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COMPARATIVE VALUE OF ELECTROMYOGRAPHIC, MYELOGRAPHIC AND CLINICAL-NEUROLOGICAL EXAMINATIONS IN DIAGNOSIS OF LUMBAR ROOT COMPRESSION SYNDROME

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Chapter 1

INTRODUCTION

Occasionally clinical-neurological as well as myelographic examination will fail to indicate the level of lumbar root compression. There is, however, a third method which has not been widely used for this purpose, namely, electromyography.

After perusal of the literature on the clinical application of electromyography in lumbar nerve root compression syndrome, the present investigation was started, the purposes of which were to find answers to the following questions:

1) To what extent can electromyography be utilized in the investigation of the level of lumbar root compression syndrome?
2) To what extent do denervation potentials persist postoperatively? (Can the method be used for recurrences?)

In the investigation patients with sciatica were examined:

1) electromyographically by the author personally who had no knowledge of the patient's history or clinical findings;
2) clinically-neurologically by the author personally;
3) myelographically (Abrodil) at the Roentgen Department II, University Hospital, Lund;
4) electromyographically and clinically-neurologically 1 year after the operation.

Chapter II

HISTORICAL REVIEW

Sciatica — formerly a syndrome of unknown aetiology — has aroused the interest of research workers for almost two centuries, and each generation of investigators has added to our knowledge in this field.

The first to describe sciatica as a disease was COTUNNIUS (1764). He distinguished 3 types of the disease, namely, arthritic sciatica, in which pain was limited to the hip joint, nervous posterior and anterior sciatica, in which pain was confined to the posterior and anterior parts, respectively, of the leg. He described muscular atrophy and ascribed the symptoms to neuritis with oedema of the nerve sheath and consequent compression of the nerve. He drew attention to the neural origin of the disease, which distinguished it clearly from joint pain.

A hundred years later (1864) LASÉGUE described his now well-known leg raising test.

40 years later (1904) the Frenchmen LORTAT-JACOB and SABAREANU showed that in certain cases of sciatica: "sensory disturbances presented a segmentary distribution", and they introduced the term "sciatique radiculaire", which gained a firm footing by the work of DEJERINE (1916). Reports on the frequency of radicular sciatica in relation to sciatica in general vary. DEJERINE & REGNARD (1912) regarded the form as very common. WERTHEIM-SALOMONSON (1911) belived that two thirds of all cases of sciatica were of radicular type and LARI & SCHAEFFER (1916) expressed the view that sciatica is most commonly of radicular origin. STURSBERG (1910) propounded that radicular sciatica was a correct diagnosis if sensibility

disorders of segmentary types could be demonstrated and that a probable diagnosis could be made if other symptoms were found, such as muscular atrophy, weakness of certain muscle groups, etc.

The aetiology of sciatica has been the subject of much speculation, and it was not until 1934 that MIXTER & BARR showed that root compression due to disk herniation in the lumbar region was the commonest cause of sciatica.

Many years previously, however, cases of intraspinal disk herniation had been published, but they had fallen into oblivion. For example, KEY (1838) reported a case of intraspinal disk herniation from the 11th thoracic interspace; the disease resulted in paraplegia and death. LUSCHKA (1858) presented 2 cases of intraspinal disk herniation and demonstrated their relation to nucleus pulposus. This herniation produced no symptoms, but LUSCHKA claimed that if these formations had grown, they could have caused pressure of the spinal cord.

But, as mentioned, LUSCHKA's observation passed unnoticed or into oblivion because with advances in intraspinal surgery these symptomatic disk herniations became accessible to operation and they were then regarded as tumours of the intervertebral disk. They were usually classified as chondroma or fibrochondroma (OPPENHEIM & KRAUSE (1909), ADSON & OTT (1922), ELSBERG (1925), ALAJOUANINE & PETIT-DUTAILLIS (1929), BUCY (1930)).

The first to report a case of traumatic dislocation of an intervertebral disk was KOCHER (1896). A 26-year old man had fallen from a height of 100 feet in a standing position. At autopsy the disk between LI and LII showed a large bulge, but no vertebral fracture was demonstrable. KOCHER believed the change to be due not to protrusion but to proliferation.

In 1911 MIDDLETON & TEACHER described a case. A 38-year old man felt something snap in the back when lifting a heavy weight. Local pain and paraplegia of the legs developed during the following night. The patient died 16 days later from urinary tract infection. Post mortem examination showed retropulsion of the disk between the 12th thoracic and 1st lumbar vertebrae

in the spinal canal. "The mass was white and firm and particularly resembled the central part of the intervertebral disk."

The same year (1911) GOLDTHWAIT published a paper in which he tried to find a relationship between sciatica and lumbosacral anomalies, sacralization, lumbalization, spina bifida and with the development of irregularities on the small joint surfaces of the arches. He soon discovered, however, that many patients with congenital anomalies had not sciatica. GOLDTHWAIT concluded that subluxation of lumbosacral joints was the commonest cause of sciatica.

In 1916 ELSBERG described extradural chondromata in the spinal canal, and in 1925 he reported 3 cases of extradural chondromas that he had operated upon. The patients had been treated for several years for sciatica. Atrophy of the bone musculature, paresis of the peroneus and weakness of the dorsal flexion of the foot were noted.

In 1927 SCHMORL described "Knorpelknötchen": ruptures of the nucleus pulposus into the spongiosa. 2 years later SCHMORL & ANDRAE described also "hintere Knorpelknötchen": ruptures of the nucleus pulposus into the spinal canal. They did not, however, believe these changes to be of clinical importance. In 1932 SCHMORL & JUNGHANS assumed that ruptures might cause compression of the spinal cord if the ruptures assumed considerable dimensions.

Some authors felt that an affection of the musculature might be the primary disorder responsible for sciatica, *e.g.*, PETRÉN (1908). This opinion had been propounded earlier by HELLEDAY (1876) in his paper: "On myitis chronica." PETRÉN suggested that particularly m. piriformis, because of its close relationship to the nerve trunk, might be capable of affecting the nerve. Several other authors have described this muscle as a possible cause of sciatica (FREIBERG & VINKE (1934), FREIBERG (1937), BEATON & ANSOM (1938), HAGGART (1938)).

In 1920 HELWEG postulated that the pathological-anatomical cause of the disease was myopathia, probably of ischaemic origin due to muscular hyperfunction. INGVAR (1936) shared his view. LINDSTEDT (1920, 1922, 1937) inclined to the view

that sciatica was neuralgia due to chronic irritation, *e.g.*, muscular hyperfunction. ÅKERBLOM (1908) more or less shared LINDSTEDT's opinion.

The theoretical speculations on the aetiology of sciatica also included the doctrine of the viscerosensory reflex (MACKENZIE 1893). According to that theory sciatic pain is a sort of "referred pain" (KELLGREN (1938), LEWIS (1942)) from pathological changes in various joints in the lumbosacral region or from the surroundings of the joints (LJUNGDAHL (1919), SMITH-PETERSEN & ROGER (1926), BURT (1934), WAGNER (1935), PITKIN & PHEASANT (1936), BROCHER (1936), KIMBERLEY (1937), BADGLEY (1937, 1941), STAINDLER (1940), SCHOBER (1940)).

CRAIG & WALSH (1941) claimed: "While it is probably true that reflex pain exists in the leg, still, with our present knowledge, it is difficult to estimate its frequency, and an intraspinal affection certainly must be excluded before the deduction can be made that the patient's pain is reflectory." Even though a number of sciatic symptoms can be explained by a referred mechanism such as muscle tenderness, it is, of course, difficult to explain the neural loss symptoms. Some of the above mentioned authors (BURT, BADGLEY, STAINDLER) are also of the opinion that in those cases where neural loss symptoms are demonstrable, this loss might suggest injury of a nerve root.

Anomalies and pathological changes in the sacro-iliac joints and in the lumbosacral region have been held responsible for sciatica particularly by orthopaedic surgeons. FRIBERG (1941) reviewed papers by various authors in this field. Arthritic changes in the sacro-iliac joints were regarded by many authors as being capable of compressing the lumbosacral cord. (GOLDTHWAIT & OSGOOD (1905), ROGERS (1911), YEOMAN (1928), KLEINBERG (1929), SASHIN (1930)), but changes in the lumbosacral region were also held responsible for sciatic pain by the pressure they exerted on different nerve roots. (BAUMAN (1924), DANFORTH & WILSON (1925), KLEINBERG (1929), AYERS (1929), HIBBS & SWIFT (1929), WILLIAMS (1932), GHORMLEY (1933), SMITH (1934), KIMBERLEY (1937), MAYERDING (1938)).

As known, sciatica has often been ascribed to a radicular affection (LORTAT-JACOB (1904)). SICARD (1918) felt that the site of affection of the roots is situated peripheral to the spinal ganglion and is due to changes in the intervertebral foramen, which by pressure against the spinal nerve gives rise to sciatica. He called this form of sciatica "sciatique funiculaire", and ROGER (1930) felt that this form of sciatica is the commonest and that changes in the intervertebral foramen are of rheumatic origin.

FOERSTER (1936) also expressed the view that some cases of sciatica may be due to arthritic changes in the intervertebral foramen between the 5th lumbar vertebrae and the sacrum. This view has been shared by HEUMAN (1920) in Sweden. PUTTI (1927) shared SICARD's view that sciatica is a form of vertebral arthritis. SICARD (1918) claimed that the common form of sciatica is funiculitis in which the IIIrd and IVth and Vth lumbar and Ist sacral roots were affected while lumbago is a funiculitis in which the IInd, IIIrd and IVth lumbar roots were involved. This relation between sciatica and lumbago has been discussed earlier by ROMBERG (1853) and GOWERS (1892) and particularly by GARA (1907) who also stressed that tenderness to pressure over the spinal process of the last lumbar vertebra is a common symptom of sciatica (even in such cases in which sciatica is not preceded by lumbago). He regarded this symptom as a support for the opinion that sciatica is a root affection. In Sweden LINDSTEDT (1922) clearly showed the relationship between sciatica and lumbago.

In 1925 DANFORTH & WILSON claimed on the basis of a clinical and anatomical investigation that sciatic pain is a symptom of injury to the lower lumbar region, commonly localized to the junction between LV and sacrum, and that the LV root is the one primarily involved.

In 1931 STENSTRÖM performed a clinical analysis of so-called neuritic symptoms in sciatica and arrived at the conclusion that in a fair number of cases of sciatica there was nerve injury apparently localized to the spinal nerves at the very site where they enter the sacral plexus. He felt that it

was not certain whether this form of sciatica could be distinguished pathogenetically from other forms of the disease.

EKVALL (1939) discovered the neuritic symptom in 90 % of his cases and stressed the importance of careful neurological examination. He believed that the site af attack was radicular.

After MIXTER & BARR's (1934) renowned work had been published many other series of operated disk herniations were reported. BARR, HAMPTON & MIXTER published (1937) 58 cases and LOVE & WALSH 100 cases the following year. In 1940 LOVE & WALSH reported on 500 cases and stated that 96 % of the disk herniations were situated in the lower lumbar region. In 1947 LOVE extended his operated material to 1217 cases. LOVE published other series together with CAMP (1937) and WALSH published together with CRAIG (1941). Among other American investigators who have collected operated cases, mention might be made of: DANDY, NAFZIGER, INMAN & SAUNDERS, BRADFORD & SPURLING, SPURLING & BRADFORD, SPURLING & GRANTHAM.

Large series of operated cases were also collected in Europe (BUSCH & CHRISTENSEN, PENNYBACKER, DE SÈZE, O'CONNEL, FRIBERG, SJÖQVIST, MALMROS, WIBERG, NORLÉN, WARIS, RÖVIG, KNUTSSON & WIBERG, HANRAETZ).

Of these, NAFZIGER et al. (1938) showed that ligamentum flavum might also be the cause of root compression, a view shared by other neurosurgeons (BARR, MALMROS). Other authors who have found a thickening of the ligamentum flavum to be a cause of compression are ELSBERG, FLORES, TOWNE & REICHERT, PUUSEPP, ABBOT, SPURLING, MAYFIELD & ROGERS, BROWN, BRADFORD & SPURLING and LOVE. In 1940 PENNYBACKER stressed that certain myelographic findings may be explained by hypertrophy of the ligament, but he never found any such case in which the sciatic syndrome could be ascribed entirely to hypertrophy of the ligament. It was soon realized that in some cases of sciatica operated upon, no disk herniation could be found at operation. In Sweden it was, in particular, FRIBERG (1941) and LINDBLOM (1941) who by anatomical examinations demonstrated that root compression might

be situated in the intervertebral foramen. Similar opinions have been expressed by, *inter alia,* BRADFORD & SPURLING (1939) and O'CONNEL (1943).

According to BARR & MIXTER (1941) it is extremely difficult to ascertain preoperatively the level of a disk herniation with certainity, and no method for this is available. MALMROS (1942) expressed the same view. According to SJÖQVIST (1942), clinical localization of a herniation between LV and SI is possible under certain circumstances. Like SPURLING & GRANTHAM (1940) he based his opinion on demonstrable weakness of the Achilles tendon reflex, but he also described the value of pain projection in the localization of a disk herniation. SPURLING, BRADFORD & GRANTHAM propounded that myelography is not necessary in indicating the level of disk lesions. CRAIG & WALSH (1941), on the other hand, stressed that reliable clinical localization is not possible.

Much work has been done to devise a reliable clinical method for localizing disk herniation, *i.e.*, to find the right intervertebral space involved. It was mainly NORLÉN, who by his excellent work in 1944, cleared the compression syndrome of the IVth and Vth lumbar and Ist sacral roots.

The surgical technique and methods have been devised mainly along lines laid down by MIXTER & BARR and experts in America (LOVE), and, particularly, in Scandinavia (FRIBERG, OLIVECRONA, MALMROS, SJÖQVIST, HIRSCH).

Myelography has become of considerable value in locating the level of disk herniation. In the beginning, air was used as contrast medium. It was introduced by DANDY in 1918. In 1938 YOUNG & SCOTT reported that they had used air myelography for diagnosing disk herniation and that 4 cases diagnosed in this way were confirmed at operation. CHAMBERLAIN & YOUNG (1939) used oxygen instead of air (more readily re-absorbed). BUSH, who had experimented with air myelography in 1935, published his over-pressure method in 1940. Of Scandinavian investigators who have published works on air myelography, mention might be made of LINDGREN, ANDERSEN & SCHROM, REFSLUND POULSEN, LASSILA. Positive contrast medium in

the form of "iodized oil" was frequently used after a publication by SICARD & FORESTIER (1921). The preparations used were Lipiodol, Jodipin and Immertal. These contrast media, however, were found to have side effects: They produced discomfort; signs of meningeal inflammation, such as headache, vomiting, pain and stiffness of the neck and back, was a common untoward reaction. These preparations were not absorbable. The side effects they produced have been described by ODIN, RUNSTRÖM & LINDBLOM (1929) and others. Pantopaque (ethyl iodophenylundecylate) is successively absorbed from the spinal canal and has been widely used in the USA (SCOTT & FURLOW (1944)).

Thorotrast (thorium dioxide) has been used experimentally as a contrast medium by NICHOLS & NOSIC (1940) and BUNTS (1941) in the USA and by LEKSELL (1943) in Sweden. The roentgenograms obtained with this contrast medium were better than those produced with air or iodized oil as a contrast medium. The root pockets were brought out more distinctly. A few reports on thorotrast had been published previously by RADOVICI & MELLER (1932), CAPUA (1933), LUCHERINI (1934), JACOBI, LÖHR & WUSTMAN (1934)).

However, thorotrast did not find wide use because of its unabsorbability.

Because of the above mentioned side effects, further contrast media were tried, and in 1931 ARNELL & LIDSTRÖM published the results of experiments with a new contrast medium, Abrodil (sodium monoiodomethyl sulphonyl). This substance has been used most commonly for myelography (ARNELL, FELTSTRÖM, NORDENTOFT, LINDBLOM, JOHANSSON and others).

In 1791 LUIGI GALVANI, a professor of anatomy, showed that muscles contract when stimulated electrically and that an electrical current is produced during muscular contraction.

Today, it is known that the current produced on muscle contraction is the manifestation of a motor unit action potential produced by volontary contraction.

This was first recorded by DENNY-BROWN (1929) and the same year by ADRIAN & BRONK, independently of one another. Later, further observations were made of the muscle action potentials by ECCLES & SHERINGTON (1930), CLARK (1931), LINDSLEY (1935) and HOEFER & PUTNAM (1939).

The use of electromyography in the diagnosis of pathological changes in human beings was decribed in 1938 by DENNY-BROWN & PENNYBACKER. The clinical use of the method is based to a large extent on the discovery of the denervation fibrillations. The first to observe fibrillations in denervated muscle was SCHIFF (1851). After having excised the n. hypoglossus on dogs, he observed 5 days later fibrillations in the affected muscle. He believed the fibrillations observed in the denervated muscle to be due to muscular activity and to degeneration of the nerve.

Denervation-fibrillations were rediscovered by LANGLEY & KATO (1915).

The first clinical observations were made by PROEBSTER (1928), who described denervation-fibrillations which he had recorded from an affected muscle in a 13-year old boy with injury to the plexus brachialis. He observed that these fibrillations did not occur in normal muscle on the opposite side. He also described denervation potentials from patients with poliomyelitis.

Later investigations of denervation fibrillations have been performed by BROWN (1937), DENNY-BROWN & PENNYBACKER (1938), HOEFER & PUTNAM (1939).

WEDDELL, FEINSTEIN & PATTLE (1944) observed that fibrillations occurred in human beings 18—21 days after the denervation.

These studies led to investigations with electromyography of the lower motor neuron disease. GOLSETH & FIZZELL (1947), JASPER & JOHNSTON (1945), JASPER (1945) and LOOFBOURROW (1948) demonstrated that electromyography can record the electric abnormalities accompanying lower neuron disease. The clinical use of the method as the diagnostic tool in the investigation of neurological diseases has been stressed by

HOEFER & GUTTMAN (1944), BRAZZIER, WATKINS & MICHELSEN (1946), KUGELBERG (1947) and HUDDLESTON & GOLSETH (1948).

