

ACTA ORTHOPAEDICA SCANDINAVICA
SUPPLEMENTUM no. XXXV

*FROM THE ORTHOPAEDIC HOSPITAL OF THE INVALID FOUNDATION,
HELSINGFORS, HEAD: DOCENT ANDERS LANGENSKIÖLD, M.D.*

SPONDYLOLISTHESIS

A STUDY OF 53 CASES TREATED BY SPINE FUSION
AND 32 CASES TREATED BY LAMINECTOMY

BY

L. E. LAURENT

EJNAR MUNKSGAARD
COPENHAGEN 1958

Translated by *Gunvor Hustich*

Printed in Finland
MERCATORS TRYCKERI
Helsingfors 1958

CONTENTS

	Page
INTRODUCTION AND PROBLEMS	7
SURVEY OF 809 DIAGNOSED CASES	9
<i>Clinical data concerning 58 patients under 20 years of age</i>	17
<i>Radiographic studies on slipping of vertebrae</i>	19
OPERATIVE TREATMENT	27
<i>Clinical data concerning 85 operatively treated patients</i>	27
<i>Operative findings</i>	29
<i>Operative methods</i>	31
<i>Results of operative treatment</i>	35
DISCUSSION ON ETIOLOGY AND PATHOGENESIS	38
SUMMARY AND CONCLUSIONS	41
REFERENCES	43

INTRODUCTION AND PROBLEMS

Spondylolisthesis and spondylolysis of the lumbar vertebrae are by no means rare lesions. The incidence in anatomically examined series is estimated at about 5 per cent (Neugebauer 5%, Willis 5.19%, Roche & Rowe 4.2%). An uncommonly high incidence of spondylolysis (40 per cent in men and 37 per cent in women) was found by Stewart in skeletons of Eskimoes in the northern part of Yukon and by Schreiner in Lapps in Norway (12.8%). — In clinical series the frequency is somewhat lower, owing to the fact that the condition is frequently without any clinical symptoms. Besides, spondylolysis may often be hard to diagnose radiographically without oblique projections or tomography. At a radiographic examination of 4654 persons, Runge found 97 cases of spondylolisthesis (2.08%). Almost all of them were symptom-free. Allen & Lindem observed spondylolisthesis in 2.96 per cent of 3000 and Hult in 2.1 per cent of 1178 industrial workers examined.

Despite numerous investigations, the etiology and pathogenesis of this lesion still remain obscure. In the majority of cases there is hypoplasia, and an elongation and defect of the neural arch. How this defect in the arch arises has not been conclusively demonstrated. Hypoplasia and a malformation of the articular processes of the olisthetic vertebra and the one situated ventrally of it were in a number of cases demonstrated by Brocher, Taillard and Newman, among others. Ventral displacement of the entire vertebra without any elongation or defect of the arch (Junghann's anterior pseudospondylolisthesis), a condition common in elderly women, seems to be due to degeneration of the disc and osteoarthritis of the intervertebral joints (Junghanns, Brocher, Macnab, Adkins, and others). Despite numerous investigations neither spondylolisthesis nor spondylolysis has been demonstrated in fetuses or newborn infants (Batts, Brocher, Glorieux & Roederer, Friberg, Hitchcock, and others). The only exception is a case of unilateral spondylolysis in a 5-month-old fetus (Pfähler & Vastine). The incidence of diagnosed cases of spondylolisthesis in children under 10 years is very low. Up to 1951, 12 such cases had been published (Marique). The incidence of spondylolisthesis does not seem to increase between the ages of twenty

and seventy years, and a progression of the displacement after the age of twenty seems to be exceptional (Friberg, Brocher, Taillard, and others). All this would seem to indicate that, as a rule, the lesion occurs between the ages of five and fifteen years. A progressive slipping of the olisthetic vertebral body in children and adolescents has been demonstrated by Brocher, Brailsford, Francillon, Harris and Taillard, among others. Later, I shall describe similar cases in my series.

In a minor proportion of cases of spondylolisthesis, there is radiating pain to the lower extremities with or without neurological symptoms. The incidence of such symptoms varies in different reports, the average being, according to Marique, about 20 per cent. The mechanism of origin of these symptoms is still not conclusively established. Therefore, opinions vary with regard to the operative treatment of the lesion. Earlier, in cases where conservative treatment did not adequately relieve the pain, dorsal fusion was, as a rule, performed. Later, some surgeons performed intercorporal spondylodesis, ventral or dorsal, in order to stabilize the slipping portion of the vertebra. Certain authors (James & Nisbet, King et al., Gill et al.) consider laminectomy alone sufficient to produce relief of the patient's symptoms.

The present paper is chiefly an account of the neurological symptoms, different operative methods employed and results of the operative treatment. Special attention has been attached to a comparison between the results of spondylodesis and laminectomy. Spondylolisthesis in children and adolescents presents special problems and these will therefore be dealt with in sections of their own. Ventral displacement of vertebrae as a result of fractures, tumours or inflammatory processes will not be discussed in this work.

SURVEY OF 809 DIAGNOSED CASES

During the 13-year period 1944 to 1956, 809 cases of spondylolisthesis or spondylolysis were diagnosed at the Orthopaedic Hospital of the Invalid Foundation. Of these, 85 were treated surgically and will be discussed in detail in this report. The remaining cases were treated at the out patient department and will not be closely studied. I considered it of value, however, to present some figures concerning the whole material. As a rule only frontal and sagittal radio-grams were made and it was therefore not always possible to decide whether or not there was a defect of the vertebral arch. In the majority of cases, however, the olisthesis was associated with lysis.

Age and sex

The age and sex of the patients are given in table I. In the majority of cases the condition had not been previously diagnosed.

TABLE I
Age and sex

Age	Men	Women	Total	%
0—9	1	—	1	—
10—19	30	27	57	7 %
20—29	70	49	119	14.7%
30—39	99	86	185	22.9%
40—49	94	149	243	30 %
50—59	55	84	139	17.2%
60—69	23	42	65	8.1%
372 (46%)		437 (54%)	809	

The table shows a slight predominance of females (54% and 46%). In other series (George, Friberg, Meyerding) men predominate, a feature which has been attributed to the fact that heavy masculine work more often produces pain conditions in the back. The incidence rises somewhat in the age groups 30 to 49 years, falling again in the older age groups. The large number of women in the group 40 to 49 years is remarkable. Friberg assumed that the onset of

the climacterium may contribute to the manifestation of symptoms and the accumulation of cases in this age group. It is a fact that at this age osteoporosis of varying degree may often be observed in the spine, evidently as a result of reduced production of sex hormones.

Location and nature of lesions

The location and nature of the lesions are seen in table II.

TABLE II
Sex and location

		Men	Women	Total
Lysis	L2	1	—	1
	L3	3	5	8
	L4	6	11	17
	L5	9	16	25
Olisthesis	L2	—	4	4
	L3	8	11	19
	L4	62	128	190
	L5	289	273	562
		378	448	826

The figures in this table are higher than the number of cases since multiple lesions occurred in 15 patients in a total of 32 vertebrae. The number of lyses without olisthesis was 19 in men and 32 in women. Five of the lyses located in the fifth lumbar vertebra were unilateral. The fifth lumbar vertebra was affected in 71.1 per cent of cases and the fourth in 25.1 per cent. Thus, in 96.2 per cent of cases, the lesion was situated in the two lowest vertebrae and this is in harmony with the findings of others (Friberg 93.6%, Roche & Rowe 94.6%). The fourth lumbar vertebra was more frequently affected in women (31%) than in men (18%). This sex difference is not apparent in previously published series. The location in the cases with multiple lesions is seen in table III.

TABLE III
Location of 32 multiple lesions in 15 patients

Men				Women			
Lysis	L2 and L3	+	olisthesis L5	Lysis	L3 + Lysis L4		
»	L3	+	» L4	»	L3 + » L5		
»	L4	+	» L5	»	L3 and L4 + olisthesis L5		
»	L5	+	» L4	»	L3	+	» L4
Olisthesis	L4	+	» L5	»	L4	+	» L5 (3 cases)
				»	L5	+	» L4
				Olisthesis	L3	+	» L4
				»	L4	+	L5

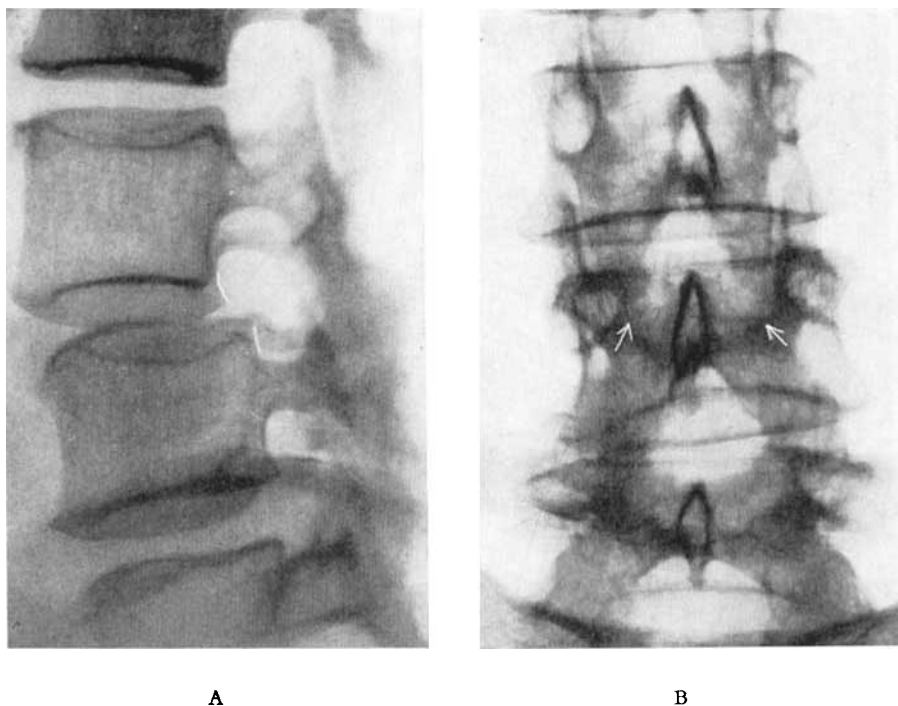


Fig. 1. 65 year old woman. 'Pseudospondylolisthesis of the third lumbar vertebra which is ventrally displaced 4 mm (A). The frontal radiogram (B) shows osteoarthritis of the intervertebral joints and changes in the caudal articular processes of the olisthetic vertebra.

This irregular distribution of the lesions rather seems to suggest the presence of a congenital disposition to the lesion. In this connection, I should mention that I have observed a rare location of bilateral spondylolysis in the third cervical vertebra in a 24-year-old woman who had had pain in her neck since childhood. Cases of spondylolisthesis in cervical vertebrae have been reported by Perlmann & Howes and by Durbin.

