les stades plus avancés, on a observé que le sacrum était vertical et les épines iliaques horizontales; et il y a une légère lordose dans la région lombaire dont la limite inférieure est légèrement plus élevée que de normale. Une excavation s'est formée sur l'apophyse épineuse de la vertèbra déplacée, parce que l'apophyse épineuse de la vertèbre juste au-dessus participe à la courbure en avant et s'incline plus ou moins vers le haut.

L'interprétation des radiographies est examinée et il est relevé, en particulier, qu'il est nécessaire, pour le diagnostic de la spondylolysis et des légers degrés de spondylolisthésis, de prendre des épreuves en projection oblique permettant de voir les apophyses articulaires et l'isthme interarticulaire.

Le traitement est discuté. Il est signalé qu'un certain nombre de ces malades n'exigent pas de traitement spécial. La reposition des vertèbres déviées est considérée comme impraticable dans la plupart des cas. Le traitement orthopédique sous forme de

corset, qui est suffisant dans un peu plus d'un tiers des cas, est recommandé comme traitement d'essai avant de pratiquer l'opération.

Les différentes méthodes de traitement opératoire sont examinées et l'auteur arrive à la conclusion que la méthode de choix est celle qui combine la technique la plus simple avec les meilleures perspectives d'obtenir une ankylose osseuse solide de la portion du rachis atteinte.

Schematic Survey

Case No.	Sex	Age	X-ray diagnosis	Traumatic injury	Duration of symptoms before adm. in years	Character o		
						Loss of muscular power	Pain not radiating	Radiating pain
1	F.	12	Spondylolisthesis of L 5, Stage II. Progressing to Stage III. Sacral spina bifida	0	8	Tiredness	Pain in loins on stooping	0
2	M.	22	Spondylolisthesis of L 5, Stage II. Sacral spina bifida	0	2	Tiredness. Loss of muscular power	Pain on stooping	Down in the thighs
3	F.	27	Spondylolisthesis of L 5, Stage IV	0	1/2		Moderate pain in loins on movements	0
4	F.	20	Spondylolisthesis of L 5, Stage II	Fall on stairway 7 years before	A few months		Pain in the back	Occasionally at night and at work
5	M.	24	Spondylolisthesis of L 5, Stage II	Run over by farm waggon	?	Tiredness	Pain in the loins	0
6	F.	32	Spondylolisthesis of 5 L, stage unknown	0	1		Pain in the loins	Down in the legs
7	M.	37	Spondylolisthesis of L 5, Stage II	Runaway	22		Pain in the back	Down in the right leg
8	F.	22	Spondylolisthesis of L 5, Stage II	0	12		Pain in the loins	Down in the right leg

of the Material.

symptoms Neurological symptoms	Parturitions	Treatment	Observation period in years	Results	Remarks
0	0	Supporting corset. Operation advised	24	Still moderate pain	See Figs. 25 and 26
Sensibility lowered (exam. by neurologist, see p. 34), Spinal fluid normal	0	Supporting corset for one year, then Albee's operation	10	Recovery. Working on a farm	
0	4, without complications	None. (Abdominal belt for pendulous abdomen.)	11	Symptom-free. Two parturitions in the observation period	See Fig. 27
0	1 induced abortion	Supporting corset	9	Occasionally pain in the buttocks	
0		Albee's operation (in another hosp.)	2 years after operation	Still attacks of pain	
Not examined	?	Operation advised but refused	Not returned for reexamination	?	
Not examined		Supporting corset	6	Completely free from pain on wearing corset	
0 (Exam. by neurologist)	4, without complications	Supporting corset for 1 year, then Albee's oper.	5	Slight pain and tiredness in loins after work. Never radiating pain. Still wearing corset	

(*Schematic survey*

Case No.	Sex	Age	X-ray diagnosis	Traumatic injury	Duration of symptoms before adm. in years	Character o		
						Loss of muscular power	Pain not radiating	Radiating pain
9	F.	21	Spondylolisthesis of L 5, Stage IV	0	4	Tiredness	Pain in the loins	»Sciatica« of right leg
10	F.	44	Spondylolisthesis of L 5, Stage II	0	?		Pain in the loins	0
11	M.	32	Spondylolisthesis of L 5, Stage II	Overstrain on lifting 19 years ago	1		Habitual »lumbago«	Tingling in left leg
12	F.	31	Spondylolisthesis of L 5, Stage I	Low fall, landing on buttocks	2		Pain in the sacral region	0
13	F.	13	Spondylolisthesis of L 5, Stage II. Sacral spina bif.	Heavy work for her age (delivering washing)	1/2		Slight pain in the back	0
14	F.	41	Spondylolisthesis of L 4, Stage I	0	2		Pain in the lumbar region	Queer sensations in left leg
15	M.	24	Spondylolisthesis of L 5, Stage II. Sacral spina bif.	Hard labor. Fall from tree 14 yrs. before	4		Pain in the loins	Down along the post. aspect of left thigh on working

cont. 1)