It is BUCHTHAL who must be credited most with the development of electromyography and the range of application of the method. Together with his co-workers BUCHTHAL has published numerous papers in this field.

Concerning electromyography as a diagnostic adjunct in lumbar nerve root compression, the reader is referred to chapt. III, subheading "Electromyographic findings". Of authors, who have published works in this field mention might be made of SHEA, WOODS & WERDEN (1950), GOLSETH (1950), VON HAGEN (1955), MARINACCI (1954, 1955, 1958), SHEA & WOODS (1955, 1956), CRUE; PUDENZ & SHELDEN (1957), BONNER & SCHMIDT (1957), MENDELSOHN & SOLA (1958) and KNUTSSON (1958).

Chapter III

MATERIAL

Classification

The material consisted of 205 patients (124 males [60.49 %] and 81 females [39.51 %]) operated upon for herniated intervertebral disks at the Orthopedic Department, University Hospital of Lund, during the years 1958 and 1959. One of the patients was operated upon twice.

(During the above mentioned 2 years a total of 227 operations were performed for intervertebral disk herniation (115 in 1958 and 112 in 1959). In 13 of these cases electromyography was not done owing to the absence of the author at the time of admission of these patients to the Department. In a further 8 cases myelography was not performed, so that the number of patients submitted to clinical examination and myelography as well as electromyography was reduced to 205, including the patient operated upon twice, thus bringing the number of operations up to 206.)

The material was divided into 2 groups:

Group 1. — This group consisted of 182 patients, who had *not* been operated upon previously.

Group 2. — This group consisted of 23 patients, who had been operated upon previously. One of the patients was operated upon twice.

The operative findings made in the 182 patients in group 1 were as follows:

Findings	Total	Males	Females
a) disk herniation between LV and SI	60	36	24
b) disk herniation between LV and LVI	1	1	—
c) disk herniation between LIV and LV	74	46	28
d) disk herniation between LIII and LIV	2	1	1
e) protrusion between LV and SI	11	6	5
f) protrusion between LIV and LV	14	7	7
g) "negative"	20	13	7

Group 2 consisted of 23 patients operated upon a total of 24 times for disk herniation, and the operative findings are given below:

Findings	Total	Males	Females
a) herniation between LV and SI	6	5	1
b) herniation between LIV and LV	4	3	1
c) herniation between LIII and LIV	1	—	1
d) protrusion between LV and SI	3	1	2
e) protrusion between LIV and LV	1	—	1
f) protrusion between LIII and LIV	1	1	—
g) adhesions between LV and SI	3	—	3
h) adhesions between LIV and LV	2	2	—
i) adhesions between LV and SI and LIV and LV	2	2	—
j) "negative"	1	1	—

Of the 20 patients, in whom the operative findings were "negative" (group 1, subheading g), there were 7 with osteophytes, which thus provided a satisfactory explanation for the root symptoms, in 1 the space was narrow and 4 had pronounced varices. In the remaining 8 cases exploration revealed no signs at all of a pathological condition.

A comparison of these operative findings with those reported by earlier investigators is given below:

Intervertebral disk herniation

1941	FRIBERG	76 %	(44/58)
1942	MALMROS	85 %	(100/118)
1944	SHINNERS & HAMBY	83 %	(116/140)
1946	SENNING & SJÖQVIST	77 %	(309/403)
1948	WARIS	77 %	(289/374)
1961	Author's group 1	75.3 %	(137/182)
1961	Author's entire material	71.8 %	(148/206)

All disk lesions (protrusions included)

1941	FRIBERG	88 %	(51/58)
1942	MALMROS	85 %	(100/118)
1944	SHINNERS & HAMBY	83 %	(116/140)
1946	SENNING & SJÖQVIST	85 %	(342/403)
1948	WARIS	88 %	(330/374)
1961	Author's group 1	89 %	(162/182)
1961	Author's entire material	86.2 %	(178/206)

Other probable causes of root compression

1941	FRIBERG	7 %	(4/58)
1942	MALMROS	13 %	(15/118)
1946	SENNING & SJÖQVIST	2 %	(8/403)
1948	WARIS	4 %	(16/374)
1961	Author's group 1	6.6 %	(12/182)
1961	Author's entire material	9.2 %	(19/206)

Negative findings

1941	FRIBERG	5 %	(3/58)
1942	MALMROS	3 %	(3/118)
1944	SHINNERS & HAMBY	17 %	(24/140)
1946	SENNING & SJÖQVIST	13 %	(53/403)
1948	WARIS	4 %	(16/374)
1961	Author's group 1	4.4 %	(8/182)
1961	Author's entire material	4.4 %	(9/206)

There is general agreement that the 2 lowest lumbar disks are those most commonly herniated. This was also found in the present material.

The cases are listed according to the side involved, below:

Group 1

	Findings	Males	Females
a)	34 left-sided	22	12
	26 right-sided	14	12
b)	1 right-sided	1	—
c)	46 left-sided	29	17
	28 right-sided	17	11
d)	1 left-sided	1	—
	1 right-sided	—	1
e)	9 left-sided	6	3
	2 right-sided	1	1
f)	9 left-sided	3	6
	5 right-sided	4	1
g)	11 left-sided	7	4
	9 right-sided	6	3

Total number of left-sided disk herniations 81:52 m., 29 f.
„ „ „ right-sided „ „ 56:32 m., 24 f.
„ „ „ left-sided protrusions 18:9 m., 9 f.
„ „ „ right-sided „ 7:5 m., 2 f.

Group 2

	Findings	Males	Females
a)	3 left-sided	2	1
	3 right-sided	3	—
b)	4 left-sided	3	1
c)	1 left-sided	—	1
d)	2 left-sided	1	1
	1 right-sided	—	1
e)	1 left-sided	—	1
f)	1 left-sided	1	—
g)	2 left-sided	—	2
	1 right-sided	—	1
h)	2 left-sided	2	—
i)	2 right-sided	2	—
j)	1 right-sided	1	—

Total number of left-sided disk herniations 8:5 m., 3 f.
„ „ „ right-sided „ „ 3:3 m.
„ „ „ left-sided protrusions 4:2 m., 2 f.
„ „ „ right-sided „ 1:1 m.
„ „ „ left-sided adhesions 4:2 m., 2 f.
„ „ „ right-sided „ 3:2 m., 1 f.

Of the 206 cases, the symptoms were left-sided in 111 (53.9 %) and right-sided in 75 (36.4 %), while in 20 (9.7 %) they were bilateral. Of these 20, the symptoms were predominant on the left side in 15 and on the right side in 5. Thus, the symptoms were predominant on the left side in 126 (61.2 %) and on the right side in 80 (38.8 %). As mentioned, in the present material males were predominant (60.49 against 39.51 % females). This preponderance is in agreement with that found in most previous series. [LOVE & WALSH (1940) 71 %, MALMROS (1942) 63 %, WARIS (1949) 72 %, RÖVIG (1949) 70 %, BARR & MIXTER (1941) 78 % and FRIBERG (1941) 61.4 %.]

In the present material the left side was involved more frequently than the right. This observation has also been made by earlier authors. [MALMROS (1942) 62 %, YASKIN et al. (1944)

TABLE 1

The age distribution

	Diskherniation								Protrusion L V-S I		Protrusion L IV-L V		»Negative»		Total Group 1		Group 2		Entire material	
	L V-S I		L V-L VI		L IV-L V		L III-L IV													
10—19 years	1	—	—	—	1	1	—	—	—	—	—	—	—	—	2	1	—	—	2	1
20—29 „	7	4	—	—	4	2	—	—	1	1	—	2	1	—	13	9	1	2	14	11
30—39 „	12	7	1	—	14	7	—	—	1	1	3	2	—	2	31	19	7	2	38	21
40—49 „	9	9	—	—	15	10	—	—	3	3	1	3	5	2	33	27	3	4	36	31
50—59 „	6	4	—	—	10	4	1	1	—	—	3	—	6	2	26	11	4	1	30	12
60—69 „	1	—	—	—	2	3	—	—	1	—	—	—	1	1	5	4	—	—	5	4
70—79 „	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1	—	—	—	1
Total	36	24	1	—	46	28	1	1	6	5	7	7	13	7	110	72	15	9	125	81
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F

A comparison with other materials

Age	Love 1947 % of 1217 cases	Waris 1948 % of 374 cases	Knutsson—Wiberg 1958 % of 251 cases	Knutsson 1961 % of 206 cases
10—19 years	2.1	—	3.2	1.4
20—29 „	16.3	18	11.5	12.1
30—39 „	35.3	43	30.7	28.6
40—49 „	30.5	28	34.3	32.5
50—59 „	13.1	10	15.1	20.4
60—69 „	2.7	1	5.2	4.4
70—79 „	—	—	—	0.5

TABLE 2

Duration of the symptoms

	Less than 3 weaks	1—3 months	4—6 months	7—12 months	More than 1 year
Disk herniation L V=S I	—	20	21	13	6
„ „ L V—L VI	—	1	—	—	—
„ „ L IV—L V	1	28	26	10	9
„ „ L III—L IV	—	2	—	—	—
Protrusion L V—S I	—	3	1	4	3
Protrusion L IV—L V	—	2	4	6	2
Negative findings	—	5	6	3	6
Group 2	1	5	9	6	3
Total	2	66	67	42	29

58 %, PETITS-DUTAILLIS & DE SÈZE (1945) 59 % and WARIS (1949) 51 %. RÖVIG (1949), however, found the disease to be slightly more common on the right side (50 right-sided, 45 left-sided and 4 bilateral)].

As to the ratio between unilateral and bilateral projection of pain, it was unilateral in 90.3 % of the present material and bilateral in 9.7 %. A similar ratio was given by BRADFORD & SPURLING (1945), namely, 8 % bilateral sciatica, while most other authors give a somewhat higher figure for bilateral radiation of pain, *e.g.*, LOVE & WALSH (1938) 16 %, BARR & MIXTER (1941) 20 %, FRIBERG (1941) 22.7 % and MACEY (1940) 12 %.

The age distribution of the material is given in Table 1, and the duration of the symptoms in Table 2.

Projection of pain

Sciatic pain and its projection has been the subject of discussion by many authors.

In 1841 VALLEIX distinguished 2 types of sciatic pain, namely, spontaneous and provoked. According to him, provoked pain consisted of pain produced by compression of the nerve, for example, cough and special bodily movements. Pain produced

by cough and sneezing has proved useful in the diagnosis of sciatica due to intervertebral disk herniation. These attacks of pain are, however, of no value for locating the site of the disk herniation and will therefore not be discussed in detail here.

According to SAHLGREN (1942), however, exaggerated hyperextension of the leg to produce Lasègue's sign can often cause projection of pain, which may be of value in locating the disk involved.

COTUGNO described pain as being confined to the region of the hip, whence it radiated down along the posterior aspect of the thigh, the outer surface of the lower leg and down into the foot. He added that if a patient were asked to indicate the site of the pain, "he will trace the line of the sciatic nerve just as exactly as the best anatomist".

VALLEIX (1841) stressed that pain need not always extend along the entire length of the nerve but may be confined to shorter segments or, even isolated points.

HELWEG (1920) expressed the view that pain is so subjective a phenomenon that it is of no value in locating the disk involved. He also very much doubted whether patients are able to locate such a phenomenon as pain.

In the abundant literature, published after MIXTER & BARR's demonstration of the lumbar disk herniation as a causal factor of sciatica, the location of the pain is described in full agreement with the classical description of spontaneous sciatic pain. Thus BARR & MIXTER, for example, described pain as "a pain localized to the deep parts, beginning in the hip region, radiating down the posterior thigh, the posterolateral aspect of the calf, and occasionally going into the lateral border of the foot or the great toe".

In 1937 BARR wrote that "the spread of the pain is identical if it is the 5th lumbar or 1st sacral root that is affected. The spread of the pain, will, accordingly, be of no value in locating the site of the injury". This opinion is shared by BRADFORD & SPURLING (1945), while other authors have a different opinion.

In herniation of the 4th and 5th lumbar disks, "the pain is projected to the sciatic area" (MALMROS (1942), SPURLING &

GRANTHAM (1940)), while in cases with herniation of a somewhat higher intervertebral disk "the pain is projected to the anterior side of the thigh and sometimes also to the sciatic area". Sometimes, the pain is projected to the entire area innervated by the segment, in other cases only to parts of the area. In some cases, the pain may be confined to a very small area. MALMROS (1942), for example, described cases of intervertebral disk herniation in which the pain was localized only to the great toe or lateral margin of the foot.

FOERSTER (1936) claims that severe irritation of a sensory root causes pain in the entire area supplied by the root, while less severe irritation causes pain in a smaller area, and slight irritation often causes pain in only a very small area called punctum maximum of the innervation segment.

According to FOERSTER these points are:

for 3rd lumbar root: anterior of knee and immediate surroundings,

for 4th lumbar root: medial malleolus and great toe,

for 5th lumbar root: all toes and dorsum of foot,

for 1st sacral root: heel and sole,

for 2nd sacral root: posterior aspect of thigh, back of knee.

FOERSTER claimed that the site of punctum maximum of the innervation segment is so constant that he could locate the different roots at operation from the position of the punctum maximum.

NORLÉN (1944) analyzed a clinical material of 99 intervertebral disk herniations and found that of 53 patients with herniations between LIV and LV:

13 had projected pain in the great toe,

3 had projected pain in the heel.

Of 46 with disk herniation between LV and SI:

16 had projection of pain in the heel,

2 projection of pain in the great toe.

Thus, of 99 patients, 34 had projection of pain either in the great toe or the heel.

Of 2 with disk herniation between LIII and LIV, both had projected pain in the region of the hip and anterior surface of

the thigh, and 1 patient reported pain even on the posterior surface of the leg and down into the great toe.

Since the results of NORLÉN's clinical investigations did not agree entirely with FOERSTER's assertion, NORLÉN performed an experimental investigation. He irritated the 4th and 5th lumbar roots as well as the 1st and 2nd sacral roots mechanically at operation and reported the following findings:

1. On irritation of the 4th lumbar root (14 cases), the patients reported that they felt projected pain in the hip and the anterior surface and inner side of the thigh, down to the knee, and several also reported pain on the anterior side of the lower leg. 2 also described pain in the calf. None of them reported projection of pain into the foot or great toe.

2. On irritation of the 5th lumbar root (16 cases), 14 patients reported that they felt projected pain on the posterior side of the leg and in the great toe. 2 of the patients described pain radiating out into the foot without saying where in the foot.

3. In 33 cases, the 1st sacral root was irritated. Of these patients, 25 reported that they felt radiating pain on the back of the leg down to the heel, 3 described pain in the foot without saying where, 3 claimed pain in the entire foot and lateral border of the foot, and 1 pain down to the ankle, but not into the foot. In 1 case, a patient reported pain down to the back of the knee but not further.

4. The 2nd sacral root was irritated in 10 cases. 7 of them reported projection of pain to the back of the thigh down to the back of the knee. 2 described pain on the back of the leg to just below the knee and 1 down to the foot, but did not say where.

In WARIS' material from 1948, 42 % (64 of 153) of the herniations between LV and SI described projection of pain resembling NORLÉN's SI-syndrome. In only 1 of the cases of herniation at this level, was pain projected out into the great toe, in 3 into the perineum and in 56 % (85 of 153) the pain was less defined and radiated into the thigh, calf or ankles.

Of patients with herniation between LIV and LV, 21 % (27 of 129) reported projection of pain into the great toe (typical

of compression of the 5th lumbar root). 17 % (22 of 129) reported pain in the heel (characteristic of compression of the 1st sacral root). In 62 % of the cases (80 of 129) pain was diffuse and radiated mainly down to the calf.

TABLE 3

Projection of pain

	Hip	Thigh	Knee	Calf	Ankles	Foot	Lat. toes	Great toe	Heel	
Group 1 Herniated disk between:										
L V—S I	3	—	4	15	3	10	10	3[1]	12[2]	60
L V—L VI	—	—	—	—	—	—	—	—	1	1
L IV—L V	—	3	4	17	11	10	7	16[3]	6[4]	74
L III—L IV	—	—	2	—	—	—	—	—	—	2
Protrusion L V—S I	—	—	—	3	2	2	1	—	3	11
„ L IV—L V	—	—	1	6	1	5	1	—	—	14
"Negative"	1	—	2	5	1	5	2	3	1	20
Total group 1	4	3	13	46	18	32	21	22	23	182
Group 2 Herniated disk										
L V—S I	—	—	—	1	—	—	—	2	3	6
L IV—L V	—	—	—	—	2	1	—	—	1	4
L III—L IV	—	—	—	—	—	—	—	1	—	1
Protrusion L V—S I	1	—	—	—	1	—	—	—	1	3
„ L IV—L V	—	—	—	—	—	1	—	—	—	1
„ L III—L IV	—	—	—	—	—	—	1	—	—	1
Adhesions L V—S I	—	—	—	2	—	—	1	—	—	3
„ L IV=L V	—	—	—	—	—	1	—	1	—	2
„ L V—S I+ + L IV—L V	—	—	—	1	—	—	—	1	—	2
Negative expl.	—	—	—	—	—	—	—	—	1	1
Total group 2	1	—	—	4	3	3	2	5	6	24
Entire material total	5	3	13	50	21	35	23	27	29	206

[1] 5 % projected pain into the great toe.
[2] 20 % projected pain into the heel.
[3] 21.6 % projected pain into the great toe.
[4] 8.1 % projected pain into the heel.

Of those with herniation between LIII and LIV (7), 4 showed a typical LIV-syndrome pain, projected out into the antero-median part of the thigh and hip joints. In the remaining 3 cases, projection of pain was diffuse.

The projection of pain in the present material is apparent from Table 3.

Table 4 gives a comparison with NORLÉN's and WARIS' material regarding projection of pain into the great toe and into the heel in patients with disk herniation between LIV and LV, and between LV and SI, respectively.

Pain in association with cough and/or sneezing occured in 96 (46.6 %) of the present cases.