As already mentioned, it was not always possible to decide from the radiograms whether spondylolysis was present or not. Olisthesis without any defect of the arch could be observed in 10 cases, however, 8 women and 2 men. In 3 cases, operation revealed that there was no defect of the arch. In 1 case the lesion was located in the third lumbar vertebra, in 3 cases in the fourth and in 6 cases in the fifth. The average age of the patients was 45 years. Figures 1 and 2 show cases of olisthesis without defect of the arch.

Trauma as the releasing factor was reported by 52 patients, 38 men and 14 women, amounting to 6.4 per cent of the cases. This figure is considerably



A



B



C



D

Fig. 2. 48 year old man. The fifth lumbar vertebra is ventrally displaced 10 mm, the presacral disc is degenerated (A). The frontal radiogram (B) shows hypoplasia and sclerosis of the neural arch. The spinous process is poorly developed. The oblique pictures show hypoplasia and attenuation of the arch (C, D). No lysis is visible.

lower than the incidence of trauma reported by Meyerding and Friberg, for instance. This low incidence might be due to the circumstance that the clinic does not accept recent traumatic cases for treatment, being an orthopaedic consultation clinic serving the whole country.

Clinical signs

Since the clinical picture of spondylolisthesis has been described in detail in earlier papers and textbooks, I shall only briefly discuss some details. In many cases I have observed a slight non-fixed lumbar *scoliosis*, particularly in patients belonging the age group group 11 to 19 years. Like Friberg, I did not in these cases find unilateral spondylolysis which, according to Glorieux & Roederer, predisposes to scoliosis. In several cases, however, a tilt of the olisthetic vertebra in the frontal plane seems to have taken place and may be observed in antero-posterior radiograms. 3 cases of scoliosis of comparatively high degree

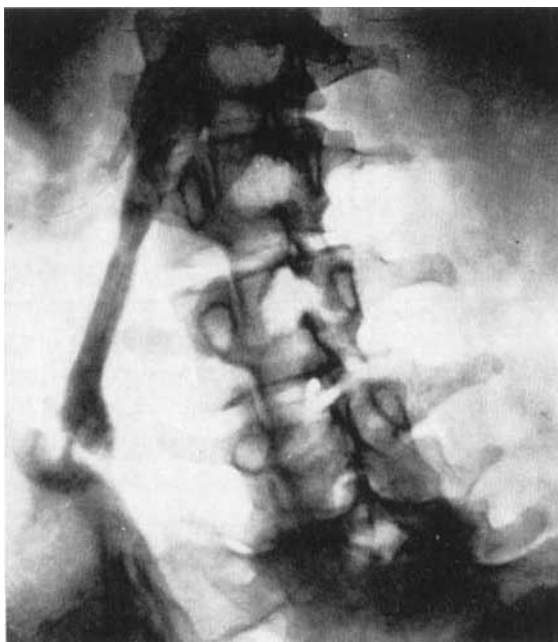


Fig. 3. 25 year old man. Total olisthesis of the lumbarized first sacral vertebra. There is a lumbar scoliosis due to a tilt of the olisthetic vertebra in the frontal plane. A tibial graft was implanted eighteen months earlier between the crest of the ilium and the transverse process of the first lumbar vertebra. There is non-union at the lower attachment of the graft.

were observed. One of these (Fig. 3) was treated with implantation of a tibial graft from the crista iliaca to the transverse process of the first lumbar vertebra.

In some cases I observed other *deformities* in the lumbar spine *combined* with spondylolisthesis. These cases seem to indicate a congenital origin of the deformities and will therefore be described. A 23-year-old man had spina bifida of all lumbar and sacral vertebrae from the third lumbar vertebra downwards. The fifth lumbar vertebra showed bilateral spondylolysis, being 12 mm. forwardly displaced. Moreover, the patient had right-sided pes varus and left-sided pes planovalgus. A 47-year-old woman showed radiographically congenital synostosis of the third and fourth lumbar vertebra and a 10 mm. ventral displacement of the fifth lumbar vertebra in which there was bilateral defect of the arch. A 43-year-old woman had right-sided unilateral spondylolysis of the fifth lumbar and first sacral vertebra and considerable hypoplasia of the entire right side of the first sacral vertebra. — Spina bifida was present in 7 out of the 85 operated cases (8.2%). A considerably higher frequency was reported by Meyerding (35%), Friberg (28.6%) and Taillard (20.8%).

The frequency of *neurological symptoms* in spondylolisthesis varies considerably in different reports, evidently depending upon how much attention has been attached to such an examination. In the present series, complete neurological examination was not performed, particularly not on the outpatients. Patients admitted for surgery underwent more thorough neurological examination, although without consultation of a neurologist. Neurological signs were therefore more frequently established in these patients. A large number of them were operated on because of sciatica with neurological symptoms.

10 patients had no subjective symptoms, the spondylolisthesis being an accessory finding. Of 809 patients, 569 (70.3%) had pain of varying degree in the lumbar region only. Radiating pain to the thigh, the calf or the foot, in some cases combined with a positive Lasègue's sign but with normal jerks, occurred in 156 cases. There were disturbances of the jerks in 74 cases. Table IV shows the frequency of neurological symptoms in cases treated conservatively or by surgery.

TABLE IV
Frequency of neurological signs

	Radiating pain	Jerk disturb- ances	Total
Not operated	122	49	171
Operated	34	25	59
	156	74	230

Signs of root irritation occurred in 230 out of 809 cases (28.3%). Of conservatively treated patients, 23.6 per cent exhibited such symptoms, while this figure was 59/85 (69%) for surgically treated patients.

Of 85 operatively treated patients, 54 reported radiating pain to the thigh, the calf or the foot. Five patients did not report such pain but exhibited absence of jerks. A positive Lasègue's sign was present in 22 of these 59 patients, 9 had radiating pain on coughing, in 25 jerks were absent, 5 had uncertain reduction of the sensitivity of the lower limbs, while one patient had a cauda equina syndrome with saddle anaesthesia and bladder disturbance. The nature of the jerk disturbances in the 25 cases is seen in table V.

TABLE V
Jerk disturbances in relation to location of spondylolisthesis

	L4	L5	Total
Loss of the ankle jerk, uni- or bilateral	1	15	16
Diminution of the ankle jerk, uni- or bilateral	1	4	5
Unilat. diminution in extension power of the big toe	3	—	3
Unilat. diminution of the patellar jerk	1	—	1
	6	19	25

Combinations of neurological symptoms which could be interpreted as root syndrome appeared in 12 cases. A syndrome emanating from the first sacral root occurred in 8 cases, from the fifth lumbar in 1 case, from the fourth lumbar in 1 case and in 2 cases there was a combination of syndromes from the first sacral and fifth lumbar root. H. Neugebauer observed neurological symptoms in 28 cases out of 59. In 8 cases there was a root syndrome, the remaining cases being monosymptomatic. Of Meyerding's 745 patients, 80 (10.7%) had sciatica. Of these, 17 cases were investigated in a neurological clinic, being diagnosed as prolapse of a disc. In 6 of these cases operation for disc protrusion, and fusion were performed. — Out of 11 cases of subtotal or total spondylolisthesis of the fifth lumbar vertebra, the ankle jerk was absent bilaterally in 5 and unilaterally in 6 cases. In most of these cases there were no other neurological signs. This seems to me to indicate that absence of the jerk is brought about by a stretching of the first sacral roots owing to slowly progressive severe olisthesis. *Myelography* was performed in some 20 cases. However, myelograms are often difficult to interpret in case of spondylolisthesis. In some cases the myelogram may indicate prolapse and root compression in some interspace cranially or caudally of the olisthetic vertebra; in such cases exploration of the discs should be made in connection with operation for olisthesis. Sagittal myelograms of severe spondylolisthesis show the S-shaped dural sac which lies far dorsally of the olisthetic

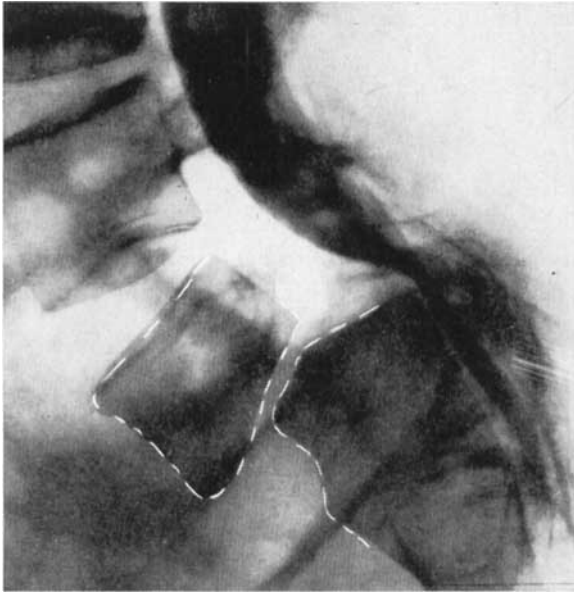


Fig. 4. 18 year old youth. The fifth lumbar vertebra is ventrally displaced 20 mm. The myelogram shows the dural sac lying dorsally well back from the fourth and fifth lumbar vertebral bodies and discs. The dural sack is compressed in the frontal plane at the sacral border. The fifth lumbar disc is low in contrast to the fourth.

vertebra (fig. 4). Sometimes the contrast medium is arrested practically at the sacral border. Idelberger & Pia made similar observations.

Myelography may give valuable information in certain cases of spondylolisthesis but, in my opinion, need not be performed as a routine.

A fairly common complex of symptoms which may indicate spondylolisthesis consists of radiating pain resembling prolapse pain, a negative Lasègue's sign and often very good flexion of the back. This has earlier been pointed out by Francillon and Brocher, among others.

From the point of view of *differential diagnosis*, it should be remembered that spondylolisthesis is a comparatively common lesion which may be combined with other disorders with neurological symptoms. The present series comprises 2 cases of moderate olisthesis of the fifth lumbar vertebra with rather pronounced neurological symptoms which were first interpreted as root symptoms caused by olisthesis.

The first case was a 21-year-old man on whom half a year previously dorsal fusion because of olisthesis of the fifth lumbar vertebra had been performed in another hospital. Because of continued symptoms and incomplete fusion, respondylodesis with a tibial

graft was performed. Radiographic check-up ten years later showed an expansive process in the spinal canal in which the olisthetic vertebral body and the well-healed graft had undergone erosion. There were sensory disturbances and the ankle jerks were absent. Since the patient was fully capable of work and subjectively comparatively symptom-free, it was considered, after a neurosurgeon had been consulted, that exploration was as yet uncalled for.

In a second case of olisthesis in the fifth lumbar vertebra, an intradural neurinoma was observed at the level of the twelfth thoracic vertebra, the neurological symptoms being traced to this growth.

Treatment

Of the 809 patients who visited the outpatients' department of the hospital, 85 were admitted for surgery and 40 were referred to other hospitals for operation. Plaster jackets were prescribed in 10 cases and leather corsets in 22. Surgical corsets reinforced with steel springs were prescribed to 566 patients, while no treatment was considered necessary in 76 cases and 10 patients were symptom-free. It has not been possible to perform follow-up examination of the patients treated conservatively. However, the majority of the patients did not return to the outpatients' department of the hospital, which would seem to indicate that the symptoms were mild enough for the corset to afford sufficient relief.