symptoms Neurological symptoms	Parturitions	Treatment	Observation period in years	Results	Remarks
0 (Exam. by neurologist)	0	Albee's operation (in another hosp.)	8 years, after the operation	Pain and tiredness in the legs too still wearing corset	Working all day as photographer See Figs. 10, 11 and 12
0	3	Supporting corset	Not returned for reexamination	?	
0		Supporting corset	Not returned for reexamination	?	
Not examined	?	Supporting corset	Not returned for reexamination	?	
Not examined	0	None. Operation advised in case of aggravation	Not returned for reexamination	?	Applied to the clinic because she discovered accidentally the deformity of her back
0	0	Hip corset with pelvic strap	2	?	Refuses to return for reexamination. In replying to enquiry, she gives no information
Hypersensibility corresponding to the left peroneal nerve. Hyposensibility round left ant. sub. iliac spine. Hypersensibility on right side correspond. to peroneal, 11'—12' ribs and upper inside of thigh. Reflexes normal	0	Supporting corset. Operation advised but refused	2	Still considerable pain; unable to work. He has ceased wearing corset	Receiving Invalidity Insurance benefit

(*Schematic survey*

Case No.	Sex	Age	X-ray diagnosis	Traumatic injury	Duration of symptoms before adm. in years	Character o		
						Loss of muscular power	Pain not radiating	Radiating pain
16	F.	32	Spondylolisthesis of L 5, Stage II	Pain commenced during pregnancy.	2		Pain in the loins	Down on the posterior aspect of the thigh
17	F.	24	Spondylolisthesis. Vertebra not given (X-ray picture not available.)	0	?	Tiredness	Pain in the back	0
18	M.	34	Spondylolisthesis of L 5, Stage I	Fall from ladder, hanging by the hands, 3 yrs. before	2	Loss of muscular power of the back	Pain in the loins	Pain radiating to left buttock and thigh
19	M	39	Spondylolisthesis of L 5, Stage I. Sacral spina bif.	0	$1^1/_2$	Tiredness and pain in legs. Stiffness of the back	Pain in the loins	Pain in legs
20	F.	18	Spondylolisthesis of L 5, Stage II. Sacral spina bif.	0	5	Paralysis of the bladder	No pain	0
21	F.	50	Spondylolisthesis of L 5, Stage I	0	7		Pain in the loins	Radiating to right inguen
22	M	21	Spondylolisthesis of L 5, unilateral	0	3		Pain in left loin	0

cont. 2)

symptoms Neurological symptoms	Parturitions	Treatment	Observation period in years	Results	Remarks
0	1. without complieations	Supporting corset for 7 months. Then Albee's oper. Still wearing corset	1	Still some pain, condition rather unchanged	
Not examined	No information	Supporting corset	Not returned for reexamination	?	
Paresthesias of lower extremities. No disturbance of sensibility. Reflexes normal		Supporting corset. Operation advised but refused	2	Unchanged	Receives Invalidity Insurance benefit. See Fig. 19
Sensations of cold in the legs. No objective signs. Exam. by neurologist		Supporting corset. Operation advised but refused	4	Unchanged	Able to do lighter work; has changed occupation
See p. 33	0	None	Not returned for reexamination	?	See Figs. 23 and 24
0	3	Supporting corset for 1 month. Then Albee's oper. Still wearing corset	$1^1/_2$	Improved	The graft has broken. She refuses reoperation. Extradural myelography. See Figs. 20, 8 and 9
0		Plaster corset	2	Recovered	Not wearing corset

(Schematic survey

Case No.	Sex	Age	X-ray diagnosis	Traumatic injury	Duration of symptoms before adm. in years	Character of		
						Loss of muscular power	Pain not radiating	Radiating pain
23	M.	57	Spondylolisthesis of L 4, Stage I-II	Adm. for traumatic injury, hit in the back by falling iron rod	5—6		Slight pain in the back on working	0
24	M.	68	Spondylolysis of L 5, bilateral, L 4 unilateral. Sacral spina bif. (See Figs. 16, 17)	0	Always disposed to slight backache		Periodical pain in the loins	0
25	F.	54	Spondylolysis of L 5. Sacral spina bifida	0	6		Pain in loins and back	Down in posterior aspect of both thighs
26	F.	29	Spondylolysis of L 5	Excessive physical strain	$1^1/_2$		Pain in the loins	Down in left leg and left side of abdomen
27	F.	26	Spondylolisthesis of L 5, Stage I	Fall on stairway 11 years before, hurting the upper part of her back	10		Pain in the loins	Periodically in both legs

cont. 3)

symptoms Neurological symptoms	Parturitions	Treatment	Observation period in years	Results	Remarks
0		None	$2^1/_4$	Slight aggravation	
0		None	$1^1/_4$	Unchanged	Diagnosis made accidentally on roentgenography for kidney lesion. See Figs. 15, 16 and 17
Achilles tendon reflexes absent. Otherwise no abnormality	1	None	$2^1/_2$	Unchanged	Applying for Invalidity Insurance benefit — also for several other reasons. See Fig. 18
0	0	None	A short time	?	Extradural myelography No abnormality
Transitory cold paresthesias of the legs. + Lasegue. No disturbance of sensibility. Reflexes normal. Spinal fluid normal	0	Plaster cast tentatively a short time	A short time	?	Syphilis. Extradural myelography. See Figs. 7, 21 and 22

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