TABLE 4

Projection of pain

	Into the great toe	Into the heel	Uncertain	Total	Number of cases
L V—S I					
NORLÉN	4 %	35 %	61 %	100 %	46
WARIS	1 %	42 %	57 %	100 %	153
Author's group 1	5 %	20 %	75 %	100 %	60
L IV—L V					
NORLÉN	25 %	6 %	69 %	100 %	53
WARIS	21 %	17 %	62 %	100 %	129
Author's group 1	21.6 %	8.1 %	70.3 %	100 %	74

Clinical neurological examination

On clinical neurological examination of the patients, the following findings were made:

Changes in Achilles tendon reflex
48/60 80 %

I. *Weakness or absence of Achilles tendon reflex*

A. *Group 1*

a) *Disk herniation between LV and SI.* — Of the 60 cases of disk herniation between LV and SI, the achilles tendon reflex was weak or absent in 48. The weakness or absence of the Achilles tendon reflex was the only change in 25 cases, while

15 also had paresis of the great toe, and in 5 the patellar reflex was weak or absent. In the other 3 cases the weakness or absence of the Achilles tendon reflex was also accompanied by weakness or absence of the patellar reflex and paresis of the great toe.

b) *Disk herniation between LV and LVI.* —. —

c) *Disk herniation between LIV and LV.* — Of the 74 cases of herniation of the disk between LIV and LV, the Achilles tendon reflex was weak or absent in 28. It was the only finding in 9, it was combined with weakness or absence of the patellar reflex as well as paresis of the great toe in 3, but only with paresis of the great toe in 15 and only with weakness or absence of the patellar reflex in 1. 28/74 37.8 %

d) *Disk herniation between LIII and LIV.* —. —

e) *Protrusion between LV and SI.* — Of the 11 cases of protrusion between LV and SI, the Achilles tendon reflex was weak or absent in 8. In 1 of these cases it was combined with weakness or absence of the patellar reflex and great toe paresis, and in 2 with paresis of the great toe, while in 5 it was the only finding. 8/11 72.7 %

f) *Protrusion between LIV and LV.* — Weakness or absence of the Achilles tendon reflex was the only finding in 1 case of the 14 cases of protrusion between LIV and LV, and it was combined with paresis of the great toe in 2 cases. 3/14 21.4 %

g) *"Negative" findings at operation.* — Of the 20 cases in which the findings at operation showed no disk pathology, weakness or absence of the Achilles tendon reflex was the only finding in 4, it was combined with paresis of the great toe in 3 and with weakness of the patellar reflex as well as paresis of the great toe in 1 case. 8/20 40 %

95/182 52.2 %

B. *Group 2.*

a) *Disk herniation between LV and SI.* — Of the 6 cases of disk herniation between LV and SI, the Achilles tendon reflex was weak or absent in 5. This weakness or absence of the Achilles tendon reflex was the only finding in 2, while it was combined with weakness of the great toe in 2 and with weak- 5/6

ness of the patellar reflex as well as weakness of the great toe in 1.

3/4 b) *Disk herniation between LIV and LV.* — Of the 4 cases of disk herniation between LIV and LV, the Achilles tendon reflex was weak or absent in 3. It was the only finding in 1 case, while in 1 it was combined with weakness of the great toe and in 1 with weakness of the patellar reflex.

1/1 c) *Disk herniation between LIII and LIV.* — Herniation at this level was seen in 1 case, and in that one the weakness of the Achilles tendon reflex was accompanied by paresis of the great toe and weakness of the patellar reflex.

3/3 d) *Protrusion between LV and SI.* — Of the 3 patients with protrusions between LV and SI, the Achilles tendon reflex was weak or absent in all. It was the only change in 2, while it was combined with weakness of the great toe in 1.

— e) *Protrusion between LIV and LV.* —.

1/1 f) *Protrusion between LIII and LIV.* — This was seen in 1 case. The Achilles tendon reflex was weak and was associated with ready fatigueability of the great toe and weakness of the patellar reflex.

2/3 g) *Adhesions between LV and SI.* — This was seen in 3 cases. In 2 of them, the Achilles tendon reflex was weak or absent and in both it was combined with weakness of the great toe.

1/2 h) *Adhesions between LIV and LV.* — This was seen in 2 cases. In 1 of them, the Achilles tendon reflex was absent and the great toe was weak.

1/2 i) *Adhesions between LIV and LV+LV and SI.* — Adhesions were seen in 2 cases. In 1 of them there was weakness of the Achilles tendon reflex and of the great toe.

1/1 j) *Negative finding at operation.* — This subgroup consisted of a single case. There was possibly slight weakness of the Achilles tendon reflex.

The literature on changes in the Achilles tendon reflex in

113/206 59.7 % patients with sciatica is abundant.

STERNBERG (1893) was probably the first to report a case of sciatica in which the Achilles tendon reflex was absent.

BABINSKI (1896) expressed the view that the absence of the Achilles tendon reflex in sciatica, was evidence of inflammation of the sciatic nerve in such cases.

BABINSKI, like BIRO (1897), reported areflexia in patients without measurable atrophy or weakness of the calf muscles. Likewise, the Achilles tendon reflex could be absent in patients with normal sensibility.

ACCORNEO (1914) also found that some cases, which appeared to be severe with muscular atrophy and sensibility disorders, showed normal Achilles tendon reflex, while others, which appeared to be slight cases showed areflexia.

How often is the Achilles tendon reflex absent in sciatica?

The frequency with which the Achilles tendon reflex has been found to be absent in sciatica due to intervertebral disk herniation varies somewhat from one author to another. As a rule, the authors did not state whether the reflex was weak or absent, and data on the site or level of the herniation in patients with areflexia are incomplete and scanty.

For example, LOVE & WALSH (1938) stated that the reflex was weak or absent in 57 % of their cases, and in 1940 the same authors gave 60 %. BRADFORD & SPURLING (1939) found the reflex to be weak or absent in 15 of 35 cases. In 10 of these cases, the herniation was located between LV and SI, and in 5 between LIV and LV. BARR (1938) found the Achilles tendon reflex to be absent in 50 % of his cases and in 1941 BARR & MIXTER reported weakness or absence of the Achilles tendon reflex in 70 % of their cases. PENNYBACKER found the Achilles tendon reflex to be normal in only 5 of his 28 cases, but on analysis of his series it will be seen that he had 23 cases of herniation of the disk between LV and SI, and only 5 between LIV and LV. In 1942 SJÖQVIST found the Achilles tendon reflex to be absent in 12 and weak in 5 of a total of 17 cases of herniation of the disk between LV and SI. In 4 cases of disk herniation between LIV and LV, 2 had a normal Achilles tendon reflex, and in 2 it was weak. In MALMROS' series of 90 cases, areflexia was noted in 38 (bilateral in 11) and weakness in 18.

WIBERG (1943) found the Achilles tendon reflex to be un-

changed in 31 cases, weak in 15 and absent in 22 of 68 cases of herniation of the disk between LIV and LV, while in 69 cases of disk herniation between LV and SI, the Achilles tendon reflex was unchanged in 12, weak in 15 and absent in 42. SPURLING & BRADFORD (1939) and SPURLING & GRANTHAM (1940) claimed that weakness or absence of the Achilles tendon reflex is suggestive of herniation of the disk between LV and SI. They claim that it is a sign of an affection of the root of SI to which the Achilles tendon reflex is believed to be linked. DANDY (1941) wrote that weakness of the reflex suggests affection of the 4th lumbar disk, even though the 5th disk may be injured.

FOERSTER, OPPENHEIM, DEJERINE and others believe that the Achilles tendon reflex is linked to the 5th lumbar and 1st and 2nd sacral roots.

According to ACCORNEO, the centre of the Achilles tendon reflex is situated at the level of the 5th lumbar segment, while ELSBERG and BRAIN write that the centre of the Achilles tendon reflex is situated in the 1st and 2nd sacral segments. FOERSTER resected the posterior part of the 5th lumbar and 1st sacral roots, of the 1st and 2nd sacral roots, and of the 5th lumbar and 2nd sacral roots, respectively, and found that only 1 of these roots needs to be intact in order to preserve the reflex. These experiments were, however, carried out on spastic patients in whom the reflex irritability is increased. And FOERSTER (1936) writes that he cannot say whether or to what extent this may hold for normals.

NORLÉN (1944) in a series of 99 herniations of the 2 lowest lumbar disks found the Achilles tendon reflex to be absent in 34 (bilateral in 4) and to be weak in 32. Of 53 cases of disk herniation between LIV and LV, the Achilles tendon reflex was absent in 7 and weak in 15, and in 46 cases of herniation between LV and SI, the Achilles tendon reflex was absent in 27 and weak in 14.

NORLÉN in an experimental investigation blocked the 5th lumbar and 1st and 2nd sacral roots, 1 at a time, with novocaine at operation. He obtained the following results:

1. Blocking of the SI-root alone was followed by loss of Achilles tendon reflex in 40 cases studied.

2. Blocking of the LV-root alone had no effect on the Achilles tendon reflex in 17 cases studied. In 9 cases, subsequent blocking of the SI-root produced a prompt disappearance of the Achilles tendon reflex.

3. Blocking of the SII-root alone produced no effect on the Achilles tendon reflex in 9 cases studied. In 5, subsequent blocking of the SI-root was promptly followed by disappearance of the Achilles tendon reflex.

4. Blocking of the LV- and SII-roots produced none or only a slight weakening of the reflex in 7 cases studied. Subsequent blocking of the SI-root was promptly followed by disappearance of the Achilles tendon reflex in all these cases.

5. Blocking of the SI-root was follwed by a marked weakening but not absence of the reflex in 2 cases studied.

6. Blocking of the SI-root had no effect on the Achilles tendon reflex but subsequent blocking of the LV-root resulted in absence of the Achilles tendon reflex in 2 patients studied.

WARIS (1948) reported that of 374 cases of disk herniation, changes in the Achilles tendon reflex were noted in 275 (74 %), absence in 176 (47 %), weakness in 99 (26 %), and in 98 (26 %) the reflex was normal.

The following tables give a comparison of the results obtained in previous investigations and in the present study.

TABLE 5

Changes in the Achilles tendon reflex

	Absent %	Weak %	Total %	Number of cases
1941 CRAIG & WALSH	—	—	60	285
1941 LOVE & WALSH	—	—	59	185
1941 BARR & MIXTER	—	—	70	139
1941 FRIBERG	37	31	68	44
1942 MALMROS	45	19	64	100
1944 NORLÉN	35	32	67	99
1945 PETIT-DUTAILLIS & DE SÈZE	24	43	67	45
1948 WARIS	47	26	73	374
1949 RÖVIG	—	—	49	100
1961 Author's group 1	19.2	33	52.2	182
1961 Author's entire material	20.4	34.5	54.9	206

TABLE 6

Changes in the Achilles tendon reflex

(According to different authors)

	Absent %	Weak %	Total %	Number of cases
Disk herniation between L V and S I				
1941 CRAIG & WALSH	—	—	68	*
1942 MALMROS	—	—	70	37
1943 WIBERG	60	23	83	69
1944 NORLÉN	57	32	89	46
1948 STÅHL	31	25	56	167
1948 WARIS	70	24	94	153
1951 FRIBERG & HULT	—	—	80	124
1958 KNUTSSON & WIBERG	—	—	83	133
1961 Author's group 1	38.3	41.7	80	60
1961 Author's entire material	39.4	40.9	80.3	66
Disk herniation between L IV and L V				
1941 CRAIG & WALSH	—	—	37	*
1942 MALMROS	—	—	58	50
1943 WIBERG	32	22	54	68
1944 NORLÉN	13	28	41	53
1948 STÅHL	6	10	16	117
1948 WARIS	25	25	50	129
1961 Author's group 1	10.8	27	37.8	74
1961 Author's entire material	12.8	26.9	39.7	78

* In a series of cases, in which the number of herniations in the different interspaces not is given.

Changes in patellar reflex

II. *Weakness or absence of patellar reflex*

A. *Group 1.*

9/60 15 % a) *Disk herniation between LV and SI.* — The patellar reflex was changed in association with a change in the Achilles tendon reflex in 5 cases, and together with weakness of the great toe in 1, and in combination with both of these changes in 3 patients with herniation in the lumbosacral space.

b) *Disk herniation between LV and LVI.* — This was seen in 1 case and here a weakness of the patellar reflex was accompanied by a weakness of the great toe.	1/1	100 %
c) *Disk herniation between LIV and LV.* — The patellar reflex was weak or absent in combination with weakness or absense of the Achilles tendon reflex in 1 case, in combination with paresis of the great toe in 5 cases and in combination with both in 3 cases.	9/74	12.2 %
d) *Disk herniation between LIII and LIV.* — This was noted in 2 cases in which a change in the patellar reflex was the only finding.	2/2	100 %
e) *Protrusion between LV and SI.* — The patellar reflex was changed in 1 case and then in combination with change of the Achilles tendon reflex and weakness of the great toe.	1/11	9.1 %
f) *Protrusion between LIV and LV.* — The patellar reflex was changed in combination with weakness of the great toe in 1 case.	1/14	7.1 %
g) *"Negative" findings at operation.* — A change in the patellar reflex was the only finding in 2 cases, it was seen in association with weakness of the great toe in 4 and in combination with a changed Achilles tendon reflex and weakness of the great toe in 1.	7/20	35 %
	30/182	16.5 %

B. *Group 2.*

a) *Disk herniation between LV and SI.* — Of the 6 cases of herniation between LV and SI, the patellar reflex was weak in 1 and was then combined with absence of the Achilles tendon reflex and weakness of the great toe.	1/6	
b) *Disk herniation between LIV and LV.* — Of the 4 cases of herniation of the disk between LIV and LV, the patellar reflex was absent in 1 and was then combined with absence of the Achilles tendon reflex.	1/4	
c) *Disk herniation between LIII and LIV.* — This was seen in 1 case and in this a weakness of the patellar reflex was accompanied by a weakness of the great toe as well as a weakness of the Achilles tendon reflex.	1/1	
d) *Protrusion between LV and SI:* —.	—	

— e) *Protrusion between LIV and LV:* —.

1/1 f) *Protrusion between LIII and LIV.* — This was seen in 1 case and here a weakness of the patellar reflex was accompanied by a weakness of the great toe as well as a weakness of the Achilles tendon reflex.

— g) *Adhesions between LV and SI:* —.

— h) *Adhesions between LIV and LV:* —.

— i) *Adhesions between LV and SI+LIV and LV:*

— j) *Negative findings:* —.

34/206 16.5 % Only scanty data are available in the literature on the weakness or absence of the patellar reflex in sciatica or in disk herniation between LIV and LV and LV and SI. WIBERG (1943) reported weakness of the patellar reflex in 13 cases and absence in 1 of 137 cases of disk herniation of the 2 lowermost lumbar intervertebral disks.

Herniations between LIII and LIV are very uncommon in the various series on record, but it was pointed out that the patellar reflex was absent or may have been weak in these cases (SPURLING & GRANTHAM 1940, CRAIG & WALSH 1941). WIBERG (1943) reported unchanged patellar reflex in 2 cases and weakness of the reflex in 1 of a total of 3 cases of herniation between LIII and LIV.

In NORLÉN's (1944) series of 115 cases of sciatica, the patellar reflex was weak in 5. In 3 the herniation was situated between LIV and LV, and 2 between LV and SI. In 2 cases of disk herniation between LIII and LIV, the patellar reflex was weak.

It has been claimed that the pathways of the patellar reflex run through the 2nd, 3rd and 4th lumbar roots. (FOERSTER, OPPENHEIM, DEJERINE and ELSBERG). It is therefore quite understandable why the patellar reflex is changed in the presence of disk herniation between LIII and LIV where it is mainly the LIV-root that is exposed to compression. SHERRINGTON showed this as early as 1893 in experiments on Macacus Rhesus.

In operations for arthrosis deformans coxae, in which the sensible part of the LIV-root was cut off, the patellar reflex was, as a rule weak and, in some cases, it even disappeared

completely. (VON REIS, SAHLGREN and SJÖQVIST 1943, NORLÉN 1944).

WARIS (1948) observed distinct changes of the patellar re-

TABLE 7

Changes in the patellar reflex
(According to different authors)

	Absent %	Weak %	Total %	Number of cases
1942 MALMROS	1	8	9	90
1943 WIBERG	1	10	11	140
1944 YASKIN & FINKELSTEIN	—	—	18	50
1945 BRADFORD & SPURLING	—	—	>10	—
1948 WARIS	2	5	7	374
1961 Author's group 1	2.2	14.3	16.5	182
1961 Author's entire material	2.4	14.1	16.5	206

TABLE 8

Changes in the patellar reflex

	Herniation between L III and L IV	Herniation between L IV and L V	Hernition between L V and S I
1941 CRAIG & WALSH[1]	49 %	20 %	9 %
1942 MALMROS	—	16 % (8/50)	—
1943 WIBERG	33 % (1/3)	10 % (14/137)[2]	
1944 NORLÉN	100 % (2/2)	3/?	2/?[3]
1948 WARIS absent	43 % (3/7)	3 % (4/129)	1 % (1/153)
„ weak	57 % (4/7)	3 % (4/129)	5 % (8/153)
„ total	100 % (7/7)	6 % (8/129)	6 % (9/153)
1961 Author's group 1			
absent	—	2.7 % (2/74)	—
weak	100 % (2/2)	9.5 % (7/74)	1.7 % (1/60)
total	100 % (2/2)	12.2 % (9/74)	1.7 % (1/60)
1961 Author's entire material			
absent	—	3.8 % (3/74)	—
weak	100 % (3/3)	9 % (7/78)	3 % (2/66)
total	100 % (3/3)	12.8 % (10/78)	3 % (2/66)

[1] In a series of 449 cases, the level of the herniations not given.
[2] 4th and 5th interspace jointly.
[3] In a series of 115 cases, the level of the herniations not given.

flex in 27 (7 %) of his patients. The reflex was absent in 9 and weakened in 18. WARIS stated that nothing definite can be said about the inconstant changes of the patellar reflex and BRADFORD & SPURLING arrived at the same conclusion.

The results reported by previous authors and those found in the present investigation are compared below.

Weakness or paralysis of the great toe

III. *Weakness or paralysis of the great toe*

A. *Group 1.*

28/60 46.7 % a) *Disk herniation between LV and SI.* — Paralysis or weakening of the great toe occurred in 28 cases of 60 cases of disk herniation between LV and SI. In 3 of these the change was accompanied by changes in the patellar and Achilles tendon reflexes, in 1 case together with a changed patellar reflex and in 15 together with a changed Achilles tendon reflex, while weakness of the great toe was the only finding in 9 cases.