CLINICAL DATA CONCERNING 58 PATIENTS UNDER 20 YEARS OF AGE

In spondylolisthesis in children and adolescents there is a danger of progressive slipping. At this age, patients often have symptoms indicative of root irritation.

The number of patients of this group was 58. The age of the patients was as follows: 5—10 years 1 patient, 11—15 years 22 patients, 16—19 years 35 patients. There were 30 boys and 28 girls. In 53 cases the lesion was localized to the fifth lumbar vertebra and in 5 cases to the fourth. Olisthesis was present in 55 cases and lysis without olisthesis in 3 cases. There were 9 cases of subtotal or total olisthesis of the fifth lumbar vertebra. Slipping to more than 50 per cent of the vertebral length occurred in another 8 cases. Thus, in this age group, 17 cases out of 58 exhibited marked displacement of the fifth lumbar vertebra.

It appears from this survey that, in this group, the sex distribution was about even, which tallies with Taillard's observations on 50 patients of similar age. Lesion of the fifth lumbar vertebra occurred in 91 per cent of cases, while the frequency of this lesion in the entire series was 71 per cent. This is evidently due to the fact that, owing to static conditions, the slipping of the fourth lumbar vertebra can never become considerable and that symptoms of a lesion localized to the fourth lumbar vertebra do not present themselves until a later age.

Taillard reported that ischialgia often occurs in spondylolisthesis in young individuals. In his series of 50 cases aged 5 to 19 years, sciatica occurred in two-thirds of cases of 5—15 years, while one-third had pain in the lumbar region only. In the age group 16—19 years the situation was reversed. In the present series the distribution of symptoms was as follows (Table VI):

TABLE VI
Clinical picture in patients under 20 years of age

Age	5—15	16—19	Total
No pain	2	1	3
Low back pain	9	19	28
Radiating pain	2	5	7
Positive Lasègue's sign	6	5	11
Loss of the ankle jerk	5	4	9
	24	34	58

Symptoms of root irritation occurred in the younger age groups in 13 out of 24 cases, in the older age groups in 14 out of 34 cases. This agrees with Taillard's observations. A 14-year-old girl exhibited a *cauda equina syndrome* with saddle anaesthesia and bilateral sensory disturbance in the first sacral dermatome. She suffered periodically from bladder incontinence and had neurotrophic ulcers in her heels. The feet showed a deformity of excavatus type. Lasègue's sign was negative and the ankle jerks were absent on both sides. There was total olisthesis of the fifth lumbar vertebra (Fig. 5). The symptoms had presented at the age of ten. Laminectomy showed that the dural sac was highly compressed in the frontal plane at the level of the fifth lumbar vertebra. There was spina bifida and unilateral spondylolysis of the arch. No pulsation could be observed in the dural sac until the arches of the fifth and fourth lumbar vertebra had been removed. At follow-up examination two years later, the neurological picture was unchanged. The bladder incontinence, however, had become reduced and the pain in the back had disappeared. The olisthetic vertebral body had rotated to some extent, being now in close contact with the ventral surface of the sacrum.

In spondylolisthesis, a cauda equina syndrome is rare. There are cases reported in the literature by Adkins, Arden, Hulbert, Newman, Prip-Buus and Turney. Marked compression of the cauda does not, as a rule, occur, even though cases of total olisthesis are not rare. Pronounced instability of the lumbar region in serious olisthesis might, in exceptional cases, result in such a static condition in the lumbosacral region that the spinous process of the fourth lumbar vertebra transfers the weight of the trunk to the cauda, which becomes compressed in

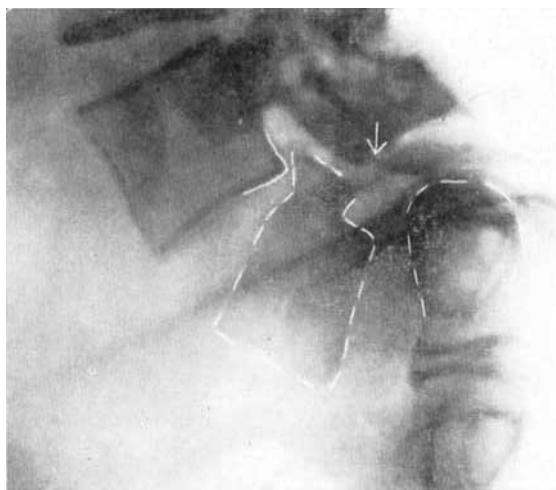


Fig. 5. 14 year old girl with a cauda equina syndrome. Total olisthesis of the fifth lumbar vertebra. Spina bifida and unilateral lysis of the arch were present.

a frontal direction. Under such circumstances the spina bifida in the case described above might be of significance. The sacrum was vertical, a condition which may often be observed in cases of severe olisthesis.

Radiating pain and neurological symptoms in the lower extremities in children and adolescents should immediately lead to suspicion of spondylolisthesis.

RADIOGRAPHIC STUDIES ON SLIPPING OF VERTEBRAE

The degree of slipping in 85 operatively treated cases is shown in table VII. Olisthesis of the fifth lumbar vertebra occurred in 67 cases, of the fourth lumbar vertebra in 15 cases, and spondylolysis without slipping in 3 cases. There was lesion of two vertebrae in 4 cases. The distance was measured from the dorsal

TABLE VII

Degree of slipping in relation to location of the lesion

		L3	L4	L5	Total
0 mm = lysis		2	4	1	7
Less than 10 mm (Meyerding's grade I)		—	12	24	36
11—20 mm	»	—	3	20	23
21—30 mm	»	—	—	11	11
Subtotal or total	»	—	—	12	12
		2	19	68	89

lower corner of the olisthetic vertebral body to the upper dorsal corner of the distally situated vertebral body or sacrum respectively. Comparing the figures obtained with Meyerding's scheme, a slipping of less than 10 mm. corresponds to Meyerding's grade I, 11—20 mm. to grade II, 21—30 mm. to grade III, subtotal or total olisthesis to Meyerding's grade IV. In this connection I did not consider it necessary to use more exact methods of measurement of the olisthesis, such as those described by Hagelstam and Marique, for instance.

It is seen from the table that the slipping of the fourth lumbar vertebra does not exceed 20 mm. The degree of slipping in relation to the age of the patient is shown in table VIII.

TABLE VIII
Degree of slipping in relation to age

	Lysis	Less than 10 mm	11—20 mm	21—30 mm	Subtotal or total	Total
10—19	—	1	1	2	8	12
20—29	—	5	3	3	2	13
30—39	2	13	5	3	2	25
40—49	1	12	8	3	—	24
50—59	—	5	6	—	—	11
	3	36	23	11	12	85

It is evident that the degree of slipping does not increase with increasing age. The largest number of subtotal and total olistheses occurs in the youngest age group. This tallies with Friberg's observation and indicates that during the growth period the olisthesis progresses to a certain degree and does not subsequently increase save in exceptional cases. Why the slipping may be arrested at any degree of displacement has not been explained. Bosworth & al. believed that the spondylolytic arch constitutes a stabilizing factor. They further thought that in certain cases the spinous process of the olisthetic vertebra extrudes backwards, contributing to stabilization by being squeezed against the spinous process of the cranially situated vertebra. In my opinion the arch, and particularly the ligaments attached to it, such as the ligamentum flavum, and, in cases of spondylolysis, the tense fibrous tissue of the defect, constitute stabilizing factors in the movement of the vertebra, also affecting the stability of the disc. It is natural that the degree of stability provided by the dorsal vertebral structures varies from case to case. The arch cannot arrest the slipping during the growth period, and is not likely to do so even later. Bosworth observed progressive olisthesis in 19 cases out of 63 in which laminectomy and fusion had been performed. The average progression was 16.5 per cent. Bosworth did not mention the age of the patients but stated that there seemed to be no relation between the age

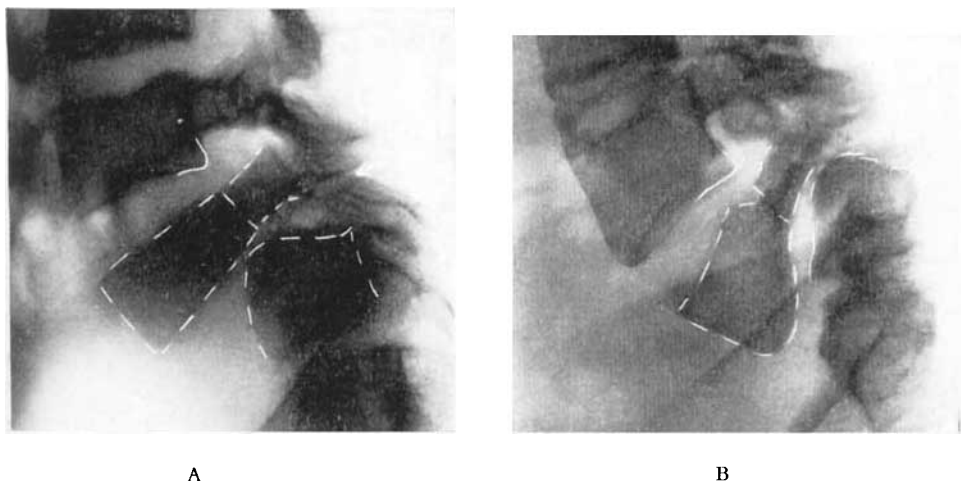


Fig. 6. 13 year old boy. Subtotal olisthesis of the fifth lumbar vertebra. The vertebral body is low particularly in its dorsal portion and the ventral surface of the sacrum is rounded off. The first sacral vertebra is lumbarized (A). Four years later slipping has continued, the olisthesis being now total (B).

of the patient and the progression of slipping. Taillard demonstrated that progression may take place during the growth period despite solid dorsal fusion. I have made similar observations to which I shall return later. Bosworth mentioned that slipping was progressive only in cases in which the arch had been removed in connection with fusion operation and he believed this to be the cause of the progression. I have observed increased slipping in adults in 1 case after spondylosis and in 7 cases after laminectomy without fusion. In 6 cases the slipping was 3—4 mm. and in 2 cases 6 mm. I believe this increased slipping to be due in most cases to the disc degeneration. The instability of the disc increases after laminectomy when the stabilizing dorsal structures have been removed. In flexion-extension radiograms after laminectomy, I have, in certain cases, been able to observe increased instability. Progressive olisthesis of the fifth lumbar vertebra was observed in 7 adolescents aged 13 to 18 years. In 5 of these, the progression took place after operation.

During a 4-year period of observation, a 13-year-old boy showed a progression of the olisthesis from grade III to total olisthesis (fig. 6). There was further spina bifida of the lumbar vertebrae caudally of the third lumbar vertebra and of the entire sacrum. The first sacral vertebra was lumbarized. Bilateral spondylolysis was established. The fifth lumbar vertebral body was lower than the fourth, particularly in its dorsal portion and the vertebral surface of the sacrum was rounded off. Where such changes have taken place the danger of progression of the olisthesis is great (Taillard, Bosworth, and others).

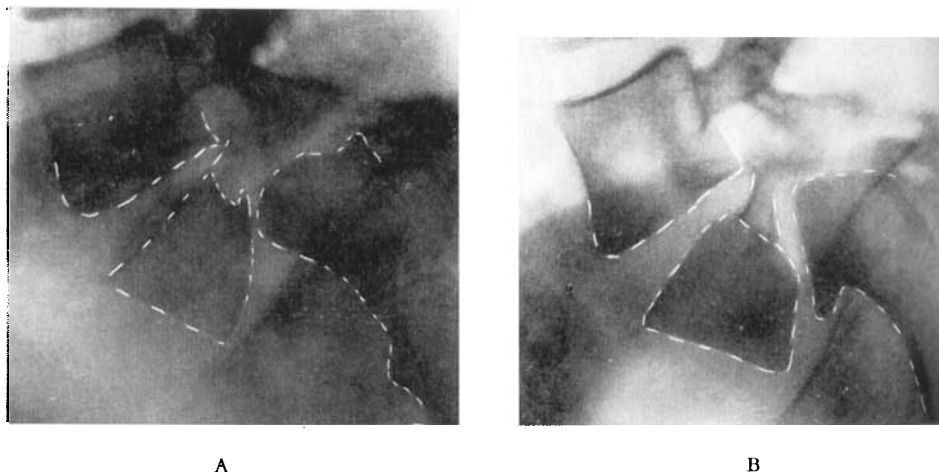
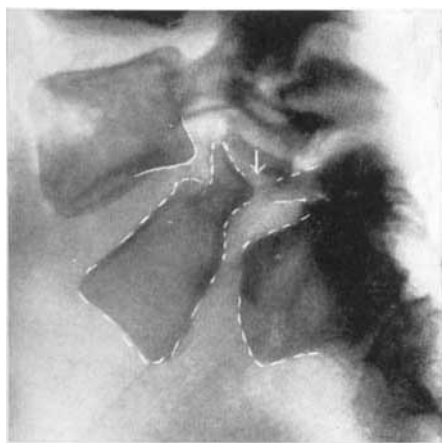


Fig. 7. 15 year old girl. Subtotal olisthesis of the fifth lumbar vertebra (A). Three years later (B) the vertebral body has rotated somewhat and slipped slightly caudally. The shape of the upper surface of sacrum has changed and a console has developed. There is marked retroposition of the fourth lumbar vertebra.

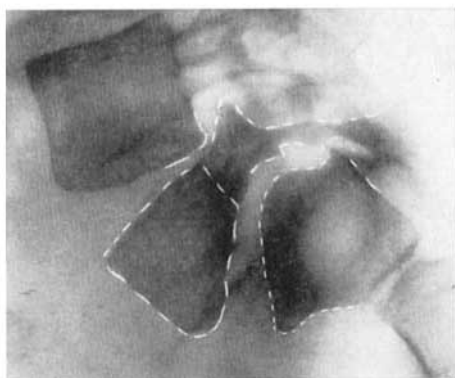
A 15-year-old girl had subtotal olisthesis in the fifth lumbar vertebra with elongation of the arch and uncertain spondylolysis (fig. 7). Three years later the vertebral body had rotated somewhat in a ventral direction and there was a slight caudal displacement. The shape of the upper surface of the sacrum had changed, it was now plane and a console had developed. It was improbable that the slipping would continue in this case after these reparative changes had taken place in the sacrum. Because of the presence of sciatica exploration was performed and it appeared that the arch of the fifth lumbar vertebra was stable and there was evidently not spondylolysis. The arch of the fourth lumbar vertebra, which seemed to compress the dural sac, was therefore removed. At follow-up examination one year later, the olisthesis was unchanged. The patient still had periodic radiating pain and back-ache.

The figure shows retroposition of the fourth lumbar vertebra, a common finding in high-grade olisthesis, and resulting from degeneration and instability of the cranial disc.

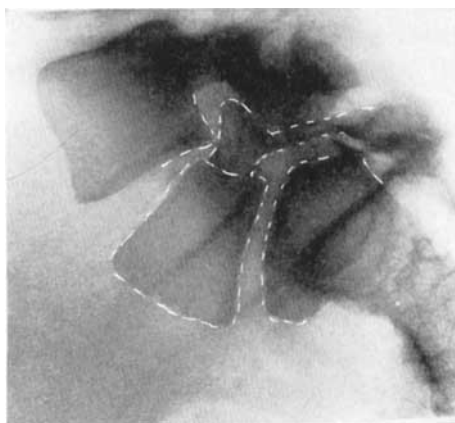
In a 16-year-old boy there was olisthesis of 25 mm of the fifth lumbar vertebra (fig. 8). There seemed to be spondylolysis. At follow-up one year later, the vertebral body had rotated somewhat in a ventral direction and the slipping had increased by some mm. Dorsal fusion was performed and at follow-up 3 years later the slipping was unchanged, the presacral disc had become somewhat flatter and a console had developed in the sacrum. There was elongation of the arch but no lysis was now visible. In this case healing of the spondylolysis may have taken place. The graft was solid between the third lumbar vertebra and the sacrum but showed non-union between the second and third lumbar vertebra. The patient was symptom-free in light work.



A

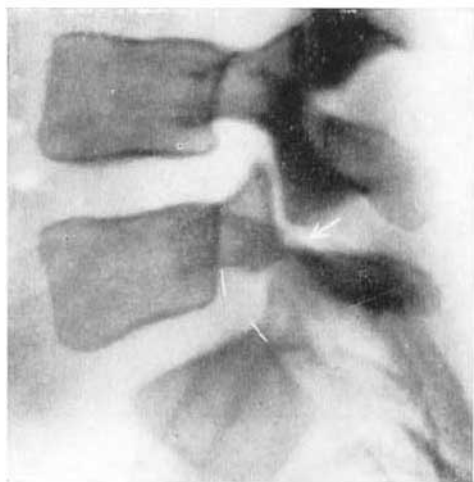


B

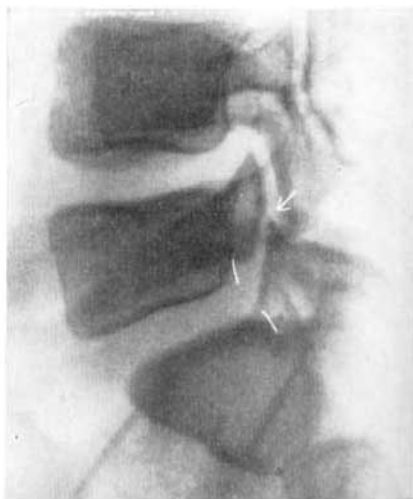


C

Fig. 8. 16 year old youth. The fifth lumbar vertebra is ventrally displaced 25 mm (A). The vertebral body has a trapezoid shape. There seems to be a defect in the neural arch. One year later (B) the vertebral body has rotated slightly and the slipping has somewhat increased. Dorsal fusion was performed. Three years later (C) the slipping is unchanged. There is elongation of the arch but the defect is now not visible, healing of the lysis may have taken place. The presacral disc has become lower and there is repositioning of the fourth lumbar vertebra.



A



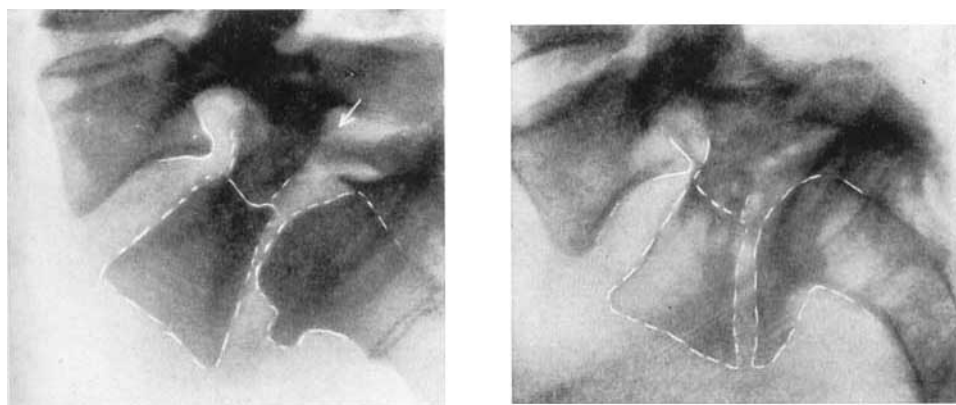
B

Fig. 9. 7 year old boy. The fifth lumbar vertebra is slightly ventrally displaced. Hypoplasia of the neural arch, no certain defect (A). Three months later there is a wide defect (B) which is located more ventrally than was expected. This suggests that the osteolytic process can affect different parts of the arch.

In the present series, a 7-year-old boy was the only patient under 10 years and this case will therefore be described. There was displacement of the fifth lumbar vertebra of some mm. (fig. 9). Elongation and hypoplasia of the arch were present, spondylolysis being uncertain. Three months later wide spondylolysis was observed, being, however, located more ventrally than is commonly the case and in front of the point which in the previous picture seemed to be the site of the lesion. This would indicate that different parts of the dysplastic arch may be affected by the osteolytic process. The previous case and other observations suggest that the process might be reversible. Brocher compared the changes in the spondylolytic arch with infantile coxa vara, in which similar changes occur.

If we compare olisthesis with progression during the growth period and olisthesis of about the same degree but in which the progression has become arrested, we are faced by the question of what mechanism stops the progression.

A 28-year-old man exhibited olisthesis of the fifth lumbar vertebra of 20 mm. and bilateral spondylolysis (fig. 10). The vertebral body was flattened, being lower dorsally. The upper sacral surface was rounded, and the beginning of a console could be observed. Dorsal fusion was performed. Eight years later slipping was unchanged; there might possibly have been slight rotation of the vertebral body. A marked console formation could now be seen.



A

B

Fig. 10. 28 year old man. The fifth lumbar vertebra is ventrally displaced 20 mm (A). The vertebral body has a trapezoid shape, the upper surface of sacrum is rounded off. There is a beginning consol. Dorsal fusion was performed. Eight years later (B) the slipping is unchanged, a slight rotation has possibly taken place. A marked consol can now be seen.