1/1 100 % b) *Disk herniation between LV and LVI.* — 1 case, and then there was weakening of the great toe in combination with slight weakness of the patellar reflex.

56/74 75.7 % c) *Disk herniation between LIV and LV.* — In the 74 cases of disk herniation between LIV and LV, weakness of the great toe was the only finding in 33, it was combined with changes in the Achilles tendon reflex in 15, with changes in the patellar reflex in 5, and in combination with changes in the patellar reflex and the Achilles tendon reflex in 3.

— d) *Disk herniation between LIII and LIV:* —.

5/11 45.5 % e) *Protrusion between LV and SI.* — Weakness of the great toe was the only finding in 2 cases, it was seen in combination with changes of the patellar reflex as well as the Achilles tendon reflex in 1, and in combination with a change in the Achilles tendon reflex only in 2.

10/14 71.4 % f) *Protrusion between LIV and LV.* — Weakness of the great toe was the only finding in 7 cases and was seen in combination with a change in the Achilles tendon reflex in 2, and with a change in the patellar reflex in 1.

10/20 50 % g) *"Negative" findings at operation.* — Weakness of the great toe was the only finding in 2 cases, it was seen in combination

110/182 60.4 %

with a change in the patellar reflex as well as in the Achilles tendon reflex in 1, in combination with the patellar reflex only in 4 and in combination with the Achilles tendon reflex only, in 3.

B. *Group 2.*

a) Of the 6 cases of *herniation between LV and SI*, weakness of the great toe was noted in 4. In 1 of them this was the only change, it was seen in combination with weakness of the Achilles tendon reflex in 2, and in 1 the patellar reflex was weak and the Achilles tendon reflex was absent. 4/6

b) In the 4 cases of *disk herniation between LIV and LV*, there was weakness of the great toe in 2. In 1 of them it was the only change and in 1 it was associated with weakness of the Achilles tendon reflex. 2/4

c) *Disk herniation between LIII and LIV.* — This was seen in only 1 case and here a paresis of the great toe was associated with a weakness of the patellar reflex as well as a weakness of the Achilles tendon reflex. 1/1

d) *Protrusion between LV and SI.* — Of the 3 protrusions between LV and SI, there was weakness of the great toe in 1 and then associated with a weakness of the Achilles tendon reflex. 1/3

e) *Protrusion between LIV and LV.* — This was seen in 1 case and then weakness of the great toe was the only finding. 1/1

f) *Protrusion between LIII and LIV.* — Protrusion at this level was noted in only 1 case and here a weakness of the great toe was combined with weakness of the patellar- as well as the Achilles tendon reflexes. 1/1

g) *Adhesions between LV and SI.* — Of these 3 cases, 2 showed weakness of the great toe as well as a changed Achilles tendon reflex. 2/3

h) *Adhesions between LIV and LV.* — There were 2 cases and in both there was weakness of the great toe, in combination with absence of the Achilles tendon reflex in 1 of them and as the only finding in 1. 2/2

i) *Adhesions between LIV and LV+LV and SI.* — There 2/2

were 2 cases and in both there was weakness of the great toe which was combined with weakness of the Achilles tendon reflex in 1.

—

j) *Negative findings:* —.

126/206 61.2 %

It appears that less importance was attached to paresis in sciatica until a relatively long time after MIXTER & BARR had described the causal relation between disk herniations and sciatica.

In 1890 GUINON & PARMENTIER reported a number of cases with loss of local motor symptoms particularly in the form of paresis and atrophy of the dorsal flexor tendons of the foot and toes.

EKVALL (1939) called attention to the fact that paresis of the dorsal flexors of the great toe is by no means uncommon in sciatica.

SPURLING & GRANTHAM (1940) pointed out that in sciatica due to disk herniation paresis of certain groups of muscles have been observed but one had not made any detailed study of these cases.

SJÖQVIST (1942) writes that in 1 of his cases he found paresis of the dorsal flexors of the great toe. In that case the disk herniation was between LIV and LV.

MALMROS (1942) observed that of his 90 patients, 5 had fairly severe paresis of the dorsal flexors of the foot and great toe, and that 1 case had isolated paresis of the dorsal flexors of the great toe. In all of these patients the herniation was situated between LIV and LV. MALMROS did not draw any far-reaching conclusions from this observation concerning the site of the herniation.

The significance of paresis of the great toe has been stressed, above all, by NORLÉN (1944). He found such paresis in more than 25 % of patients with herniation of the disk between LIV and LV. The corresponding figure in WARIS' (1948) material was 22 % (+uncertain weakness in a further 7 %), and STÅHL (1948) gave 45 % and RÖVIG (1949) 47 %. FRIBERG & HULT (1951) reported 48 % and KNUTSSON & WIBERG (1958) 71 %.

In the present group 1, weakness of the great toe was seen

in 56 (75.7 %) of the 74 cases of disk herniation between LIV and LV.

These figures, 71 % and 75.7 %, respectively, appear very high, but in this series the strength of the dorsal flexors of the great toe was tested very carefully. The patient was thus instructed to bend the great toe, not only a few times but 10—15 times, and in this way it was possible to note any fatigability on the affected side, which is a satisfactory sign for diagnosing weakness of the muscles.

In cases of disk herniation between LV and SI WARIS found a weakness of the great toe in 7 %, STÅHL in 5.4 % and RÖVIG in 12 %, while, in the present material, it was found with such a high frequency as 46.7 % (28/60). Of these cases, however, weakness of the great toe in 19 was combined with reflex changes, and thus weakness of the great toe was the only clinical finding in lumbo-sacral disk herniation in 9 (15 %). (These cases are discussed further in the chapter on "Correlation with operative findings".)

Paresis and atrophy of musc. exst, dig. brev. have been described by KUGELBERG & PETERSÉN (1950) as a common symptom in disk herniation between LIV and LV. In a series of 41 cases of disk herniation between LIV and LV, they found these symptoms in 35 (85 %) cases and weakness of the great toe in 46 % of the same cases.

As to the musc. exst. dig. brev. the atrophy was either clear (23 cases) or the consistency of the muscle on maximum contraction was softer than that of the contralateral foot (12 cases).

In 35 cases electromyography also showed signs of denervation of the muscle in question. The electromyographic findings agreed with the clinical picture in all cases except 2.

A corresponding examination of the present material showed atrophy+electromyographic denervation potentials in musc. exst. dig. brev. in 11 cases (14.9 %) of the 74 cases of herniation of the disk between LIV and LV in group 1.

Of the 25 cases of herniation of the disk between LV and SI KUGELBERG & PETERSÉN found atrophy of the musc. exst. dig. brev. in 2, and of the 60 with lumbosacral disk herniation

(group 1) in the present material, 9 were found to have atrophy and denervation of the musc. exst. dig. brev. This finding is discussed in further detail in the chapter on "Correlation with operative findings".

IV. *Impaired sensibility*

ROUSSET (1804) appears to have been the first to describe "sensory disturbances" in sciatica.

NOTTA (1854) studied these "sensory disturbances" in greater detail and stressed that they never involve the entire area of innervation but only irregular parts of it.

HUBERT-VALLEROUX (1870) claimed that sciatica always shows "sensory disturbances", but PHULPIN (1895) stated that although such disturbances are common, they are not constant accompaniments of sciatica. They are characterized by lack of uniformity.

DUBARRY (1902) found impaired sensibility in 50 % of his cases.

PHULPIN pointed out that in a number of cases in which the anaesthesia coincided with the spread of one or more nervous branches, the underlying muscles innervated by the same nerve often atrophied.

LORTAT-JACOB & SABARÉANU (1904) showed that some cases of sciatica were accompanied by "sensory disturbances" of radicular distribution and suggested the term "sciatique radiculaire" as a particular form of the disease.

Many authors claim that this form of sciatica is very common (DEJERINE, WERTHEIM-SALOMONSON, LERI & SCHAEFFER, STURSBERG).

According to HELWEG (1920) those cases in which "sensory disturbances" occurred, the latter are localized to the area of supply of the larger or smaller cutaneous nerves and never to the area of the plexus or the roots.

In 1931 STENSTRÖM demonstrated the occurrence of "sensory disturbances" in 26 of 110 patients and showed that their spread coincided with the skin segments of the 1st and 2nd sacral root.

SAHLGREN in his series of 53 cases of sciatica (unoperated) found 21 to have "sensory disturbances" with radicular distribution corresponding to the 5th lumbar and 1st sacral root.

In cases of sciatica due to disk herniation, "sensory disturbances" have been described with varying frequency within the dermatome of the 5th lumbar and 1st sacral root. (FINCHER 84 %, BRADFORD & SPURLING 77 %, LOVE & WALSH 21 %, BARR & MIXTER 35 %) PENNYBACKER found sensory disorders in 21 cases out of 28. It was, above all, SPURLING & BRADFORD (1939) who pointed out the significance of the spread of impaired sensibility in the location of a lumbar disk herniation, and they claimed that knowledge of the extent of impaired sensibility was often enough to locate the level of the herniation.

MALMROS (1942), on the other hand, expressed the view that the level of the lesion cannot be determined on the basis of sensory disturbances.

NORLÉN (1944) found that it was difficult to outline the limits of the dermatome on clinical grounds only. NORLÉN arrived at the conclusion that: "if a patient with sciatica has impaired sensibility of the great toe or of the adjacent parts of the dorsum of the foot, it suggests disk herniation between LIV and LV".

Sensory disturbances

	According to different authors	
1940 LOVE & WALSH	21 %	
1941 BARR & MIXTER	35 %	(of 139)
1941 CRAIG & WALSH	57 %	(285/500)
1941 FRIBERG	64 %	(28/44)
1942 MALMROS	58 %	(52/90)
1944 NORLÉN	64 %	(63/99) on the basis of the subjective symptoms; objective findings in only 41 cases
1947 AITKEN & BRADFORD	59 %	(48/82) disk herniations
1947 —	44 %	(27/62) negative explorations
1948 WARIS	62 %	(224/374)
1949 RÖVIG	76 %	(76/100)
1961 Author's group 1	29.2 %	(53/182)
1961 Author's entire material	29.6 %	(61/206)

KEEGAN (1943) described distinct tracks of impaired sensibility in relation to the different nerve roots:

LIV-root: medial side of knee, medial side of tibia to great toe.

LV-root: lateral side of knee, antero-lateral part of lower leg, dorsum of foot and the 3 middle toes, lateral side of heel.

SI-root: lateral side of leg and foot out into the small toe.

Other authors were unable to confirm the exact limits and extent of these tracks of impaired sensibility.

FOERSTER's investigation of the skin dermatomes of the lumbar roots are cited for comparison:

"Das 5. Lumbaldermatom nimmt ebenfalls die Vorderseite des Unterschenkels ein, den gesamten Fussrücken und an der Plantarseite die mediale Hälfte der Fussohle, sowie die 1., 2. und 3. Zehe."

"Das erste Sakraldermatom nimmt die gesamte Planta pedis ein und erstreckt sich von hier an der Hinterseite, Aussen- und Innenseite des Unterschenkels empor; es greift auf die Dorsalseite der Zehen über."

NORLÉN (1944) found impaired sensibility in 41 of his 99 patients. In patients with herniation between LIV and LV NORLÉN found hypoaesthesia, particularly of the dorsum of the foot or in the big toe. In patients with herniation between LV and SI he found hypoaesthesia, particularly on the lateral side of the foot and the posterior of the calf.

In the present material impaired sensibility was noted as follows:

Impaired sensibility	
	A. *Group 1.*
17/60	28.3 % a) *Disk herniation between LV and SI:* of the 60 patients with lumbosacral disk herniations, 17 had impaired sensibility. Of these, the impairment was localized to the lateral aspect of the lower leg and/or foot in 10, to the dorsum of the foot and/or the lower leg in 4, to the heel in 1, to the dorsal part of the calf in 1 and to the dorsum of the foot and great toe in 1.
1/1	100 % b) *Disk herniation between LV and LVI:* Herniation at this

level was seen in 1 patient and then it was associated with impaired sensibility of the dorsum of the foot.

c) *Disk herniation between LIV and LV:* There were 74 patients of whom 21 had impaired sensibility; of the dorsum of the foot and of the great toe (6); of the dorsum of the foot and/or lower leg (5); of the lateral aspect of the lower leg and/or of the foot (9) and on the dorsal aspect of the calf (1). 21/74 28.4 %

d) *Disk herniation between LIII and LIV:* This group consisted of 2 patients, in 1 of whom impaired sensibility was noted and then on the medial side of the lower leg. 1/2 50 %

e) *Protrusion between LV and SI:* This lesion was noted in 11 patients and with impaired sensibility of the lateral side of the lower leg in 2 of them. 2/11 18.2 %

f) *Protrusion between LIV and LV:* This group consisted of 14 patients in whom impaired sensibility was noted of the lateral aspect of the lower leg and/or foot in 2, and of the foot and/or lower leg in 2. 4/14 28.6 %

g) *"Negative" findings:* This group comprised 20 patients with impaired sensibility in 7. In 3 the impairment was localized to the lateral side of the lower leg and/or foot, to the dorsum of the foot and/or leg in 3, and to the dorsum of the foot and great toe in 1. 7/20 35 %

53/182 29.2 %

B. *Group 2.*

a) *Disk herniation between LV and SI:* —. —

b) *Disk herniation between LIV and LV:* Of the 4 patients with disk herniation between LIV and LV, 3 had impaired sensibility, 2 of them of the lateral aspect of the lower leg and/or foot, and 1 of them of the medial side of the foot. 3/4

c) *Disk herniation between LIII and LIV:* Herniation at this level was seen in 1 patient and he had impaired sensibility of the lateral side of the foot. 1/1

d) *Protrusion between LV and SI:* Of 3 patients in this group 1 had impaired sensibility and then of the medial side of the lower leg. 1/3

e) *Protrusion between LIV and LV:* —. —

f) *Protrusion between LIII and LIV:* —. —

2/3 g) *Adhesions between LV and SI:* There were 3 patients with such adhesions, and 2 of them had impaired sensibility of the lateral side of the lower leg and/or foot.

— h) *Adhesions between LIV and LV:* —.

1/2 i) *Adhesions between LIV and LV and between LV and SI:* 2 patients showed such adhesions and 1 of them had impaired sensibility of the lateral side of the foot.

— j) *Negative findings:* —.

61/206 29.6 %

V. *Muscular atrophy*

As early as 1764 COTUGNO observed that patients with severe sciatica had pronounced muscular atrophy, and he claimed that this atrophy was due to compression of the nerve by increassing oedema of the nerve sheath.

VALLEIX (1841) expressed the view that such advanced muscular atrophy was very rare and that it occurred mainly in the serious cases, but he also observed that muscular atrophy was sometimes missing in severe cases but present in moderate cases.

LANDOUZY (1875) and FERNET (1878) distinguished 2 types of sciatica: Cases without atrophy were termed sciatic neuralgias. If muscular atrophy was present, it was regarded as a sign of the presence of true neuritis.

LANDOUZY described the atrophy as diffuse and involving all muscles, innervated by the sciatic nerve.

PETIT-DUTAILLIS & DE SÈZE found 24 of their 35 patients to have hypotension in association with atrophy (in 15 cases of the gluteal musculature, in 16 of the thigh and in 11 of the calf). In their opinion, sciatica due to disk herniation did not, as a rule, cause motor symptoms.

In their review of a series AITKEN & BRADFORD (1947) found atrophy of the leg in 57 % (55 of 97).

WARIS (1948), who measured the circumference of the middle of the thigh and the largest circumference of the calf found atrophy in 31 % (47/153) of patients with lumbosacral disk herniation. The corresponding figures for disk herniation between LIV and LV were 25 % (32/129).

RÖVIG (1949) found atrophy in as many as 87 %, while HANRAETZ (1959) found atrophy in only 4 %.

The occurrence of muscular atrophy in the present material is listed below:

	Muscular atrophy	
A. *Group 1.*		
a) *Disk herniation between LV and SI:* This group consisted of 60 patients, of whom 22 had muscular atrophy, 9 of the thigh and calf, 7 of the calf only and 6 of the thigh only.	22/60	36.7 %
b) *Disk herniation between LV and LVI:*	—	
c) *Disk herniation between LIV and LV:* Of the 74 patients in this group, 30 had muscular atrophy: 14 of both the thigh and the calf, 8 of the calf only, and 8 of the thigh only.	30/74	40.5 %
d) *Disk herniation between LIII and LIV:* There were 2 patients in this group, and 1 of them had atrophy of the thigh.	1/2	50 %
e) *Protrusion between LV and SI:* Of the 11 patients in this group, 5 had muscular atrophy: 2 of the calf only and 3 of the thigh only.	5/11	45.5 %
f) *Protrusion between LIV and LV:* This group consisted of 14 patients. 2 of them had atrophy of the calf only, and 2 of the thigh only.	4/14	28.6 %
g) *"Negative" findings:* Of the 20 patients in this group, 5 had atrophy of the thigh and calf, 1 of the calf only, and 4 of the thigh only.	10/20	50 %
	72/182	39.6 %
B. *Group 2.*		
a) *Disk herniation between LV and SI:* Of the 6 patients in this group, 1 had atrophy of the thigh and calf, 1 of the thigh only and 3 of the calf only.	5/6	
b) *Disk herniation between LIV and LV:* Of the 4 patients in this group, 1 had atrophy of the thigh and calf.	1/4	
c) *Disk herniation between LIII and LIV:*	—	
d) *Protrusion between LV and SI:* There were 3 patients with this lesion and 1 of them had atrophy of the thigh.	1/3	
e) *Protrusion between LIV and LV:* —.	—	
f) *Protrusion between LIII and LIV:* —.	—	

1/3 g) *Adhesions between LV and SI:* There was 1 patient with atrophy of the thigh and calf.

1/2 h) *Adhesions between LIV and LV:* Of the patients with this lesion 1 had atrophy of the thigh and calf.