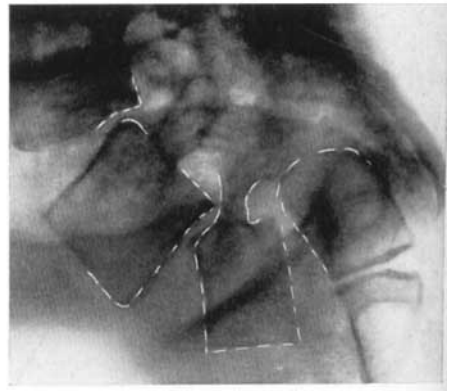
In the age group 10 to 19 years, 12 patients were operated on. In 10 cases, 8 dorsal and 2 ventral, spondylodesis was performed. In 2 cases exploration and laminectomy alone were performed. In 7 cases the olisthetic vertebra exhibited no progression of the olisthesis after fusion. The degree of olisthesis was 15—30 mm. in five of these cases, while subtotal olisthesis was observed in 2. It can be assumed that progression was arrested by means of dorsal fusion in the five first-mentioned cases. There was increased slipping in 5 cases, however, despite the fact that fusion had been carried out in 4. In all these cases there had been considerable preoperative olisthesis classified as subtotal. Follow-up examination of these patients showed that total olisthesis had taken place. Fig. 11 illustrates such a progression.

The patient was a 15-year-old boy with subtotal olisthesis. The first radiogram shows the condition 6 weeks after operation. Dorsal fusion with two tibial grafts was carried out in connection with laminectomy of the arches of the fourth and fifth lumbar vertebra. Follow-up examination 2 years later showed total olisthesis; the well-healed grafts had bent slightly. Spondylolysis was no longer visible. There was considerable retroposition of the vertebral bodies of the third and fourth lumbar vertebra and the third and fourth lumbar discs were widened in their ventral portions.

Taillard observed progression in 12 out of 50 cases at the age of 10 to 20 years. Dorsal fusion had been carried out on 47 patients but this measure did not prevent increased slipping in these twelve cases. In 7 cases reposition of the olisthetic



A



B

Fig. 11. 15 year old boy. Subtotal olisthesis of the fifth lumbar vertebra. Dorsal fusion with bilateral paraspinal grafts was performed six weeks earlier (A). Two years later (B) slipping has continued and the olisthesis is now total. The graft is slightly bent. There is retroposition of the third and fourth lumbar vertebra and the discs are deformed.

vertebral body succeeded but it remained stable in one case only, while in the remaining cases progression recurred despite spondylodesis. According to Taillard, a trapezoid shape of the olisthetic vertebral body and a rounded off upper sacral surface are factors particularly predisposing to progressive slipping.

OPERATIVE TREATMENT

CLINICAL DATA CONCERNING 85 OPERATIVELY TREATED PATIENTS

The age and sex of the patients are given in table IX.

TABLE IX
Age and sex of the operatively treated patients

	10—19	20—29	30—39	40—49	50—59	Total
Men	7	11	13	12	5	48
Women	5	2	12	12	6	37
	12	13	25	24	11	85

The table shows a slight predominance of men, particularly of the ages of 20 to 29 years, which is probably due to the fact that, at this age, the men have taken up heavy work which provoked the symptoms.

Of the patients, 53 did heavy work and 18 women did housework. There were 14 patients who were either adolescents of school-age or individuals who did light work.

The duration of symptoms before the patients presented for treatment was less than one year in 21 cases, 1 to 5 years in 42 cases, 6 to 10 years in 16 cases and more than 10 years in 6 cases.

The age of the patients at the onset of symptoms is shown in table X.

TABLE X
Age at onset of symptoms

Age	0—9	10—19	20—29	30—39	40—49	50—59
Number	1	18	18	28	17	3

The average length of the history was 4 years. The table includes 18 patients who stated that the symptoms occurred after a trauma. The history of these patients was short, as a rule. It is evident, as was also pointed out by Friberg, that the subjective symptoms are not very severe, seeing how late patients seek

medical aid. In contrast to Friberg's observations, among these 85 patients, the distribution of the time of onset of symptoms showed no preponderance in younger age groups. The frequency of trauma (18/85) was considerably higher (21%) in the operatively treated cases than in the entire series (6.4%). By producing a temporary insufficiency of the supporting soft tissues, such as ligaments, muscles and the fibrous tissue of the pars interarticularis, trauma becomes the releasing factor in the occurrence of pain in spondylolisthesis. This opinion is held by a great number of authors (Lewin, Liechti, Köhler, Friberg, Brocher, Taillard, and others).

In Finland, the insurance companies do not, as a rule, pay out compensation to those patients in whom a pain condition of the back occurs after some slight trauma, if spondylolisthesis is simultaneously present (Brofeldt). So-called muscular rupture and injury to ligaments as well as traumatic lumbago, however, are as a rule compensated if the pain condition occurred suddenly in connection with some particularly heavy task which differed from the patient's usual work. In conformity with this, such injuries occurring in patients with spondylolisthesis should be compensated, particularly if the patient, as often is the case, has previously been symptomfree. The compensation should be paid for a limited period.

Preoperative incapacity for work during periods of varying length had existed in 27, partial incapacity in 52 cases. 6 patients had been able to do their ordinary work.

In 26 cases the operative indication consisted of continuous pain in the lumbar region and in 59 cases of signs of root irritation. These symptoms are described in tables IV and V. The majority of the patients had received conservative treatment prior to operation but without effect. 43 patients had been treated with a surgical corset and 2 with a plaster jacket.

The location of lesion and the degree of slipping are shown in table VII.

In 77 of the 85 operatively treated cases, the time of observation was more than one year. The results of treatment are based on follow-up examination of these patients. 3 patients had previously been operated on in other hospitals, dorsal fusion having been carried out in two cases and exploration on account of suspected prolapse in one. The operations performed were:

Dorsal fusion without exploration	33	cases
Dorsal fusion with exploration or laminectomy	13	»
Ventral fusion without exploration	7	»
Laminectomy alone	32	»
	85 cases	

OPERATIVE FINDINGS

Slight hypoplasia of the spondylolytic arch occurred in a number of cases. The arch was mobile in a cranial-caudal direction to a varying degree, except in 3 cases where the arch was stable and where there was evidently no spondylolysis. Unilateral lysis was observed in one case in which there was also spina bifida. No significant hypoplasia of the sacral facets could, as a rule, be observed. The ligamentum flavum was thickened, particularly in its cranial portion, an observation also made by Bosworth. When, in a number of cases, the spondylolytic arch was manipulated in different directions from the spinous process during the operation, which was carried out under local anaesthesia until lumbar anaesthesia was later given, the patients did not report any pain in the back, nor any radiating pain. This is contrary to the clinical finding when patients often report pain in the back on pressure upon the spinous process of the spondylolytic vertebra. This, in my opinion, seems to indicate that, to some extent at any rate, the pain in the back originates in muscles and ligaments. In similar experiments Taillard was able to elicit both back pain and radiating pain from the intervertebral joints.

There were in some cases adhesions between the dura and the ligamentum flavum. In advancedolisthesis the arch was forwardly rotated owing to the pull exerted by the cranially situated vertebra. As was pointed out by Bosworth, the distance between the fourth lumbar vertebra and the sacrum was considerably shortened in these cases. The pars interarticularis was filled with fibrous tissue of varying volume. No evident pseudarthrosis was found but in two cases bony islands were observed in the fibrous tissue. Muroid degeneration, such as was observed by Adkins, was not seen. There was no significant hyperplasia of the fibrous tissue, neither had Bosworth observed any. In severe olisthesis of the fifth lumbar vertebra, the cauda was often compressed from behind by the arch of the fourth lumbar vertebra, an impression furrow being observed in 2 cases. Snellman observed a case in which the dural sac was compressed both dorsally and from either side by the ligamentum flavum. In one of my cases with a cauda equina syndrome already described, the dural sac was highly compressed in a frontal direction. Severin assumed that in olisthesis, sciatica may occur because of pressure from behind on the cauda.

Root compression

The operative findings concerning root compression are based on 45 explorations. Disc protrusion was observed twice (4%). The prolapse was situated in the interspace between the third and the fourth lumbar vertebra in one case

and between the fourth and the fifth lumbar vertebra in the other. The site of the prolapses bore no relation to the neurological findings. However, the patients were symptom-free after the operation. Before the operation for prolapse, dorsal fusion had been carried out on one patient. Five years after the second operation, there was fracture of the graft and the radiating pains recurred.

In their series of spondylolisthesis, Bosworth and Adkins both had two cases of prolapse. Meyerding found 7 prolapses in 143 operated cases (5.5%). Disc protrusion may thus constitute the reason for sciatica in spondylolisthesis but this is rare. These are cases of olisthesis of slight degree. Adkins quite rightly pointed out that owing to the circumstance that the olisthetic vertebra is displaced forwards, the intervertebral foramen actually becomes enlarged and the disc lies far ventrally. As already mentioned, retroposition of the cranially situated vertebra may often be observed. Where the degree of olisthesis is slight, the dorsal lower margin of the retropositioned vertebra, where there is often osteophyte formation, may cause constriction of the intervertebral foramen. This has been observed by Adkins, among others. In pseudospondylolisthesis, where the whole vertebra is forwardly displaced, the possibility of root compression is evident (Macnab, Adkins).

Adhesions to the roots, possibly caused by the fibrous tissue in the pars interarticularis, were observed in 6 cases. The adhesions were bilateral in 2 cases, and unilateral in 4. In these cases the roots were freed at operation. In 5 of these cases mere laminectomy of the spondylolytic vertebra was performed. The symptoms were alleviated in 2 cases but there was still periodic radiating pain. In 3 cases the relief was insignificant and even light work provoked increased symptoms. On the remaining patient dorsal fusion had previously been carried out and exploration was subsequently made because of root symptoms. There was relief after the last operation but he still had radiating pain from time to time. When there are visible changes in the roots, Adkins and Idelberger & Pia suggest dorsal rhizotomy to prevent recurrence of the symptoms. In none of the remaining cases of laminectomy or exploration (39/45) could compression or irritation of the roots be observed. It should be mentioned in this connection that successful fusion also brings relief of the radiating pain, a fact which was stressed by Taillard, among others. I have already mentioned that bilateral or unilateral absence of the ankle jerk is a common symptom in severe olisthesis of the fifth lumbar vertebra and that this may be due to stretching of the roots. Idelberger & Pia are of the same opinion.

All these observations seem to indicate that the fibrocartilaginous tissue in the pars interarticularis in spondylolysis and olisthesis does not directly compress the roots, as was suggested by Gill & al. I agree with Adkins, however, that irritation

of the roots by the fibrous tissue occurs in some cases. I believe, however, that instability of the spondylolytic vertebra and the adjoining discs as such may give rise to irritation of the roots, thus producing radiating pain and, in certain cases, neurological symptoms. The backache is caused by the instability which results in sensations of pain from the ligaments and the intervertebral joints. Degeneration of the disc may cause pain from the posterior longitudinal ligament (Wiberg, and others).

After laminectomy without fusion, there occurred, as was already mentioned, progression of the slipping in 7 out of 26 cases followed-up. 6 of these patients were adults, the average age being 40 years. The increase of the slipping was 3 to 6 mm. and, in my opinion, was due to increased instability after laminectomy of the spondylolytic neural arch.

These findings seem to indicate that laminectomy without simultaneous fusion should be carried out in exceptional cases only. This operation is, however, indicated in pseudospondylolisthesis with signs of root compression.