1/2 i) *Adhesions between LV and SI+LIV and LV:* 2 patients had this lesion and 1 of them had atrophy of the thigh.

— j) *Negative findings:* —.

82/206 39.8 %

VI. *Lasègue's test*

It is clear from all publications on lumbar disk herniation that Lasègue's test is of decisive importance for the clinical diagnosis of the disease.

BARR & MIXTER (1941) in a series of 135 patients with lumbar disk herniation "usually" found Lasègue's sign positive. LOVE & WALSH (1940) found Lasègue to be positive in 84 % (480 cases), and CRAIG & WALSH (1941) have similar figures, namely, 81 % (285 cases).

FRIBERG (1941) found Lasègue's sign to be positive on one side in 34 % and on both sides in 59 % of his 44 cases.

RÖVIG (1949), whose series consisted of 100 cases, found Lasègue's sign to be positive in 98 %.

HANRAETZ (1959) found in a series from Ursula Clinic (number of cases not stated) that Lasègue's sign was positive in herniation of the lowermost disks in 94 % (also crossed in 46 %), and in herniation of the disk between LIII and LIV in 60 %.

In the present material, the results of Lasègue's test were as follows in Table 9.

Myelographic findings

All myelographic examinations were performed with water-soluble contrast medium (Abrodil, Contrast U) which was first used for myelography by ARNELL & LIDSTRÖM (1931). The method employed in the present investigation was that described by LINDBLOM (1946).

193 of the examinations were performed at the Roentgen-diagnostic Department II, University Hospital of Lund, and the remaining 13 in other hospitals, but the films taken in these

TABLE 9

Lasègue's test

Group 1	Negative	Positive	Bilat.	Crossed
Herniation L V—S I	2	58	26	14
„ L V—L VI	—	1	—	—
„ L IV—L V	3	71	39	19
„ L III—LIV	—	2	—	—
Protrusion L V—S I	—	11	9	4
„ L IV—L V	2	12	9	3
Negative findings	2	18	9	1
Group 2	2	22	10	2
Total	11	195	102	43

Total positive	94.7 %	Crossed	20.9 %
Unilateral	45.1 %	Total negative	5.3 %
Bilateral	49.5 %		

last mentioned 13 cases were re-examined at the Roentgen-diagnostic Department II, Lund, before operation.

In the evaluation of the cases, consideration was given mainly to the preoperative reports, but all films were checked for the present investigation in association with Dr. STEN CRONQUIST of the Department of Neurologic Roentgenology, Lund, and sometimes also with Associate-professor NORMAN.

The primary roentgenologic findings and the operative findings are summarized in Tables 10 and 11.

It is clear from Table 10 that in the 60 cases in which operation revealed disk herniation between LV and SI, the herniation had been diagnosed by myelography at the same level in 37 (61.7 %) cases. In 14 (23.3 %) of these 60 cases, myelography revealed no signs of a pathological condition, and in 9 (15 %) the myelogram was misleading (the misleading myelograms will be discussed in the chapter: "Correlation with operative findings").

In the 74 cases in which operation revealed disk herniation between LIV and LV, the herniation had been diagnosed by myelography in 69 (93.2 %), while it had failed to show herniation in 1 (1.4 %) and was misleading in 4 (5.4 %).

As to disk herniation between LIII and LIV (2) and LV and

TABLE 10

Group 1

Operative finding		Myelography positive							Myel. negative	Uncertain	Only thick L V—root	Only thick L IV—root	Technical mishap
		L V—S I	L V—L VI	L IV—L V	L III—L IV	L II—L III	L V—S I + L IV—L V	L III—L IV + L II—L III					
Diskherniation L V—S I	60	36	—	9	—	—	1	—	14	—	—	—	—
„ L V—L VI	1	—	1	—	—	—	—	—	—	—	—	—	—
„ L IV—L V	74	3	—	69	—	1	—	—	1	—	—	—	—
„ L III—L IV	2	—	—	—	2	—	—	—	—	—	—	—	—
Protrusion L V—S I	11	4	—	2	—	—	—	—	4	—	—	—	1
„ L IV—L V	14	1	—	8	—	—	1	—	3	1[1]	—	—	—
"Negative"	20	2	1	5	—	—	—	1	8	—	1	1	1
Total	182	46	2	93	2	1	2	1	30	1	1	1	2

[1] The contrast medium diffuses up high. The quality of the roentgenogram is therefore unsatisfactory. To the left, however, no root pocket is demonstrable at level of lumbosacral disk. At level of 4th disk the outline is somewhat irregular but does not allow of any definite interpentation.

TABLE 11

Group 2

Operative findings		Myelography positive			Myelography shows		Myel. neg.
		L V– S I	L IV–L V	L III–L IV	Postop. change L V–S I	Only S I–root thickened	
Diskherniation L V–S I	6	3	—	—	2	—	1
„ L IV–L V	4	—	4	—	—	—	—
„ L III–L IV	1	—	—	1 + (Postop. L IV–L V)	—	—	—
Protrusions L V–S I	3	—	1 postop. or diskherniation	—	1	1	—
„ L IV–L V	1	—	1	—	—	—	—
„ L III–L IV	1	—	—	1	—	—	—
Adhesions L V–S I	3	1	—	—	—	—	2
„ L IV–L V	2	—	2	—	—	—	—
„ L V–S I + L IV–L V	2	1 diskherniation + postop.	—	—	1	—	—
Negative	1	—	—	—	—	—	1
Total	24	5	8	2	4	1	4

LVI (1), the myelograms were correct. As to protrusion between LV and SI myelography showed a protrusion at the same level in 4 (36.4 %), at an erroneous level in 2 (18.2 %) and no herniation at all in 4 (36.4 %), while in 1 (9 %), myelography failed owing to a technical mishap.

In the examination of protrusion between LIV and LV myelography produced, as in herniation at this level, better results, namely, in 9 (64.3 %) cases of the 14 protrusions found at operation at this level, myelography showed protrusion at the same level. Myelography failed to reveal a herniation in 3 (21.4 %), it was misleading in 1 (7.1 %) and uncertain in 1 (7.1 %).

Of the 162 cases in group 1 in which at operation a disk herniation or protrusion was found, agreement was found between the myelographic findings and operative findings in 122 (75.3 %).

Among the 20 cases, in which operation failed to show any disk changes, myelography showed no signs of a pathological condition in 8 (40 %). Of the remaining 12 cases, myelography failed owing to a technical mishap in 1 (5 %) and was misleading in 11 (55 %). These cases are discussed in a subsequent chapter: "Correlation with operative findings."

Concerning the myelographic findings in group 2, the number of cases was small and therefore percentages will not be given.

Most authors have not compared the frequency of agreement and disagreement between the myelographic and operative findings at the various levels, but such a comparison can be made from the material of FRIBERG & HULT (1951), for example. The contrast medium used in that investigation was also Abrodil. Of 121 lumbosacral herniations, 96 (79.3 %) were demonstrated in the myelogram at the same level. HANRAETZ (1959) reported myelography to have shown disk herniation at correct level in 35 (60.3 %) of 58 cases of disk herniation at the lumbosacral space. But he used Lipiodol as a contrast medium. For the space between LIV and LV, FRIBERG & HULT reported agreement between the operative and myelographic findings in 116

(92.1 %) out of 126 cases, and HANRAETZ in a series in 54 (83.1 %) out of 65 cases. The figures in the material of FRIBERG & HULT are not quite comparable, because they have excluded 19 cases.

Most authors simply state how frequently operation confirmed the myelographic findings without stating anything about the level.

Of series examined myelographically with Abrodil, mention might be made of JOHANSSON's (1949) series of 111 cases, in which agreement was found between the myelographic and operative findings in 90 %.

WORINGER, THOMALSKE & BAUMGARTNER (1956) reported on a series of 346 cases. In 293 (98.3 %) cases out of 298 showing myelographic changes, operation confirmed the changes demonstrated by myelography (disk herniation in 93.2 %, other root compression in 5.1 %); of the 39 cases, in which myelography showed no signs of a pathological condition, operation revealed changes in 11 (28.2 %).

DEL BUONO (1957) described a series of 373 cases, in which a herniated disk found at operation was preoperatively diagnosed by myelography at the same level in 82.7 %. In 9.3 % the method failed to reveal changes afterwards found at operation, it showed a change but at the wrong level in 4.6 %, it showed a change that could not be confirmed at operation in 1.8 %, and it showed no signs of a pathological condition in 1.6 %, in which operation revealed no change either. In other words, good agreement was found between myelography and the operative findings in 84.3 %.

HIRSCH (1958) found positive myelograms to show changes which were confirmed at operation in 90 %, and by negative myelograms he had positive operative findings in 40 %.

FASSBENDER, HÄUSSLER & STÖSSEL (1958) reported agreement between the myelographic and operative findings in 88.6 % of 470 cases (Myelographic changes confirmed at operation in 97 %; negative myelography — positive findings at operation in 86 %).

KOLSTAD & SOLEM (1959), whose series consisted of 173

cases, found myelography to give correct findings in 155 (89.5 %), uncertain in 6 (3.5 %), it failed to show the lesion in 7 (4.1 %), and the findings could not be confirmed at operation in 5 (2.9 %).

Of series, in which myelography was performed with Pantopaque, mention might be made of FORD & KEY (1950) (206 cases), in which agreement was found between the myelographic and operative findings in 72.3 %, FORD, RAMSEY, HOLT & KEY (1952) (100 cases), in which agreement was found in 60 %, and finally LANSCHE & FORD (1960) (560 cases), in which the operative findings were in complete accord with the myelographic findings in 453 cases, giving an accuracy of 80.9 %.

As to the present material agreement was found between the operative findings and the examination findings in 71.4 % in group 1 and in 72.8 % of the entire present material. The corresponding figure for FRIBERG & HULT's series was 82.1 %.

On check examination of the roentgenograms, interest was focused particularly on 1) thickened nerve roots, 2) filling defects of nerve sheaths, 3) dislocated nerve roots. All of these changes have been discussed previously and described by NICHOLS & NOSIC (1940), BUNTS (1941), LEKSELL (1943), ARNELL (1944), STENSTRÖM (1948), JOHANSSON (1949), F. KNUTSSON (1951), WALK (1958) and DAUM, SMITH, WALKER, CHAPMAN & EVERSMAN (1959), and of course, they partly were noted even in the preoperative reports.

On careful examination for these 3 factors, 9 of the 14 myelograms originally regarded as normal were found to show disk herniation between LV and SI at the level of the change found at operation, the percentage of agreement between the operative finding of a disk herniation between LV and SI and the myelographic findings was thereby increased from 61.7 % to 76.7 %. The corresponding figures for disk herniation between LIV and LV were 93.2 % to 94.6 %; for protrusion between LV and SI, from 36.4 % to 54.5 %; and for protrusion between LIV and LV, from 64.3 % to 71.4 %. This increased the frequency of agreement between the positive operative findings and myelographic findings in group 1 from 75.3 % to 83.3 %.

The corresponding increase in agreement between all operative findings and myelographic findings for group 1 was from 71.4 % to 78.6 %, and for the entire material from 72.8 % to 79.6 %.

The frequency of thickened roots, filling defects of the root sheaths and dislocated roots in relation to the operative findings is accounted for below.

Myelogram. Check examination.

	Thickened SI-root	
A. *Group 1.*		
a) *Disk herniation between LV and SI:* Of the 60 cases of lumbosacral disk herniation, the SI-root was found to be thickened in 30. (In 1 of them the LV-root was also thickened.)	30/60	50 %
b) *Disk herniation between LV and LVI:* Thickened SI-root in 1 case.	1/1	100 %
c) *Disk herniation between LIV and LV:* Of these 74 cases of disk herniation, the SI-root was found to be thickened in 17 (18?) (6 of these cases also showed a thickened LV-root).	17(18?)/74	23 % (24.3 %?)
d) *Disk herniation between LIII and LIV:* —.	—	
e) *Protrusion between LV and SI:* Thickened SI-root in 3 of the 11 cases. (1 of the cases also had a thickened LV-root.)	3/11	27.3 %
f) *Protrusion between LIV and LV:* Of these 14 cases, 1 had a thickened SI-root (in this case also a thickened LV-root).	1/14	7.1 %
g) *"Negative" operative findings:* Of these 20 cases, the SI-root was found to be thickened in 2.	2/20	10 %

	Filling defect of root sheath SI	
A. *Group 1.*		
a) *Disk herniation between LV and SI:* 44 cases (also LV in 4 cases, and LIV and LV in 1 case).	44/60	73.3 %
b) *Disk herniation between LV and LVI:* Defect of root sheath SI in 1 case.	1/1	100 %
c) *Disk herniation between LIV and LV:* 9 cases (also LV in 8 cases).	9/74	12.2 %
d) *Disk herniation between LIII and LIV:* —.	—	
e) *Protrusion between LV and SI:* 6 cases (also LV in 1 case).	6/11	54.5 %
f) *Protrusion between LIV and LV:* 2 cases (also LV in these 2 cases).	2/14	14.3 %
g) *"Negative" operative findings:* 2 cases.	2/20	10 %

Dislocated SI-root

A. *Group 1.*

15/60 25 % a) *Disk herniation between LV and SI:* 15 cases (also SII in 2 cases). (In 5 cases only SII.)

1/1 100 % b) *Disk herniation between LV and LVI:* 1 case.

27/74 36.5 % c) *Disk herniation between LIV and LV:* 27 cases (also LV in 10 cases).

— d) *Disk herniation between LIII and LIV:* —.

4/11 36.4 % e) *Protrusion between LV and SI:* 4 cases.

1/14 7.1 % f) *Protrusion between LIV and LV:* 1 case (also LV).

1/20 5 % g) *"Negative" operative findings:* 1 case.

Thickened LV-root

A. *Group 1.*

3/60 5 % a) *Disk herniation between LV and SI:* 3 cases (also SI in 1 case).

— b) *Disk herniation between LV and LVI:* —.

24/74 32.4 % c) *Disk herniation between LIV and LV:* 24 cases (also SI in 6 cases).

— d) *Disk herniation between LIII and LIV:* —.

2/11 18.2 % e) *Protrusion between LV and SI:* 2 cases (also SI in 1 case).

3/14 21.4 % f) *Protrusion between LIV and LV:* 3 cases (also SI in 1 case).

1/20 5 % g) *"Negative" findings:* 1 case.

Filling defect of root sheath LV

A. *Group 1.*

9(8)/60 15 % (13.3 %) a) *Disk herniation between LV and SI:* 9 (8) cases (also SI in 4 cases, and LIV and SI in 1 case).

— b) *Disk herniation between LV and LVI:* —.

68/74 91.9 % c) *Disk herniation between LIV and LV:* 68 cases (also SI in 8 cases and LIV in 1 case).

— d) *Disk herniation between LIII and LIV:* —.

3/11 27.3 % e) *Protrusion between LV and SI:* 3 cases (also SI in 1 case).

10/14 71.4 % f) *Protrusion between LIV and LV:* 10 cases (also SI in 2 cases).

4/20 20 % g) *"Negative" findings:* 4 cases.

Dislocated LV-root

A. *Group 1.*

— a) *Disk herniation between LV and SI:* —.

— b) *Disk herniation between LV and LVI:* —.

c) *Disk herniation between LIV and LV:* 17 cases (also SI in 10 cases and LIV in 1 case).	17/74	23 %
d) *Disk herniation between LIII and LIV:* 1 case (also LIV).	1/2	50 %
e) *Protrusion between LV and SI:* —.	—	
f) *Protrusion between LIV and LV:* 2 cases (also SI in 1 case).	2/14	14.3 %
g) *"Negative" findings:* —.	—	
	Thickened LIV-root	
A. *Group 1.*		
a) *Disk herniation between LV and SI:* —.	—	
b) *Disk herniation between LV and LVI:* —.	—	
c) *Disk herniation between LIV and LV:* —.	—	
d) *Disk herniation between LIII and LIV:* —.	—	
e) *Protrusion between LV and SI:* —.	—	
f) *Protrusion between LIV and LV:* —.	—	
g) *"Negative" findings:* —.	—	
	Filling defect of root sheath LIV	
A. *Group 1.*		
a) *Disk herniation between LV and SI:* 1 case (also LIV and LV).	1/60	1.7 %
b) *Disk herniation between LV and LVI:* —.	—	
c) *Disk herniation between LIV and LV:* 1 case (also LV).	1/74	1.4 %
d) *Disk herniation between LIII and LIV:* 1 case.	1/2	50 %
e) *Protrusion between LV and SI:* —.	—	
f) *Protrusion between LIV and LV:* —.	—	
g) *"Negative" findings:* 1 case.	1/20	5 %
	Dislocated LIV-root	
A. *Group 1.*		
a) *Disk herniation between LV and SI:* —.	—	
b) *Disk herniation between LV and LVI:* —.	—	
c) *Disk herniation between LIV and LV:* 1 case (also LV).	1/74	1.4 %
d) *Disk herniation between LIII and LIV:* 1 case (also LV).	1/2	50 %
e) *Protrusion between LV and SI:* —.	—	
f) *Protrusion between LIV and LV:* —.	—	
g) *"Negative" findings:* —.	—	
	Thickened SI-root	
B. *Group 2*		
a) *Disk herniation between LV and SI:* 3 cases.	3/6	
b) *Disk herniation between LIV and LV:* —.	—	

— c) *Disk herniation between LIII and LIV:* —.
— d) *Protrusion between LV and SI:* —.
— e) *Protrusion between LIV and LV:* —.
— f) *Protrusion between LIII and LIV:* —.
— g) *Adhesions between LV and SI:* —.
h) *Adhesions between LIV and LV:* —.
1/2 i) *Adhesions between LV and SI+LIV and LV:* 1 case.
— j) *Negative findings:* —.

Filling defect of root sheath SI

B. *Group 2*

4/6 a) *Disk herniation between LV and SI:* 4 cases (also LV in 1 case).
2/4 b) *Disk herniation between LIV and LV:* 2 cases (also LV).
1/1 c) *Disk herniation between LIII and LIV:* 1 case (also LIV and LV).
2/3 d) *Protrusion between LV and SI:* 2 cases (also LV).
— e) *Protrusion between LIV and LV:* —.
— f) *Protrusion between LIII and LIV:* —.
— g) *Adhesions between LV and SI:* —.
— h) *Adhesions between LIV and LV:* —.
1/2 i) *Adhesions between LV and SI+LIV and LV:* 1 case (also LV).
— j) *Negative findings:* —.