OPERATIVE METHODS

To achieve dorsal fusion, unilateral, paraspinal grafts from the tibia or the crest of the ilium as described by Albee, together with cancellous bone chips were used as a rule. In some cases bilateral grafts were employed. When a tibial graft was applied, it was generally long and fusion was carried all the way from the spinous process of the second or third lumbar vertebra to the first or second sacral vertebra. Latterly, iliac grafts have been most commonly used, in some cases in the shape of H-grafts (Bosworth). The number of dorsal fusions with or without exploration or laminectomy was 45. In one case with marked lumbar scoliosis, a tibial graft was inserted between the crest of the ilium and the transverse process of the first lumbar vertebra on the concave side. Tibial grafts were applied in 19 cases and iliac grafts in 21 cases of primary operation. In 4 cases, parts of the spondylolytic arch were used for fusion and in one case Hibb's operation with bank bone was performed. In 7 cases ventral transperitoneal spondylodesis was carried out. 9 cases were reoperated upon. There was infection in 3 cases and in one of these the graft was expelled. There were no other complications. The period of observation of the cases in which fusion was performed was 3 to 10 years, 6 years on average. The after-treatment was not homogeneous. All patients were confined to bed for 6 weeks after operation. About half the patients were then allowed to get out of bed without a supporting brace while some patients were given plaster jackets for two months and the remaining patients a surgical corset for 6 months to 1 year.

Consolidation of the graft

Of the 53 fusion cases, 51 were followed up. Primary consolidation had taken place in 19 out of 51 cases (37%). Consolidation of the area involved (third lumbar to first sacral, fourth lumbar to first sacral respectively) was achieved in 4 cases, in which, however, pseudarthrosis of the graft occurred at a higher level owing to too long a graft. Consolidation was considered uncertain in 10 cases, while pseudarthrosis was present in 18 cases, 9 of which were reoperated upon. The frequency of uncertain consolidation and non-union was thus 32/51 (63%).

The functional results of the operative treatment were classified in accordance with Friberg's scheme as follows:

- Group I Free from trouble in all work
- II Free from trouble in light work
- III Troubled even in light work
- IV Disabled

The functional results in relation to fusion of the graft in 51 cases of dorsal or ventral fusion are seen in table XI.

TABLE XI
Functional results in relation to fusion of the graft

	Result Graft fused	Non-union above the actual area	Fusion uncertain	Non-union	Re-operated on for non- union
I	9	—	—	1	1
II	9	4	10	7	4
III	1	—	—	1	4
	19	4	10	9	9

The table shows the best results after good fusion of the graft, but satisfactory results were also obtained when fusion was uncertain or when pseudarthrosis was present. In Friberg's and Meyerding's series the same observation was made. This evidently depends on the fact that even a non-fused graft produces stability of the lower lumbar spine and relief of symptoms in many cases (Friberg, and others). In such cases, stability of the lumbar discs could also be demonstrated in flexion-extension radiograms of the spine. A small number of patients, however, had marked symptoms due to the pseudarthrosis. At clinical examination, the patients often reported pain at the exact site of the pseudarthrosis. The case which was referred to group III despite solid fusion of the graft, was of a youth who showed progressive slipping despite fusion and bending of the graft (fig. 11).

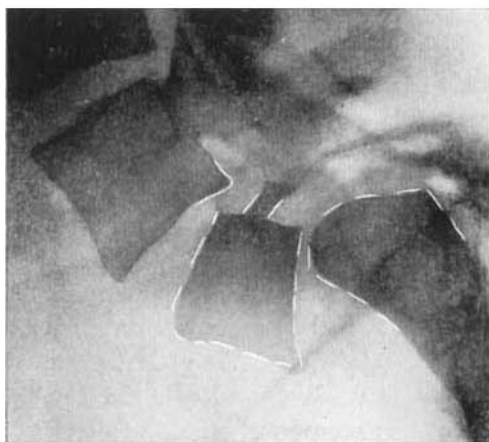
After ventral spondylodesis in 7 cases, consolidation took place in 2 cases, fusion was uncertain in 3 cases and there was no fusion in 2 cases. In those 4 cases in which pieces of the removed spondylolytic arch had been used for fusion, no consolidation could be observed, as was to be expected. The graft inserted between the crista and the transverse process of the first lumbar vertebra exhibited non-union at its lower attachment to the crista (fig. 3).

The frequency of non-union was very high (63%) Other series also show a high frequency of disturbances in consolidation after fusion for spondylolisthesis. Hammond & al. reported a frequency of 60 per cent. Newman reported that in 100 cases, in which dorsal fusion according to Steindler's procedure had been carried out, the frequency of pseudarthrosis was 34 per cent. The patients were therefore confined to bed after operation for 12 weeks instead of 6. Taillard reported uncertain fusion and pseudarthrosis in 53 per cent of cases after dorsal fusion with a double paraspinal graft in 47 cases in which the age of the patients was under 20 years. Ingebrigtsen observed pseudarthrosis in 7 out of 22 cases, Wilson in 24.3 per cent of 35 cases. Bosworth, however, obtained excellent results with his H-graft. Out of 73 patients, 62 showed primary consolidation (85%). Owing to poor results of dorsal fusion and dorsal intercorporeal fusion, Adkins decided in future to carry out intertransverse fusion (Mathieau).

Owing to the high frequency of pseudarthrosis, many authors have prolonged the time of confinement to bed after operation. Others recommend a plaster jacket as aftertreatment. By this method pseudarthrosis may be prevented in some cases. My cases of pseudarthrosis above the involved area show that too long a graft should not be applied. Follow-up examinations revealed, somewhat surprisingly, that better results were obtained by tibial than by iliac grafts. However, Bosworth's method seems to give very good results. Those of our cases in which this method has been applied are too recent to allow of any conclusions. It is sometimes difficult to determine the degree of consolidation radiologically, since the graft can be difficult to visualize in pictures.

Ventral transperitoneal spondylodesis

The number of operations was 7, 6 of these being performed by the former head of the hospital, the late Professor F. Langenskiöld. 2 patients were under 20 years, 5 were aged 40 to 60 years. These cases will be described in greater detail since experience of this method is rare. The method was first described by Capener. According to Ingebrigtsen (1953), the number of reported cases was 63. 3 operative fatalities have been reported. There were no postoperative complications in our 7 cases. There was olisthesis of the fifth lumbar vertebra in all



A



B

Fig. 12. 16 year old girl. Subtotal olisthesis of the fifth lumbar vertebra (A). A ventral transperitoneal fusion with an iliac graft was performed. Eighteen months later (B) the lumbosacral fusion is sound. The slipping is unchanged.

cases. The degree of slipping was less than 10 mm. in 2 cases, and 25—30 mm. in 3 cases, being subtotal in 2 cases.

In 5 cases a 10 mm. hole was made with a pneumatic drill through the olisthetic fifth lumbar vertebra into the first sacral vertebra, this hole being filled in 4 cases with autogenous chips and in addition, in one of these, with bank bone. In the fifth case an iliac graft was inserted into the hole. In one case a furrow was made into the caudal surface of the fifth lumbar vertebra and an iliac graft, supported against the sacrum, was inserted into the furrow. In the last case an iliac graft was applied between the caudal surface of the olisthetic vertebra and the sacrum after removal of the interposed soft tissues. This was a case of subtotal olisthesis. In this case consolidation took place (fig. 12).

In another case of subtotal olisthesis, in which chips and bank bone were inserted into the drill hole, consolidation likewise took place. Consolidation was uncertain in 5 cases but no instability in the lumbo-sacral joint could be demonstrated. In one of the cases reoperation with a dorsal graft was performed 3 months after the ventral spondylodesis since there had been no relief of the symptoms. This operation, however, was followed by infection and at follow-up examination 3 years later the dorsal graft exhibited multiple pseudarthroses, the ventral graft being, even though uncertainly, solid.

The functional results after ventral spondylodesis were all referred to group II. They were thus not better than those obtained by dorsal fusion. The procedure

is often technically difficult and there is a risk of complications. Consolidation of the graft seems to be quite as difficult to attain as in dorsal fusion. Progression of the slipping was prevented, however, in one case (fig. 12), in which the age of the patient was 16 years and in which there was a danger of continued slipping. This method is thus not to be recommended as a routine but in cases in which total dislocation of the vertebra threatens, it may possibly better prevent such dislocation than would dorsal fusion. This may particularly apply to cases in which reposition of the olisthetic vertebra was possible and in which redislocation despite dorsal fusion may occur (Taillard, Friberg). Since attempts at reduction have not been made in the present series, I have no experience of such treatment. In 7 cases out of 12, it was possible, however, as was already mentioned, to prevent progression by dorsal fusion in the age group 10 to 19 years.

RESULTS OF OPERATIVE TREATMENT

The functional results in 51 cases of dorsal and ventral spondylodesis are seen in table XII. The period of observation was 3 to 10 years. 16 patients used a corset.

TABLE XII
Functional results of 51 cases treated by dorsal or ventral fusion

	Lysis L4	Olisthesis L4	Olisthesis L5	Total	Corset
Group I	—	2	9	11	—
» II	1	2	30	33	10
» III	—	2	5	7	6
» IV	—	—	—	—	—
	1	6	44	51	16

The results of 26 laminectomies without fusion are seen in table XIII. The period of observation was 1 to 2 years.

TABLE XIII
Functional results of 26 cases treated by laminectomy without fusion

	Lysis L3	Olisthesis L4	Olisthesis L5	Total	Corset
Group I	—	—	1	1	—
» II	1	6	9	16	6
» III	—	2	5	7	4
» IV	—	—	2	2	2
	1	8	17	26	12

Tables XII and XIII show that the results after fusion, despite the high frequency of pseudarthrosis, were considerably better than after laminectomy.

If the results are divided into groups I and II, satisfactory, and groups III and IV, unsatisfactory, the following figures are obtained: Of the fusion cases 44/51 were satisfactory (86%) and of the laminectomy cases 17/26 (65%). Two laminectomy cases but no fusion case were referred to group IV.

¹ Even though in two-thirds of cases the laminectomy patients obtained considerable relief from radiating pain, the backache persisted in all cases. However, hospitalization and convalescence were, as a rule, of considerably shorter duration for laminectomized patients. 12 patients used a corset after the operation.

Although the number of laminectomized patients examined is small and the period of observation short, it seems that laminectomy without subsequent fusion is indicated in exceptional cases only. Such cases would then be older persons employed in light work and exhibiting signs of root irritation. Backache does not seem to be alleviated by laminectomy and this is hardly to be expected. The good results obtained by Gill et al. and King et al. could not be corroborated in the present series.

In table XIV the functional results in different degrees ofolisthesis are compared.

TABLE XIV
Functional results in relation to the degree of slipping in 77 cases

	Lysis	Less than 10 mm	11—20 mm	21—30 mm	Subtotal or total	Total
Group I	—	5	3	4	—	12
» II	2	14	19	4	10	49
» III	—	9	3	—	2	14
» IV	—	1	1	—	—	2
	2	29	26	8	12	77

It appears from the table that the degree of slipping is of no consequence as regards the functional results of treatment. This tallies with Friberg's and Meyerding's observations.

Table XV gives the results of treatment in all the 77 followed-up cases in which either fusion or laminectomy was performed.

TABLE XV
Functional results of 77 cases treated by fusion or laminectomy

Group	I	II	III	IV	Corset
	12	49	14	2	28

Satisfactory results (group I and II) were obtained in 61/77 cases (79%), the unsatisfactory cases amounting to 16/77 (21%). 28 patients stated that they still used a corset.

Meyerding achieved satisfactory results by fusion treatment of spondylolisthesis in 88.1 per cent of 138 cases. Bosworth stated that of 73 patients on whom fusion with an H-graft had been carried out, 89 per cent were symptom-free. This is an excellent result. Friberg obtained satisfactory results in 36 out of 44 cases treated by fusion (80.4 per cent). Satisfactory results of conservative treatment in Friberg's series constituted 80 per cent (115/143). These figures are not comparable, however, since the most difficult cases are chosen for operative treatment, a fact also stressed by Friberg.

Of the 809 cases of the present series, 85 (10.5%) were treated surgically. Of 870 cases diagnosed at the Mayo Clinic during the period 1922—1940, 143 (16.3%) were operated on, according to a statement by Meyerding. It is probable that some of the patients who were not admitted to our clinic for operative treatment, have been operated on at other hospitals. The majority of the cases, however, did not return to the clinic after the first visit, which indicates that the patients were satisfied with the conservative treatment prescribed, which, as a rule, included a surgical corset. For younger patients, training for a suitable occupation has been provided. The Rehabilitation Centre of the Invalid Foundation includes an vocational school for the disabled.

In spondylolisthesis, the nature and the duration of the pain are the factors determining the indications for operative treatment, a fact which has also been stressed by Brocher, Friberg, Marique, and others. Conservative treatment in the shape of rest, physiotherapy and a plaster jacket or a corset should always be considered first. The results are often satisfactory, as shown by Friberg, and others.

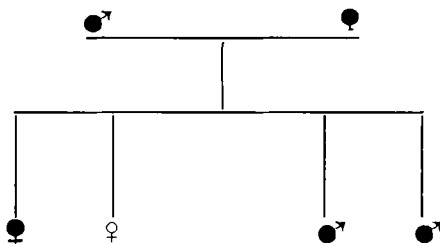
In spondylolisthesis in children and adolescents the problem is somewhat different. In most cases there is no severe progression of the olisthesis and these patients, in my opinion should be treated conservatively, particularly if the subjective symptoms are mild. Repeated follow-up examinations are necessary, however, in these cases. In the choice of occupation, the lesion should be taken into consideration. Where there is a threat of total luxation of the olisthetic fifth lumbar vertebra, which leads to deformity of the back and, in girls, to obstructed labour in some cases, spondylodesis is indicated. In such cases attempts at reduction may be made (Taillard, Friberg, Watson-Jones). The occurrence of relaxation despite solid dorsal fusion possibly indicates that ventral fusion might give better results in some cases. In pain conditions which do not respond to conservative treatment, operation is naturally also indicated in this age group.

DISCUSSION ON ETIOLOGY AND PATHOGENESIS

Numerous observations have shown that considerable progression of the olisthesis may take place during the growth period while, after the age of 20, progression occurs only exceptionally (Friberg, Taillard, Roche & Rowe, Bosworth, Adkins and others).

According to Brocher, in spondylolisthesis there is dysplasia of the arch arising from a congenital predisposition. The hereditary disposition was excellently demonstrated by Friberg in an investigation of a family in which 15 of its 61 members exhibited signs of spondylolisthesis. Familial occurrence of spondylolisthesis has been reported by Bakke, Francillon, George, Wiltse, and others. I have observed one family in which the lesion occurred in several members. The lesion was in all cases localized to the fifth lumbar vertebra. The mother and father and the oldest daughter exhibited olisthesis of grade I—II. Two twin sons had bilateral lysis without olisthesis and one of them had, in addition, marked juvenile lumbar osteochondrosis (Edgren & Vainio). One daughter had a normal back. There were back pains in four of the cases. When diagnosed the children were aged 11 to 12 years.

Family with multiple occurrence of spondylolisthesis



That there is a hereditary predisposition to spondylolisthesis can thus hardly be denied. Observations on children indicate that, as a rule, the changes set in probably after the age of five, thereafter sometimes progressing till the age of 20. Since, particularly in anatomical series, the frequency of spondylolysis without

olisthesis is comparatively high, it appears that the changes in the arch are primary and the olisthesis secondary. Roche and Rowe found unilateral spondylolysis in 32 out of 103 cases. The changes in the arch consist, according to Brocher, of elongation with or without spondylolysis, and hypoplasia and position anomalies of the articular processes. For these changes to become manifest, insufficiency of the supporting soft tissues, such as muscles and ligaments, is probably needed. Langendorff observed progression from spondylolysis to olisthesis in 3 patients aged 12 to 15 years. In a 4-year-old boy Newman observed elongation of the arch and 2 years later there was a radiologically demonstrable fissure. Like Bosworth, I have seen cases which would indicate that the spondylolysis is reversible. The changes in the discs and their role in the development of olisthesis have been stressed by Müller and Blume, among others. Bosworth and Taillard believe that the disc constitutes a factor contributing to the prevention of the slipping. Meyer-Burgdorff & Sandmann, on the other hand, consider the disc a less stabilizing structure than the arch and that the disc is not the cause of the slipping. According to Hirsch, the disc plays a far more important role in the stability of the spine than the dorsal formations. If we assume that the changes in the arch and the articular processes are primary in spondylolisthesis, then these cause an instability which secondarily affects the disc, leading to its degeneration and to instability. Why, during the growth period, the progression of the olisthesis advances in some cases and is arrested in others, while progression as a rule does not occur in adults, might possibly be explained by differences in the strength and stability of the caudal disc. In spondylolisthesis in adults, marked degeneration, particularly of the disc caudal of the olisthetic vertebra, is often present. Reactive changes, such as osteophyte formation, may be observed. Console formation of varying degree is often seen in the ventral upper corner of the sacrum. The changes seem to be reparative. Investigations by Hirsch and Schajowicz, among others, show that during the growth period the disc comparatively early attains a compact structure, partly through differentiation from the perichondrium and partly through interstitial growth. At the age of 25, the annulus fibrosus is completed, being now firmly attached to the cartilaginous plate and to the vertebral borders, and at the same time the ossification of the vertebra is completed (Köhler, Bick & Copel). This may explain why progression no longer occurs in adults. In childhood, however, there is greater elasticity of the disc, which may also depend on the fact that the nucleus pulposus has a relatively larger volume at this age. The assumption that in spondylolisthesis the strength of the disc probably varies would explain the varying degree of progression during the growth period. Additional factors affecting the situation are variations in the degree of insufficiency of the muscles and ligaments, the

shape of the olisthetic vertebra and the shape and position of the sacrum. These, which were pointed out by Taillard, may be secondary changes, however. In highly progressive olisthesis of the fifth lumbar vertebra, the attachment of the disc to the cartilaginous plate which separates it from the first sacral vertebra, may possibly give way, resulting in slipping at a certain stage between the disc and the cartilaginous plate. That there must be high-grade lesion of the discs on either side of the olisthetic vertebra is clearly seen in figure 11.

Some other theories on the etiology of spondylolisthesis should briefly be mentioned; according to Hitchcock, the lesion of the vertebral arch occurs in childhood as a result of the stress to which the arch is subjected when the child begins to walk and the lordosis of the lumbar spine develops. According to Meyer-Burgdorff's theory, too heavy a stress on a previously normal arch will result in the occurrence of an »Umbauzone» which develops into spondylolysis. Such a lesion may occur at any age. This theory is supported by Unander-Scharin's case in which spondylolysis developed in a previously healthy arch. The patient had undergone fusion because of low back pain and spondylolysis occurred in the vertebral arch cranially of the fusion area. A similar case was described by Taillard. In my opinion, the congenital disposition in the condition is proved. There is hardly any sex differentiation of this disposition. The vertebral changes occur during the growth period, the stress upon the spine and the intervertebral discs, which stabilize the spine, playing an important role in the manifestation and degree of progression of the deformity.

SUMMARY AND CONCLUSIONS

During the period 1944—1956, 809 cases of spondylolisthesis or spondylolysis were observed at the Orthopaedic Hospital of the Invalid Foundation's Rehabilitation Centre. The lesion was located in the fifth lumbar vertebra in 71.1 per cent of the cases, in the fourth lumbar vertebra in 25.1 per cent and in higher lumbar vertebrae in 3.8 per cent. The number of cases of spondylolysis without olisthesis was 51 (6.3 per cent). In 52 cases (6.4 per cent) the onset of symptoms was related to trauma. Ten patients were without subjective symptoms, 569 (70.3 per cent) had low back pain only, while 230 (28.3 per cent) suffered from sciatica with or without neurological signs. The number of patients under 20 years of age was 58. The lesion was located in the fifth lumbar vertebra in 91 per cent of these cases. Sciatica occurred in half of these cases, more often in patients under 16 years of age. A 14-year-old girl showed a cauda equina syndrome, and compression of the cauda was revealed at operation. 85 patients were treated surgically. The degree of slipping of the fourth lumbar vertebra did not exceed 20 mm. In 12 cases total or subtotal olisthesis of the fifth lumbar vertebra was present; eight of these patients were under 20 years of age. A great progression of the olisthesis was observed in seven adolescents, the age of the patients being 13—18 years. In four of these the increase in slipping occurred despite dorsal spine fusion. A slight progression (3—6 mm) was found in seven adults after surgical treatment. In six of these laminectomy without fusion had been made. The author's opinion is that the progression of slipping in these cases is due to increased instability of the discs after the removal of the spondylolytic arch with its supporting ligaments.

Investigation of a family of six members revealed olisthesis or lysis in father, mother and three of the children. This supports the observations of Friberg and points to a congenital disposition to spondylolisthesis. Insufficiency of the muscles and ligaments contributing to the stability of the lumbar spine probably plays an important role in the manifestation of the lesion. The different degrees of slipping of the olisthetic vertebral body in adolescence possibly depends on variations in the the stability of the discs at this age. Once the discs have attained

their final form at the age of twenty and ossification of the vertebrae is complete, no progression occurs as a rule.

Of the 85 patients who were operated on, 59 (69 per cent) had sciatica, 25 of these having jerk disturbances. A combination of symptoms which could be explained as root syndrome occurred in twelve cases. In 45 explorations or laminectomies, disc protrusion was present twice and adhesions to nerve roots six times. Direct compression of roots due to the fibrocartilaginous tissue in the pars interarticularis was not observed. The author's opinion is that whilst in certain cases root irritation due to the fibrocartilaginous tissue may occur, in most cases it is the instability of the spondylolytic vertebra which is responsible for the root irritation. The low back pain probably emanates from muscles, ligaments and intervertebral joints. The instability seems to increase in some cases after laminectomy without fusion.