Dislocated SI-root

B. *Group 2*

2/6 a) *Disk herniation between LV and SI:* 2 cases.
— b) *Disk herniation between LIV and LV:* —.
— c) *Disk herniation between LIII and LIV:* —.
— d) *Protrusion between LV and SI:* —.
— e) *Protrusion between LIV and LV:* —.
— f) *Protrusion between LIII and LIV:* —.
— g) *Adhesions between LV and SI:* (dislocated SII in 1 case).
— h) *Adhesions between LIV and LV:* —.
— i) *Adhesions between LV and SI+LIV and LV:* —.
— j) *Negative findings:* —.

Thickened LV-root

B. *Group 2*

— a) *Disk herniation between LV and SI:* —.

b) *Disk herniation between LIV and LV:* —. —
c) *Disk herniation between LIII and LIV:* —. —
d) *Protrusion between LV and SI:* 1 case. 1/3
e) *Protrusion between LIV and LV:* —. —
f) *Protrusion between LIII and LIV:* —. —
g) *Adhesions between LV and SI:* —. —
h) *Adhesions between LIV and LV:* —. —
i) *Adhesions between LV and SI+LIV and LV:* —. —
j) *Negative findings:* —. —

B. *Group 2* *Filling defect of root sheath LV*

a) *Disk herniation between LV and SI:* 1 case (also SI). 1/6
b) *Disk herniation between LIV and LV:* 4 cases (also SI in 2 cases). 4/4
c) *Disk herniation between LIII and LIV:* 1 case [also LIV and (SI)]. 1/1
d) *Protrusion between LV and SI:* 2 cases (also SI). 2/3
e) *Protrusion between LIV and LV:* —. —
f) *Protrusion between LIII and LIV:* (1) case (also LIV). (1)/1
g) *Adhesions between LV and SI:* 1 case. 1/3
h) *Adhesions between LIV and LV:* 2 cases. 2/2
i) *Adhesions between LV and SI+LIV and LV:* 1 case (also SI). 1/2
j) *Negative findings:* —. —

B. *Group 2* *Dislocated LV-root*

a) *Disk herniation between LV and SI:* —. —
b) *Disk herniation between LIV and LV:* 1 case. 1/4
c) *Disk herniation between LIII and LIV:* —. —
d) *Protrusion between LV and SI:* —. —
e) *Protrusion between LIV and LV:* —. —
f) *Protrusion between LIII and LIV:* —. —
g) *Adhesions between LV and SI:* —. —
h) *Adhesions between LIV and LV:* —. —
i) *Adhesions between LV and SI+LIV and LV:* —. —
j) *Negative findings:* —. —

Thickened LIV-root

B. *Group 2*

— a) *Disk herniation between LV and SI:* —.
— b) *Disk herniation between LIV and LV:* —.
1/1 c) *Disk herniation between LIII and LIV:* 1 case.
— d) *Protrusion between LV and SI:* —.
— e) *Protrusion between LIV and LV:* —.
— f) *Protrusion between LIII and LIV:* —.
— g) *Adhesions between LV and SI:* —.
— h) *Adhesions between LIV and LV:* —.
— i) *Adhesions between LV and SI+LIV and LV:* —.
— j) *Negative findings:* —.

Filling defect of root sheath LIV

B. *Group 2*

— a) *Disk herniation between LV and SI:* —.
— b) *Disk herniation between LIV and LV:* —.
1/1 c) *Disk herniation between LIII and LIV:* 1 case [also LV and (SI)].
— d) *Protrusion between LV and SI:* —.
— e) *Protrusion between LV and LIV:* —.
1/1 f) *Protrusion between LIII and LIV:* 1 case [also (LV)].
— g) *Adhesions between LV and SI:* —.
— h) *Adhesions between LIV and LV:* —.
— i) *Adhesions between LV and SI+LIV and LV:* —.
— j) *Negative findings:* —.

Dislocated LIV-root

B. *Group 2*

— a) *Disk herniation between LV and SI:* —.
— b) *Disk herniation between LIV and LV:* —.
1/1 c) *Disk herniation between LIII and LIV:* 1 case.
— d) *Protrusion between LV and SI:* —.
— e) *Protrusion between LIV and LV:* —.
— f) *Protrusion between LIII and LIV:* —.
— g) *Adhesions between LV and SI:* —.
— h) *Adhesions between LIV and LV:* —.
— i) *Adhesions between LV and SI+LIV and LV:* —.
— j) *Negative findings:* —.

The myelographic findings will be discussed further in the chapter: "Correlation with operative findings."

Electromyographic findings

In the present investigation a DISA electromyograph and concentric needle electrodes (DISA 13KO3) were used.

If a normal striated muscle is tested by electromyography during rest, no electric activity will be recorded. If, however, a skeletal muscle, for some reason or other, has been denervated, so-called denervation potentials will be recorded even from the resting muscle, approximately 18—21 days after the lesion responsible for denervation. These spontaneous abnormal action potentials appear with short duration and low voltage (0.5—3 msec. and 50—200 V). They are triphasic (the third phase is, however, of very small amplitude). At the same time, a characteristic high-pitched, clicking sound is heard in the loudspeaker. In addition to these denervation potentials, monophasic, so-called positive sharp waves, may be noted for the denervated musculature. (They are of 4—8 msec. duration.)

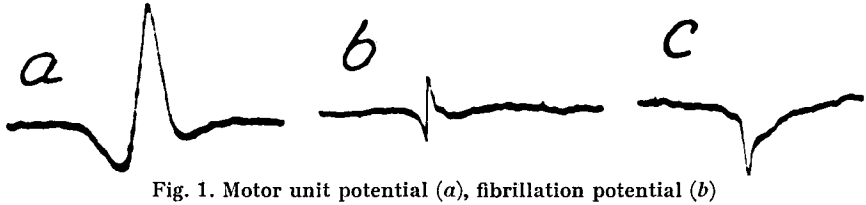

Fig. 1. Motor unit potential (*a*), fibrillation potential (*b*) positive denervation potential (*c*)

The following sources of error must be borne in mind:

a) On insertion of the electrodes or on movement of the electrodes, the electromyogram may show changes which can readily be confused with denervation potentials. This phenomenon is, however, of very short duration.

b) If the needle electrode happens to be inserted into one of the many fine nerve fibres extending through the muscle, false denervation potentials may be recorded. In such cases, however, the patient experiences severe pain.

It is sometimes necessary to insert the needle electrode several times into the muscle before denervation potentials are demonstrable. In the present investigation, a muscle examined by

electromyography was not said to be normal unless insertion of the needle at 36 different points had failed to show any denervation potentials. Three different electrodes were used for each muscle, and each electrode was inserted at 4 different sites and at 3 different depths at every site.

The examination was performed with the patient in a comfortable resting position on the examination table. The following muscles were studied in each patient: erector spinae, gluteus max. et med., tensor fascia lata, biceps femoris, quadriceps femoris, peroneus longus, extensor dig. long., extensor hallucis long., tibialis ant., soleus, the medial head of the gastrocnemius, the lateral head of the gastrocnemius and extensor dig. brev. The electromyographic examination was performed independently of, and without previous knowledge of, the clinical and myelographic examination. In other words, the examiner was not influenced by knowledge of earlier diagnostic findings.

Electromyographic localization of nerve root injury is based on the finding of denervation potentials in those muscles innervated by this particular nerve root and in no other muscles. In other words, even if an isolated muscle may have multiple nerve root innervation, it should show denervation potentials only together with the other muscles innervated by the same injured nerve root. Such a group of muscles is called a myotome.

SHEA, WOODS & WERDEN (1950) were the first to report the value of EMG as a diagnostic tool in the investigation of lumbar nerve root compression syndrome. Their report is based on 60 cases of lumbar nerve root compression syndrome. The operative findings in their material were as follows: LIV (tumour): 1, LV: 23, SI: 35, and negative operative findings: 1. In 55 of the cases, myelography (ethyl iodophenylundecylate) was performed. They compared the diagnostic possibilities of both electromyography and myelography and found the results of electromyography to coincide with those at operation in 90 % (54/60) and of myelography with 87.3 % (48/55).

In 1955 MARINACCI in his book "Clinical Electromyography"

reported on 150 operated lumbar disk herniations, which he examined electromyographically before operation. He gave the following results:

71 cases had disk herniation between LV and SI:

EMG showed:	SI	62 cases
	LV	5 „
	Normal	1 case (less than 14 days)
Myelography:	LV—SI	31 cases
	LIV—LV	4 „
	LV—SI+LIV—LV	2 „
	Normal	26 „
	No myelography	8 „

57 of them had disk herniation between LIV and LV:

EMG showed:	LV	48 cases
	LV+SI	5 „
	SI	2 „
	LIV	1 case
	Normal	1 „ (less than 14 days)
Myelography:	LIV—LV	38 cases
	LIV—LV+LV—SI	4 „
	LIII—LIV	2 „
	Opposite side	3 „
	No myelography	1 case

15 of them had disk herniation between LIV—LV+LV—SI:

EMG showed:	LV	6 cases
	SI	4 „
	LV+SI	5 „
Myelography:	LIV—LV	6 cases
	LV—SI	14 „
	LIV—LV+LV—SI	2 „
	Normal	2 „
	No myelography	1 case

3 of them had disk herniation between LIII and LIV:

EMG showed:	LIV+LV	2 cases
	LIII+LIV	1 case
Myelography:	LIII—LIV	2 cases
	LIII—LIV+LIV—LV	1 case

2 of them had spondylolisthesis of LV:

EMG showed:	LV+SI	2 cases
Myelography:	LIII—LIV	1 case
	Normal	1 „

2 patients had cauda equina tumours, EMG and myelography showed the same changes which were confirmed at operation in both cases.

SHEA & WOODS (1956) described 354 cases of spinal nerve root compression studied electromyographically and myelographically (Pantopaque in most cases) and in all cases operation was done later. The results are given below.

Root lesion found at operation	EMG		Myelography	
	Correct	Incorrect	Correct	Incorrect
L III—L IV (tumour)	1	0	1	0
L IV—L V	152	9	104	37
L V—S I	171	20	124	21
No lesion	1	0	—	—
Tolal	325 (91.8 %)	29	229 (79.8 %)	58
	354		287	

The series hitherto referred to thus showed very good agreement regarding the electromyographic findings. In 1957, however, CRUE, PUDENZ & SHELDEN described a material in which the results were not quite so good. They gave the following analysis of their 136 cases.

	Large extrusion or protrusion		Small protrusion	
	Correct localization	%	Correct localization	%
L V—S I 86 cases	68	cases	18	cases
Clinical.	57	84	15	83
EMG	56	82	14	77
Myel.	53	78	12	67
L IV—L V 50 cases	34	cases	16	cases
Clinical.	22	65	7	44
EMG	23	68	6	37
Myel.	30	88	13	81

Other authors who discussed electromyography as a diagnostic tool in the investigation of disk herniations are: BONNER & SCHMIDT (1957) who in 30 patients found an accuracy for electromyographic findings of 80 %, and MENDELSOHN & SOLA (1958) which in 45 cases found a correct electromyography in 89 %, incorrect in 7 % and normal in 4 %. In their material the myelograms were correct in 84 %, incorrect in 9 % and normal in 7 %. GOLSETH (1950), VON HAGEN (1955) only described the results in small materials (some single cases) and will therefore not be discussed further here.

Among these earlier investigators MARINACCI gave the following distribution of myotomes:

Muscle	Myotome
Quadriceps femoris Tibialis anterior Erector spinae (at the level of LIV—LV vertebrae)	L IV
Tibialis anterior Ext. hall. and dig. long. Lateral head of gastrocnemius The peroneal group Hamstrings Tensor fascia lata Gluteus med. Erector spinae (at the level of the lumbosacral interspace)	L V
Medial head of gastrocnemius Soleus Hamstrings Gluteus max. Erector spinae (at the level of SI—SII vertebrae) The peroneal group	S I

SHEA, WOODS & WERDEN and SHEA & WOODS used largely the same classification but did not test the erector spinae. CRUE, PUDENZ & SHELDEN, on the other hand, like MARINACCI, tested the erector spinae and also used largely the same myotome classification.

In the present investigation this schema was also adopted,

but with the following modifications. Of hamstrings only the biceps femoris was tested, of the peroneal group only the peroneus longus and as an addition the ext. dig. brev. (LV-innervated) was tested.

The findings made at this examination are given below:

SI-denervation

A. *Group 1.*

48/60 80 % a) *Disk herniation between LV and SI:* 48 cases (including 5 with LV and 2 with LIV).

— b) *Disk herniation between LV and LVI:* —.

20/74 27 % c) *Disk herniation between LIV and LV:* 20 cases (including 8 with LV).

— d) *Disk herniation between LIII and LIV:* —.

9/11 81.8 % e) *Protrusion between LV and SI:* 9 cases (including 2 with LV).

5/14 35.7 % f) *Protrusion between LIV and LV:* 5 cases (including 2 with LV).

8/20 40 % g) *"Negative" findings:* 8 cases (including 1 with LV).

LV-denervation

A. *Group 1.*

12/60 20 % a) *Disk herniation between LV and SI:* 12 cases (including 5 with SI).

1/1 100 % b) *Disk herniation between LV and LVI:* 1 case.

56/74 75.7 % c) *Disk herniation between LIV and LV:* 56 cases (including 8 with SI, and 1 with LIV).

— d) *Disk herniation between LIII and LIV:* —.

2/11 18.2 % e) *Protrusion between LV and SI:* 2 cases (both of them with SI).

11/14 78.6 % f) *Protrusion between LIV and LV:* 11 cases (including 1 with SI and 1 with LIV).

7/20 35 % g) *"Negative" findings:* 7 cases (including 1 with SI, and 1 with LIV).

LIV-denervation

A. *Group 1.*

2/60 3.3 % a) *Disk herniation between LV and SI:* 2 cases (both of them with SI).

— b) *Disk herniation between LV and LVI:* —.

1/74 1.4 % c) *Disk herniation between LIV and LV:* 1 case (with LV).

d) *Disk herniation between LIII and LIV:* 2 cases.	2/2	100 %
e) *Protrusion between LV and SI:* —.	—	
f) *Protrusion between LIV and LV:* —.	—	
g) *"Negative" findings:* 1 case (with LV).	1/20	5 %

B. *Group 2*	*SI-denervation*
a) *Disk herniation between LV and SI:* 6 cases (including 2 with LV).	6/6
b) *Disk herniation between LIV and LV:* 1 case.	1/4
c) *Disk herniation between LIII and LIV:* —.	—
d) *Protrusion between LV and SI:* 2 cases.	2/3
e) *Protrusion between LIV and LV:* —.	—
f) *Protrusion between LIII and LIV:* —.	—
g) *Adhesions between LV and SI:* 3 cases (including 1 with LV).	3/3
h) *Adhesions between LIV and LV:* —.	—
i) *Adhesions between LV and SI+LIV and LV:* 1 case (with LV).	1/2
j) *Negative findings:* —.	—

B. *Group 2.*	*LV-denervation*
a) *Disk herniation between LV and SI:* 2 cases (with SI).	2/6
b) *Disk herniation between LIV and LV:* 3 cases.	3/4
c) *Disk herniation between LIII and LIV:* 1 case (with LIV).	1/1
d) *Protrusion between LV and SI:* —.	—
e) *Protrusion between LIV and LV:* 1 case.	1/1
f) *Protrusion between LIII and LIV:* —.	—
g) *Adhesions between LV and SI:* 1 case (with SI).	1/3
h) *Adhesions between LIV and LV:* 2 cases (including 1 with LIV).	2/2
i) *Adhesions between LV and SI+LIV and LV:* 2 cases (including 1 with SI).	2/2
j) *Negative findings:* —.	—

B. *Group 2.*	*LIV-denervation*
a) *Disk herniation between LV and SI:* —.	—
b) *Disk herniation between LIV and LV:* —.	—

Herniated disks LIV—LV

(case 1495/58 LV—LVI)

Herniated disks LV—SI

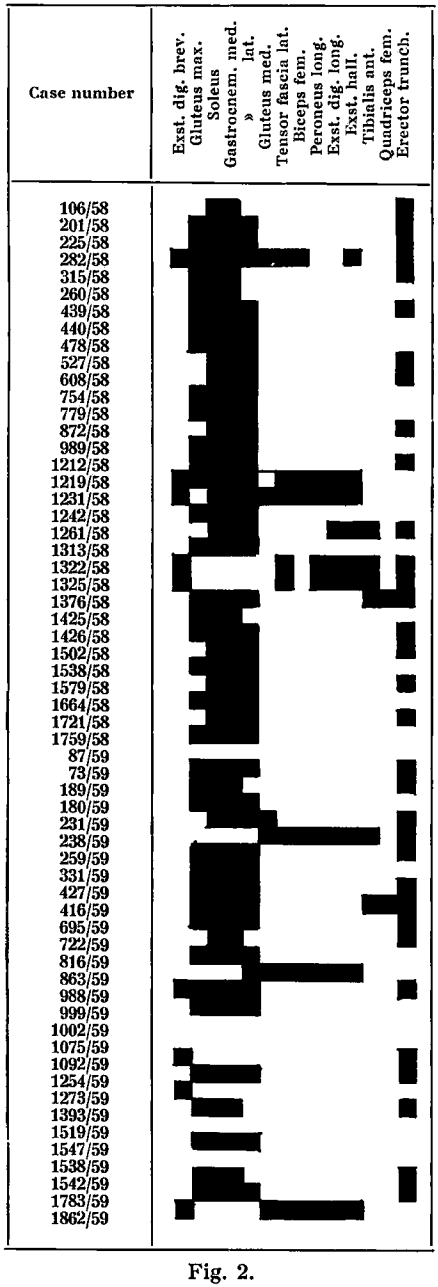

Fig. 2.