Of the 85 cases which were treated surgically, 77 underwent follow-up examination. Dorsal fusion with or without exploration was made in 44 cases, ventral transperitoneal fusion in 7 cases and laminectomy without fusion in 26 cases. The length of follow-up was 3—10 years for the fusion cases and 1—2 years for the laminectomy cases. Primary consolidation of the graft was achieved in only 19 cases (37 per cent), uncertain union or non-union occurring in 32 cases (63 per cent). The functional results were satisfactory in many cases, however, despite uncertain union or non-union. The results of treatment with fusion were clearly better than the results of laminectomy without fusion. Satisfactory results with fusion were obtained in 44/51 cases (86 per cent), after laminectomy in 17/26 cases (65 per cent). The degree of slipping did not influence the results. The observations indicate that laminectomy without fusion should be performed only in exceptional cases. Of all the 77 cases followed-up satisfactory results were achieved in 61 (79 per cent). The indications for operative treatment are longstanding pain in the back or sciatica, which are not relieved by conservative treatment. Such treatment should always be tried first. In the case ofolisthesis in adolescents with danger of total displacement of the vertebral body fusion is indicated. Progression can not always be prevented, however, despite fusion treatment.

The investigation has been aided by a grant from the Finska Läkaresällskapet.

REFERENCES

- ADKINS E. W. O.: Spondylolisthesis. *J. Bone & Joint Surg.* 37B: 48, 1955.
- » Lumbo-sacral arthrodesis after laminectomy. *J. Bone & Joint Surg.* 37B: 208, 1955.
- ALLEN, M. L. & LINDEM, M. C.: Significant roentgen findings in routine pre-employment examination of the lumbosacral spine. *Am. J. Surg.* 80: 762, 1950.
- ARDEN, P. G.: Spondylolisthesis with bilateral drop-foot. *Proc. Roy. Soc. Med.* 42: 601, 1949.
- BATTS, M. Jr.: The etiology of spondylolisthesis. *J. Bone & Joint Surg.* 21: 879, 1939.
- BAKKE, S. N.: Förhandl. Nord. Kir. Förening 21: 517, 1937.
- BICK, E. M. & COPEL, J. W.: The ring apophysis of the human vertebra. *J. Bone & Joint Surg.* 33A: 783, 1951.
- BLUME, W.: Ein Fall von Spondylolisthesis congenita. *Zschr. Anat. Entw. gesch.* 101: 719, 1933.
- BOSWORTH, D. M., FIELDING, J. W., DEMAREST, L. and BONAQUIST, M.: Spondylolisthesis. *J. Bone & Joint Surg.* 37A: 767, 1955.
- BRAILS福德, J. E.: The radiology of bones and joints. Churchill, London 1945.
- BROCHER, J. E. W.: Die Wirbelverschiebung in der Lendengegend. Thieme, Stuttgart 1956.
- BROFELDT, S. A.: Förhandl. Nord. Kir. Förening 21: 480, 1937.
- CAPENER, N.: Spondylolisthesis. *Brit. J. Surg.* 19: 374, 1931.
- DURBIN, F. C.: Spondylolisthesis of the cervical spine. *J. Bone & Joint Surg.* 38B: 734, 1956.
- EDGREN, W. & VAINIO, S.: Osteochondrosis juvenilis lumbalis. *Acta chir. Scandinav. Suppl.* 227, 1957.
- FRANCILLON, M. R.: Hérité et constitution dans le spondylolisthesis. *J. suisse méd.* 76: 141, 1946.
- » Spondylolisthesis und Spondylolysis bei Jugendlichen. Medizinische, Stuttgart, April 1953.
- FRIBERG, S.: Studies on spondylolisthesis. *Acta chir. Scandinav. Suppl.* 55, 1939.
- GEORGE, E. M.: Spondylolisthesis. *Surg., Gynec. & Obstetr.* 68: 774, 1939.
- GILL, G. G., MANNING, J. G. and WHITE, H. L.: Surgical treatment of spondylolisthesis without spine fusion. *J. Bone & Joint Surg.* 37A: 493, 1955.
- GLORIEUX, P. & ROEDERER, C.: La spondylolyse et ses conséquences. Masson, Paris 1937.
- HAGELSTAM, L.: Retroposition of lumbar vertebrae. *Acta chir. Scandinav. Suppl.* 143, 1949.
- HAMMOND, G., WISE, R. E. and HAGGART, G. E.: Spondylolisthesis. A review of seventy-three patients treated by arthrodesis of the spine. *J. Bone & Joint Surg.* 39A: 227, 1957.

- HARRIS, R. I.: Spondylolisthesis. *Ann. Roy. Coll. Surg.* 8: 259, 1951.
- HIRSCH, C.: Studies on the mechanism of low back pain. *Acta orthop. Scandinav.* 20: 261, 1951.
- HIRSCH, C. & SCHAJOWICZ, F.: Studies on structural changes in the lumbar annulus fibrosus. *Acta orthop. Scandinav.* 22: 184, 1953.
- HITCHCOCK, H. H.: Spondylolisthesis. *J. Bone & Joint Surg.* 22: 6, 1940.
- HULBERT, N. G.: Spondylolisthesis with cauda equina lesion. *Proc. Roy. Soc. Med.* 41: 97, 1948.
- HULT, L.: Cervical, dorsal and lumbar spinal syndrome. *Acta orthop. Scandinav. Suppl.* 17, 1954.
- IDELBERGER, K. & PIA, H. W.: Wurzel- und Kaudaschädigungen bei der Spondylolisthesis und ihre Bedeutung. *Zschr. Orthop.* 89: 73, 1957.
- INGEBRIGTSEN, R.: Indications for anterior transperitoneal fusion in treatment of spondylolisthesis. *Acta chir. Scandinav.* 105: 176, 1953.
- KING, A. B., BAKER, D. R. and McHOLICK, W. J.: Another approach to the treatment of spondylolisthesis and spondyloschisis. *Clinical orthopaedics*. Number ten. Lippincott, Philadelphia 1957.
- KÖHLER, A.: Grenzen des Normalen und Anfänge des Pathologischen im Röntgenbilde des Skelettes. Thieme, Stuttgart 1956.
- LANGENDORFF, G.: Über Spondylolisthesis bei Kindern und Jugendlichen. *Zschr. Orthop.* 83: 548, 1953.
- LEWIN, PH.: The back and its disk syndromes. Kimpton, London 1955.
- LIECHTI, A.: Die Röntgendiagnostik der Wirbelsäule. Springer, Wien 1948.
- MACNAB, I.: Spondylolisthesis with an intact neural arch — the so-called pseudospondylolisthesis. *J. Bone & Joint Surg.* 32B: 325, 1950.
- MARIQUE, P.: Le spondylolisthésis. *Acta chir. Belg. Suppl.* 3, 1951.
- MATHIEAU, P. & DEMIRLEAU: Traitement chirurgical du spondylolisthesis douloureux. *Rev. orthop.* 23: 352, 1936.
- MEYERDING, H. W.: Low backache and sciatic pain associated with spondylolisthesis and protruded intervertebral disc. *J. Bone & Joint Surg.* 23: 461, 1941.
- » Spondylolisthesis: Surgical treatment and results. *J. Bone & Joint Surg.* 25: 65, 1943.
- MEYER-BURGDORFF, H.: Untersuchungen über das Wirbelgleiten. Thieme, Leipzig 1931.
- MEYER-BURGDORFF, H. & SANDMANN, H.: Die Bedeutung der präasacralen Bandscheibe für die Spondylolisthesis. *D. Zschr. Chir.* 245: 173, 1935.
- NEUGEBAUER, F. L.: Zur Entwicklungsgeschichte des spondylolisthetischen Beckens und seiner Diagnose. Diss. Dorpat 1881.
- NEUGEBAUER, H.: Spondylolisthesis und ihre neurologischen Ausfallerscheinungen. *Zsch. Orthop.* 87: 393, 1956.
- MÜLLER, W.: Pathologische Physiologie der Wirbelsäule. Barth, Leipzig 1932.
- NEWMAN, P. H.: Spondylolisthesis, its cause and effect. *Ann. Roy. Coll. Surg.* 16: 305, 1955.
- » Personal communication.
- PERLMANN, R. & HAWES, L. E.: Cervical spondylolisthesis. *J. Bone & Joint Surg.* 33A: 1012, 1951.
- PFÄHLER, G. & VASTINE, J.: The interpretation of lower spine injuries. *Surg. Gynec. & Obstetr.* 67: 600, 1938.

- PRIP-BUUS, C. E.: Spondylolysis and spondylolisthesis. *Acta orthop. Scandinav.* 14: 1, 1943.
- ROCHE, M. B. & ROWE, G. G.: The incidence of separate neural arch. *J. Bone & Joint Surg.* 34A: 102, 1953.
- RUNGE, C.: Roentgenographic examination of the lumbosacral spine in routine pre-employment examinations. *J. Bone & Joint Surg.* 36A: 75, 1954.
- SCHMORL, G. & JUNGHANN, H.: Die gesunde und kranke Wirbelsäule in Röntgenbild und Klinik. Thieme, Stuttgart 1951.
- SCHREINER, K. E.: Zur Osteologie der Lappen. Oslo 1935.
- SEVERIN, E.: Ischialgi vid spondylolistes. *Nord. Med.* 57: 117, 1957.
- SNELLMAN, A.: Ligamentäre Wurzelkompression bei einem Fall von echter Spondylolisthesis. *Ac. Duod. Tom.* 34B: 18, 1945.
- STEWART, T. D.: The age incidence of neural arch defects in Alaskan natives. *J. Bone & Joint Surg.* 35A: 937, 1953.
- TAILLARD, W.: Le spondylolisthesis chez l'enfant et l'adolescent. *Acta orthop. Scandinav.* 24: 115, 1954.
- » Les spondylolisthesis. Masson, Paris 1957.
- TURNER, J. P.: A cauda equina lesion due to spondylolisthesis. *Brit. Med. J.* 11: 28, 1952.
- UNANDER-SCHARIN, L.: A case of spondylolisthesis lumbalis acquisita. *Acta orthop. Scandinav.* 19: 536, 1950.
- WATSON-JONES, R.: Fractures and joint injuries. Livingstone, London 1946.
- WIBERG, G.: Back pain in relation to the nerve supply of the intervertebral disc. *Acta orthop. Scandinav.* 19: 211, 1949.
- WILLIS, T. A.: The lumbosacral vertebral column in man. *Am. J. Anat.* 32—33: 95, 1924.
- WILSON, N. J.: Review of results of treatment of one hundred cases of spondylolisthesis. *J. Bone & Joint Surg.* 37A: 406, 1955.
- WILTSE, L. L.: Etiology of spondylolisthesis. *Clinical orthopaedics*. Number ten. Lippincott, Philadelphia 1957.