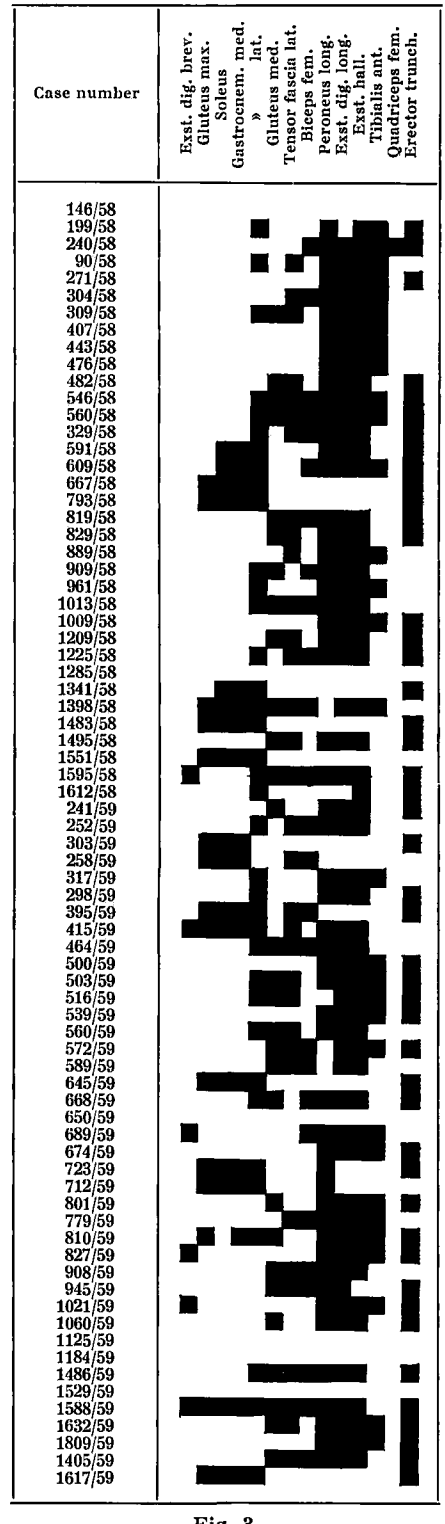

Fig. 3.

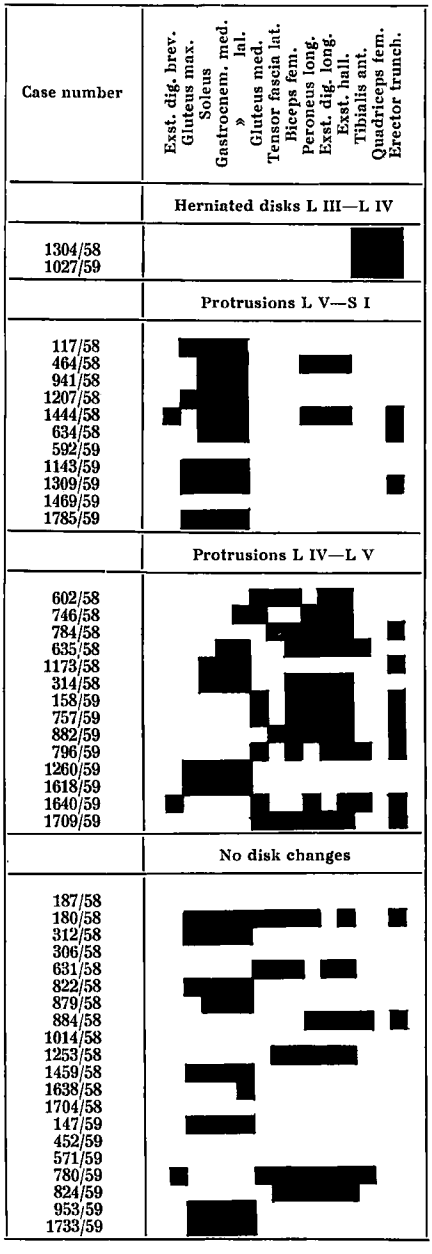

Fig. 4.

Group 2

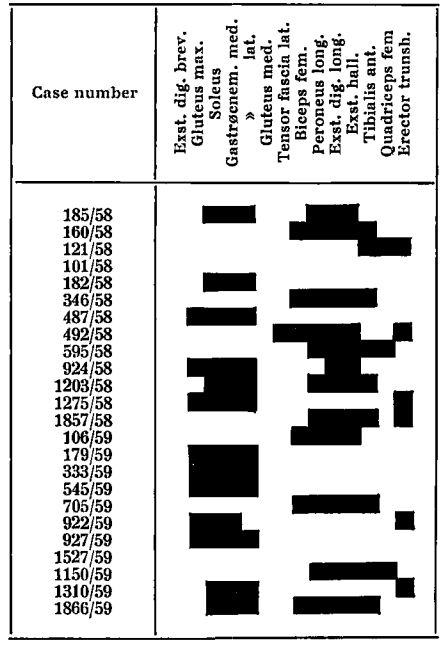

Fig. 5.

Black marks the occurence of denervation potentials in the muscle.

1/1 c) *Disk herniation between LIII and LIV:* 1 case (with LV).
— d) *Protrusion between LV and SI:* —.
— e) *Protrusion between LIV and LV:* —.
1/1 f) *Protrusion between LIII and LIV:* 1 case.
— g) *Adhesions between LV and SI:* —.
1/2 h) *Adhesions between LIV and LV:* 1 case (with LV).
— i) *Adhesions between LV and SI+LIV and LV:* —.
— j) *Negative findings:* —.

Figs. 2—5 show in which muscles denervation potentials were demonstrable.

The diagnostic results and the "incorrect" electromyograms are discussed in the next chapter.

Chapter IV

CORRELATION OF DIFFERENT DIAGNOSTIC METHODS WITH OPERATIVE FINDINGS

It is apparent from the description of the material in chapter III that projection of pain and impaired sensibility are of relatively little value in assessing the level of a lesion. Therefore, on comparison of the value of the various examination findings for assessing the level of lumbar root compression syndrome below, these two factors will be disregarded. This also applies to Laségue's test and muscular atrophy which, except for atrophy of musculus ext. dig. brev. is of no value in locating the level of a lesion.

As to the clinical-neurological examination, attention was thus given to reflex disorders and weakening or paralysis of the extensors of the great toe.

Below a comparison is made of the value of these clinical findings, of the primary myelographic findings and of the electromyographic findings, judged from the findings at operation. The results of the comparison are summarized in the tables below.

It is clear from Table 12 that lumbosacral disk herniation produced clinically and electromyographically demonstrable changes of SI in 80 %, while myelography gave a correct positive diagnosis in only 61.7 %. This is in agreement with earlier experiences and may be explained by the relatively large diameter of the spinal canal in the lumbosacral space. Of the cases of disk herniation between LIV and LV and revealed at operation, however, myelography gave correct information in 93.2 %, while clinical examination and electromyography suggested affection of LV in only 75.7 %.

As to protrusions, best agreement was found between electro-

TABLE 12

Operation findings	Clinical-neurological examination							
	Correct		Misleading		Normal		Correct	
	Number	%	Number	%	Number	%	Number	%
Diskherniation L V—S I	48	80	10	16.7	2	3.3	37	61.7
„ L IV—L V	56	75.7	10	13.5	8	10.8	69	93.2
„ L III—L IV	2	100	—	—	—	—	2	100
Protrusion L V—S I	8	72.8	2	18.2	1	9.1	4	36.4
„ L IV—L V	10	71.4	1	7.1	3	21.4	9	64.3
Total with positive operation findings	124	77	23	14.3	14	8.7	121	75.2
"Negative" findings	4	20	16	80	See correct	See correct	9	45
Total number of cases	128	70.7	39	21.5	14 (18)	7.7 (9.9)	130	71.8

myographic and operative findings: 81.8 % for lumbosacral protrusions and 78.6 % for protrusions between LIV and LV, while the corresponding figures for operative findings versus clinical-neurological findings were 72.8 % (LV and SI) and 71.4 % (LIV and LV), respectively, and for operative findings versus myelographic findings 36.4 % (LV and SI) and 64.3 % (LIV and LV), respectively.

In group 1 best agreement was found between the positive operative findings and electromyography, namely, 78.3 %, while the corresponding figure for the clinical-neurological examination was 77 % and for myelography 75.2 %.

The relatively low number of correct diagnostic results in the group in which operation revealed no signs of a pathological disk condition is due to the fact that the findings were classified as "negative" simply because they showed no disk changes. But it was only in 8 out of the 20 cases in which operation revealed no signs of a pathological condition. The other 12

A. *Group 1*

Myelography						Electromyography					
Misleading		Normal		Technical mishap		Correct		Misleading		Normal	
Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
9	15	14	23.3	—	—	48	80	7	11.7	5	8.3
4	5.4	1	1.4	—	—	56	75.7	12	16.2	6	8.1
—	—	—	—	—	—	2	100	—	—	—	—
2	18.2	4	36.4	1	9,1	9	81.8	—	—	2	18.2
2	14.3	3	21.4	—	—	11	78.6	3	21.4	—	—
17	10.6	22	13.7	1	0.5	126	78.3	22	13.7	13	8.1
10	50	See correct	See cerrect	1	5	6	30	14	70	See correct	See correct
27	14.9	22 (29)	12.2 (16.0)	2	1.1	132	72.9	36	19.9	13 (19)	7.2 (10.5)

showed root affection due to factors other than disk involvement, which is seen in Table 14.

It is therefore the figures in Table 14 that should be regarded as adequate.

With regard to the cases in group 2, myelography and electromyography agreed well with the findings made at operation. There was agreement in 91.7 %, while the corresponding figure for the clinical-neurological examination of these cases was 79.2 %.

It is clear from the description of the material that in many cases combined clinical-neurological findings, and likewise combined electromyographic findings were made. These findings are accounted for Tables 15 to 18.

The relation between unequivocal and combined clinical findings, respectively, and unequivocal and combined electromyographic findings, respectively, and the operative findings are given below.

TABLE 13

B. *Group 2*

Operative findings	Clinical-neurol. exam.			Myelography			Electromyography		
	Correct	Misleading	Normal	Correct	Misleading	Normal	Correet	Misleading	Normal
Disk herniation L V—S I	5	1	—	5	—	1	6	—	—
„ L IV—L V	2	2	—	4	—	—	3	1	—
„ L III—L IV	1	—	—	1	—	—	1	—	—
Protrusions L V—S I	3	—	—	3	—	—	2	—	1
„ L IV—L V	1	—	—	1	—	—	1	—	—
„ L III—L IV	1	—	—	1	—	—	1	—	—
Adhesions L V—S I	2	—	1	2	—	1	3	—	—
„ L IV—L V	2	—	—	2	—	—	2	—	—
„ L V—S I+ L IV—L V	2	—	—	2	—	—	2	—	—
Negative exploration	—	1	—	1	—	See correct	1	—	See correct
Total	19 (79.2 %)	4 (16.7 %)	1 (4.1 %)	22 (91.7 %)	—	2 (8.3 %) (3)	22 (91.7 %)	1 (4.2 %)	1 (4.2 %) (2)

TABLE 14

"Negative" operative findings (group 1)

Operative findings	Clinical-neurological examinations			Myelography				Electromyography		
	Correct	Mis-leading	Normal	Correct	Mis-leading	Normal	Technical mishap	Correct	Mis-leading	Normal
Negative explorations	2	6	See correct	6	2	See correct	—	3	5	See correct
Osteophytes	4	1	2	6	—	1	—	5	1	1
"Varices"	4	—	—	—	1	2	1	2	—	2
"Varices" + "narrow space"	1	—	—	1	—	—	—	1	—	—
Total	11 (55 %)	7 (35 %)	2 (10 %) (4)	13 (65 %)	3 (15 %)	3 (15 %) (7)	1 (5 %)	11 (55 %)	6 (30 %)	3 (15 %) (6)

TABLE 15

Operative findings group 1

Clinical	Disk herniation L V—S I	Disk herniation L V—L VI	Disk herniation L IV—L V	Disk herniation L III—L IV	Portrusions L V—S I	Protrusions L IV—L V	"Negative"	Total
Only one root affected								
S I	25	—	9	—	5	1	4	44
L V	9	—	33	—	2	7	2	53
L IV	—	—	—	2	—	—	2	4
Two roots affected								
S I+L V	15	—	15	—	2	2	3	37
S I+L IV	5	—	1	—	—	—	—	6
L V+L IV	1	1	5	—	—	1	4	12
Three roots affected								
S I+L V+L IV	3	—	3	—	1	—	1	8
No root affected								
0	2	—	8	—	1	3	4	18
Tolal	60	1	74	2	11	14	20	186

TABLE 16

Operative findings group 1

Electromyography	Disk herniation L V—S I	Disk herniation L V—L VI	Disk herniation L IV—L V	Disk herniation L III—L IV	Protrusions L V—S I	Protrusions L IV—L V	"Negative"	Total
Only one root affected								
S I	41	—	12	—	7	3	7	70
L V	7	1	47	—	—	9	5	69
L IV	—	—	—	2	—	—	—	2
Two roots affected								
S I+L V	5	—	8	—	2	2	1	18
S I+L IV	2	—	—	—	—	—	—	2
L V+L IV	—	—	1	—	—	—	1	2
Three roots affected								
S I+L V+L IV	—	—	—	—	—	—	—	—
No root affected								
0	5	—	6	—	2	—	6	19
Total	60	1	74	2	11	14	20	186

TABLE 17

Operative findings group 2

Clinical	Disk herniation L V—S I	Disk herniation L IV—L V	Disk herniation L III—L IV	Protrusions L V—S I	Protrusions L IV—L V	Protrusions L III—L IV	Adhesions L V—S I	Adhesions L IV—L V	Adhesions L V—S I + L IV—L V	Negative	Total
Only one root affected											
S I	2	1	—	1	—	—	—	—	—	1	5
L V	1	1	—	—	1	—	1	1	1	—	6
L IV	—	—	—	—	—	—	—	—	—	—	—
Two roots affected											
S I+L V	2	1	—	2	—	—	1	1	1	—	8
S I+L IV	—	—	—	—	—	—	—	—	—	—	—
L V+L IV	—	—	—	—	—	—	—	—	—	—	—
Three roots affected											
S I+L V+L IV	1	1	1	—	—	1	—	—	—	—	4
No root affected											
0	—	—	—	—	—	—	1	—	—	—	1
Total	6	4	1	3	1	1	3	2	2	1	24

TABLE 18

Operative findings group 2

Electromyography	Disk herniation L V—S I	Disk herniation L IV—L V	Disk herniation L III—L IV	Protrusions L V—S I	Protrusions L IV—L V	Protrusions L III—L IV	Adhesions L V—S I	Adhesions L IV—L V	Adhesions L V—S I + L IV—L V	Negative	Total
Only one root affected											
S I	4	—	—	2	—	—	2	—	—	—	8
L V	1	3	—	—	1	—	—	1	1	—	7
L IV	—	—	—	—	1	—	—	—	—	—	1
Two roots affected											
S I+L V	2	—	—	—	—	—	1	—	1	—	4
S I+L IV	—	—	—	—	—	—	—	—	—	—	—
L V+L IV	—	—	1	—	—	—	—	1	—	—	2
Three roots affected											
S I+L V+L IV	—	—	—	—	—	—	—	—	—	—	—
No root affected											
0	—	—	—	1	—	—	—	—	—	1	2
Total	7	3	1	3	2	—	3	2	2	1	24

A. *Group 1*

a) Disk herniation between LV and SI:

TABLE 19

Clinical	EMG					Total
	SI	SI+LV	SI+LIV	LV	Normal	
SI	19	2	2	1	1	25
SI+LV	11	1	—	2	1	15
SI+LIV	3	—	—	—	2	5
SI+LV+LIV	2	1	—	—	—	3
LV	3	1	—	4	1	9
LV+LIV	1	—	—	—	—	1
Normal	2	—	—	—	—	2
Total	41	5	2	7	5	60

It is clear from the table that in 41 out of 60 cases electromyography showed unequivocal evidence of a lesion of the SI-root and in 25 of 60 a similarly unequivocal clinical-neurological pattern of SI syndrome was seen. In only 19 cases was agreement found between the unequivocal diagnostic findings.

b) Disk herniation between LV and LVI: This herniation gave an unequivocal electromyographic pattern of affection of LV, while clinical-neurological examination indicated affection of both LIV and LV.

c) Disk herniation between LIV and LV:

TABLE 20

Clinical	EMG					Total
	LV	LV+SI	LV+LIV	SI	Normal	
LV	27	3	—	2	1	33
LV+SI	13	1	—	1	—	15
LV+LIV	3	—	1	—	1	5
LV+LIV+SI	1	1	—	1	—	3
SI	1	1	—	5	2	9
SI+LIV	—	—	—	1	—	1
Normal	2	2	—	2	2	8
Total	47	8	1	12	6	74

Thus electromyography had given an unequivocal diagnosis in 47 of the 74 cases of herniation found at operation between LIV and LV, the corresponding figure for the clinical-neurological examination being 33. There was agreement in 27 cases.

d) Disk herniation between LIII and LIV: In both cases clinical and electromyographic examination showed affection of LIV only.

e) Protrusions between LV and SI:

TABLE 21

Clinical	EMG			Total
	SI	SI+LV	Normal	
SI	3	—	2	5
SI+LV	1	1	—	2
SI+LV+LIV	—	1	—	1
LV	2	—	—	2
Normal	1	—	—	1
Total	7	2	2	11

f) Protrusions between LIV and LV:

TABLE 22

Clinical	EMG			Total
	LV	LV+SI	SI	
LV	6	—	1	7
LV+SI	1	1	—	2
LV+LIV	1	—	—	1
SI	—	—	1	1
Normal	1	1	1	3
Total	9	2	3	14

g_1) Negative explorations:

TABLE 23

Clinical	EMG				Total
	L V	S I	L V+S I	Normal	
L V	—	—	—	1	1
L IV+L V	—	—	—	1	1
L V+S I	1	—	1	—	2
S I	—	2	—	—	2
Normal	—	1	—	1	2
Total	1	3	1	3	8

g_2) Osteofytes or varices:

TABLE 24

Clinical	EMG				Total
	L V	S I	L IV+L V	Normal	
L IV	1	—	—	—	1
L V	1	—	—	1	2
L IV+L V	1	—	1	1	3
L IV+L V+S I	—	1	—	—	1
S I	—	2	—	—	2
L V+S I	1	—	—	—	1
Normal	—	1	—	1	2
Total	4	4	1	3	12

B. *Group 2*

a) Disk herniation between LV and SI:

TABLE 25

Clinical	EMG		Total
	S I	S I+L V	
S I	2	—	2
S I+L V	2	—	2
S I+L V+L IV	—	1	1
L V	—	1	1
Tolal	4	2	6

b) Disk herniation between LIV and LV:

TABLE 26

Clinical	EMG		Total
	LV	S1	
LV	1	—	1
LV+SI	1	—	1
LIV+SI	—	1	1
SI	1	—	1
Total	3	1	4

c) Disk herniation between LIII and LIV: There was 1 case which showed electromyographic affection of LIV+LV and of all 3 roots clinically.

d) Protrusion between LV and SI:

TABLE 27

Clinical	EMG		Total
	SI	Normal	
SI	1	1	2
SI+LV	1	—	1
Total	2	1	3

e) Protrusion between LIV and LV: 1 case with distinct affection of LV clinically as well as electromyographically.

f) Protrusion between LIII and LIV: 1 case with distinct electromyographic affection of LIV but clinically with affection of all 3 roots.

g) Adhesions between LV and SI:

TABLE 28

Clinical	EMG		Total
	SI	SI+LV	
SI+LV	1	1	2
Normal	1	—	1
Total	2	1	3

h) Adhesions between LIV and LV:

TABLE 29

Clinical	EMG		Total
	LV	LV+LIV	
LV	1	—	1
LV+SI	—	1	1
Total	1	1	2

i) Adhesions between LV and SI+LIV and LV:

TABLE 30

Clinical	EMG		Total
	LV	LV+SI	
LV	1	—	1
LV+SI	—	1	1
Total	1	1	2

j) Negative operative findings: 1 case, which gave a normal electromyogram, showed clinical sign of SI affection.

Some misleading diagnostic findings compared with the findings at operation occurred in all 3 diagnostic methods. They are discussed below.

I. GROUP 1. DISK CHANGES FOUND AT OPERATION

1) *Misleading clinical-neurological findings*

a) Disk herniation between LV and SI: In 9 of these 60 cases of disk herniation, weakness of the great toe was the only clinical finding.

In 4 of them there was a lateral disk herniation which affected the LV root (so-called lateral LV-syndrome, described among others by BRADFORD & SPURLING, 1939; CRAIG & WALSH, 1941; NORLÉN, 1944; HERRLIN, 1958). In all of these 4 cases electromyography also showed an LV affection (1 of the cases in combination with affection of SI). The myelogram was negative in 2 and showed a lesion between LV and SI in 1 and distally between LIV and LV in 1.

In the other 5 cases there was the usual type of lumbosacral disk herniation with affection of a root regarded as SI at operation. In all of these cases the vertebrae were counted and the number was found to be normal in all. Electromyography showed involvement of SI in 3 cases and normal finding in 1. In these 4 cases the weakness of the great toe *may* be explained by pain. In the 5th case the electromyogram, like the clinical findings, suggested affection of LV, while the myelogram was of normal appearance. The findings in this case may possibly be explained by an innervation anomaly.

Check examination of the myeolgram showed a thickened SI root and filling defect of the SI root sheath.

Finally, in 1 case clinical examination showed weakness of the patellar reflex and of the great toe, while EMG showed affection of SI root, and myelography indicated a lesion between LIV and LV. At operation a spontaneously perforated disk hernia was seen lumbo-sacrally and compressing an irritated and a thickened SI root. The disk between LIV and LV was empty and the herniation was certainly referable to this level. Four months had elapsed between myelography and the operation.

c) Disk herniation between LIV and LV: In 9 of the 74 cases of disk herniation between LIV and LV, the clinical-neurological finding was a changed Achilles tendon reflex (but no weakness of the great toe).

In 4 of these cases the disk herniation was very medial and could therefore satisfactorily explain the affection of the SI root. The only electromyographic finding was also affection of SI in 3 of these cases, while the electromyogram was of normal appearance in the 4th. In all 4 cases the myelogram showed a medial herniation between LIV and LV.

Also in the 5th case operation revealed a very medial disk herniation with compression of the SI root. Clinical examination of this case had, however, shown in addition to affection of SI, also involvement of LIV. Electromyography suggested involvement of the SI myotome and myelography showed a slight lumbosacral bulge.

In 1 case electromyography also showed SI denervation and

myelography indicated a lesion between LIV and LV. That patient had, however, 13 thoracic vertebraes.

In 1 case electromyography showed denervation fibrillation in LV as well as the SI myotome, myelography indicated a lesion between LIV and LV, and operation revealed a relatively large spontaneously perforated disk, which may have compressed any of the roots or both.

In the 2 remaining cases disk herniation was found at the usual site between LIV and LV. Myelography also indicated a lesion at this level. Electromyography, like the clinical examination, suggested affection of SI only in one of these cases, while in the other case the electromyogram was of normal appearance. The vertebrae were counted and found to be of normal number. In these cases then, no other explanation than innervation anomaly can be offered.

e) Protrusions between LV and SI: In 2 of these cases the only clinical-neurological finding was weakness of the great toe, while electromyography showed denervation in the SI myotome. This might be explained by the following assumption: Weakness of the great toe *may* have been due to pain, the compression of the SI root produced changes in the sensitive electromyogram but not any clinical signs.

f) Protrusions between LIV and LV: In 1 case with weakness of the Achilles tendon reflex as the only clinical finding, electromyography showed affection of SI. Operation revealed a protrusion with a very medial compression. The myelogram was negative.

2) *Misleading myelographic findings*

a) Disk herniation between LV and SI: In 9 cases myelography suggested herniation between LIV and LV, while operation revealed lumbosacral herniation.

In 1 of the cases 4 months had elapsed between myelography and operation, the disk had perforated spontaneously into the lumbosacral space, the disk between LIV and LV was empty, and the hernation had probably originated from this space.

In 1 of the cases the lumbosacral disk had herniated far out

laterally and affected the LV root and produced a myelographic change of the LV root and its sheath may be even up in the space between LIV and LV.

In the other 7 cases no explanation could be found at operation for the misleading findings.

c) Disk herniation between LIV and LV: In 3 cases myelography showed lumbosacral disk herniation: in 2 of them the herniation affected the SI root and thereby *might* have given the changed picture lumbosacrally: in the 3rd no explanation was found.

In 1 case myelography showed an inward bulge at the level of LIII. No explanation was available.

As to the protrusions, the myelogram was misleading in 2 cases of protrusion between LV and SI and in 2 between LIV and LV. Operation revealed no explanation for the changes.

3) *Misleading electromyographic findings*

a) Disk herniation between LV and SI: In 7 cases of lumbosacral disk herniation electromyography showed denervation fibrillation in the LV myotome.

In 4 of these cases the herniation was far laterally and pressed against the LV root. In these cases clinical examination had also suggested affection of LV (in 1 of the cases in combination with SI affection). In 2 cases the myelogram showed no changes suggestive of a pathological condition, in 1 it indicated a lesion between LV and SI and in 1 distally between LIV and LV (so-called lateral LV-syndrome).

In 1 of the cases the disk herniation was relatively far out laterally and affected the LV root as well as the SI root. Clinical examination revealed affection of SI and myelography showed changes between LV and SI.

In 1 case, No. 863/59, operation first revealed a vertical nerve root that was neither swollen nor irritated in the lumbosacral space. When the nerve was pricked, the patient reported pain in the dorsal part of the calf. Another nerve root running obliquely laterally downwards was also observed. This nerve root appeared to be swollen and irritated. When the nerve was

pricked, the patient complained of pain in the great toe. Lateral to this last mentioned nerve root and dislocating it medially, was a large (1.5 ml) disk herniation. In this case clinical examination had revealed weakness of the great toe and of the Achilles tendon reflex. The Achilles tendon reflex were, however, weak on both sides. The myelogram suggested a lumbosacral lesion.

In the 7th case electromyography as well as the clinical-neurological examination suggested an affection of LV. Myelography, however, showed no signs of a pathological condition. The disk herniation was found at the usual place lumbosacrally. Innervation anomaly was the only explanation available. (The number of the vertebrae was normal.)

c) Disk herniation between LIV and LV: In 12 of the patients with disk herniation between LIV and LV, electromyography showed denervation in the SI myotome.

In 9 of these cases the herniation was situated medially and pressed against the intradural SI root. Clinical examination showed affection of LV in 1 of the cases, affection of SI in 6 including 2 with combined neurological signs. In 2 cases neurological examination was normal. A medial disk herniation between LIV and LV affecting the SI root has been described by SHEA, WOODS & WERDEN (1950), CRUE, PUDENZ & SHELDEN (1957) and KNUTSSON (1958).

In 1 case clinical examination also showed SI affection and myelography indicated a lesion between LIV and LV. That patient had, however, 13 thoracic vertebraes.

In 1 case the disk herniation had perforated spontaneously and, according to the operator, it might very well have affected the SI root. Clinical examination had revealed weakness of the great toe.

In the 12th case clinical examination suggested affection of both LV and SI. Operation revealed changes only of the LV root. No explanation was found for the SI denervation and the clinical affection of SI.

f) Protrusions between LIV and LV: In 3 of these cases electromyography showed denervation of the SI myotome as the

only finding. In 2 of these cases operation revealed a definite affection of the SI root by medial pressure of the protrusion. The clinical examination in 1 case was normal, and the myelogram indicated changes between LIV and LV, in the 2nd case clinical examination suggested affection of SI, while the myelogram showed no lesions.

In the 3rd case clinical examination and myelography showed involvement of LV. The operation revealed a protrusion between LIV and LV with affection of the LV root, but lumbosacrally the interspace was narrow and thereby the SI root may have been affected.

II. GROUP 1. NO DISK LESIONS FOUND AT OPERATION

According to Table 14, there were among the "negative" findings 7 cases in which clinical neurological examination was misleading and 3 cases in which myelography and 6 cases in which electromyography had given misleading results.

On analysis of these cases it was found that 1 patient had weakness of the great toe and Achilles tendon reflex, electromyography had shown LV denervation, and myelography had suggested a lesion between LIV and LV, but no disk lesions were found at operation. At re-examination 1 year after operation, the patient felt better and the weakness of the great toe and denervation of LV had disappeared. There *may* therefore have been some pressure which was eliminated by the decompressive hemilaminectomy.

In 1 of the cases in which exploration revealed no disk changes electromyographic examination had shown denervation of the SI myotome, while the clinical-neurological examination and the myelogram both were normal. At the postoperative examination 1 year later the patient was completely recovered and no longer showed any electromyographic changes. Some pressure which could not be demonstrated at operation *may* therefore have been relieved by the operation.

In 3 other cases in which operation revealed no changes, clinical examination and electromyography had shown similar

misleading changes. In 2 of these cases the SI was found affected by both methods. The myelogram was normal in both cases. At re-examination 1 year after operation, 1 of the patients had not improved and had persistent electromyographic changes, the other patient had improved and the electromyogram was now of normal appearance. In the 3rd case clinical examination as well as electromyography showed affection of both LV and SI, while the myelogram showed a thickened LIV root. At operation the 2 lowermost spaces were exposed but with negative findings. At re-examination the patient showed no improvement.

In 2 cases, in which exploration revealed no changes, the patients had shown misleading clinical-neurological findings but normal electromyograms. In one of these 2 cases clinical examination had indicated affection of the LIV and LV roots and myelography had shown a thickened LV root (and was thus also misleading), in the other clinical examination had shown an affection of LIV, but in that patient myelography and electromyography had shown nothing abnormal. These 2 patients showed no improvement at re-examination.

In 1 case in which operation had revealed lumbosacral osteophytes pressing a nerve root, which was regarded as the SI root, clinical-neurological examination and electromyography had shown affection of LV, while the myelogram was normal. The number of vertebrae was counted and found to be normal. At re-examination the patient was better and the weakness of the great toe and the denervation of LV had disappeared.

Myelography was misleading in 1 case, in which operation revealed varices lumbosacrally and swollen SI root. Clinical examination and electromyography had also shown SI affection. The myelogram, on the other hand, indicated a lesion between LIV and LV, where operation revealed no changes. At re-examination the patient was better and the electromyographic changes had disappeared.

Group 2

The misleading clinical findings noted in 4 cases, may all be due to persistent changes from earlier operation and will therefore not be considered.

The patient that showed misleading electromyographic findings had a medially disk herniation between LIV and LV with pressure of the intradural part of the SI root.

As to atrophy and denervation of musculus ext. dig. brev., such changes were found (see chapt. III) in 11 of 74 cases of disk herniation between LIV and LV, or in 14.9 %, while KUGELBERG & PETERSÉN (1950) gave such a high frequency as 85 %.

In patients with disk herniation between LV and SI, KUGELBERG & PETERSÉN found the same change in only 8 %. In the present investigation, on the other hand, corresponding findings were made in 9 of 60 cases, *i.e.*, 15 %. This figure appears high: therefore these 9 cases are discussed further below.

In 4 of the 9 cases there was a lateral disk herniation (so-called lateral LV syndrome), in 1 the herniation was situated relatively laterally and affected the LV root as well as the SI root. Clinical examination has shown weakness of the Achilles tendon reflex and electromyography had shown LV denervation. In the 6th case the electromyogram and clinical-neurological examination also suggested affection of LV.

In 2 cases clinical examination showed not only atrophy and denervation of musculus ext. dig. brev., but also weakness of the great toe and of the Achilles tendon reflex.

In the 9th case electromyography and clinical-neurological examination showed affection of SI.

Chapter V

THE REVIEW

In order to study the effect of operation and to ascertain whether the electromyographic and clinical-neurological changes persisted after the operation, the patients were examined clinically and electromyographically 1 year after the operation.

Of the 206 operations, 202 were reviewed. Of the 4, who were not reviewed, 2 had died in the meantime from some intercurrent disease. The other 2 refused to cooperate.

I. Results

All of the 60 patients with lumbosacral disk herniation, cooperated and 33 (55 %) were found to have made a complete recovery, 17 (28.3 %) had symptoms in the form of weakness of the back or back pain but no longer any leg pain. 9 of these 17 wore a corset. 9 (15 %) had persistent sciatic pain but felt better than before the operation. Finally 1 (1.7 %) showed no improvement.

As to the patient in whom operation revealed herniation of the disk between LV and LVI, he had made a complete recovery by the time of the review.

Of the 74 patients who had been operated upon for disk herniation between LIV and LV, 71 (1 dead, 2 refused to cooperate) were reviewed. 40 (56.3 %) had made a complete recovery, while 16 (22.5 %) complained of weakness and pain of the back (9 wore a corset). 11 (15.5 %) felt better, but they still had sciatic pain, while 4 (5.6 %) showed no improvement at all.

The two patients, operated upon for disk herniation between

LIII and LIV, were found to have made a complete recovery by the time of the review.

As to the 11 patients, operated upon for a lumbosacral protrusion, 10 were examined (1 had died in the meantime). Of these 10, 6 (60 %) had made a complete recovery, while 2 (20 %) complained of back pain (1 of them wore a corset) and 2 (20 %) had persistent sciatic pain but felt better than before the operation.

The 14 patients, who had had a protrusion between LIV and LV, all were examined. A complete recovery had been made by 7 (50 %), while 5 (35.7 %) complained of back pain and 2 of them wore a corset, 1 (7.1 %) felt better but still had sciatic pain and only 1 (7.1 %) reported no improvement at all.

All of the 20, in whom operation had failed to reveal any disk changes, were reviewed. In the 7 cases, in which operation showed osteophytes explaining the root compression syndrome, 2 (28.6 %) had made a complete recovery, while 3 (42.9 %) felt better but still had sciatic pain and 2 (28.6 %) were unimproved. Of the 4 patients, in whom the only operative finding was "varices", 1 (25 %) hade made a complete recovery, 2 (50 %) still had leg pain but otherwise felt better and 1 (25 %) was unimproved. In the case in which operation showed not only "varices" but also a narrow intervertebral space, the patient had no sciatic pain at the review but had back pain and he wore a corset. Of the 8 cases, in which operation revealed no signs of a pathological condition at all, 1 (12.5 %) had made a complete recovery, 1 (12.5 %) no longer had sciatic pain but persistent back pain (used corset), 3 (37.5 %) felt better but still had sciatic pain, and 3 (37.5 %) were unimproved.

Of the 24 patients, who had been operated upon previously, 13 (54.2 %) had made a complete recovery, 2 (8.3 %) no longer had sciatic pain but complained of back weakness (both wore a corset), 7 (29.2 %) were improved but still had sciatic pain and 2 (8.3 %) showed no improvement at all.

The results may thus be summarized as follows:

Group 1:

Complete recovery	93/178 — 52.2 %	75.8 %	93.2 %
Recovery but persistent back pain	42/178 — 23.6 %		
Improved	31/178 — 17.4 %		
Unimproved	12/178 — 6.7 %		

Entire material:

Complete recovery	106/202 — 52.5 %	74.3 %	93.1 %
Recovery but persistent back pain	44/202 — 21.8 %		
Improved	38/202 — 18.8 %		
Unimproved	14/202 — 6.9 %		

For comparison the literature was studied for the results of operation in previous materials. The analysis showed as follows:

In 1937 BARR reported on 58 cases: 54 (93.1 %) made a complete recovery or improved, while 3 (5.2 %) were unimproved and 1 had died from post-operative uraemia. The same year LOVE & CAMP reported complete recovery in 66 %, improvement in 30 % and no improvement in 4 %. These reports may be regarded as the immediate results of operation. In 1939 CRAIG described a series which he had followed up for 1½—2 years and in which 67 % of the patients were completely recovered, while 29 % still had pain of varying degree. Half of these patients were unable to work. In only 5 % were the results really unsatisfactory.

BARR & MIXTER (1941) reviewed 94 of 135 patients operated upon for disk herniation. The interval between operation and the review was at least 1 year (average 1.5 years). They gave the following results: complete recovery 77 %, persistent mild symptoms 18 %, moderate pain 2 %, severe pain 3 %. The same year FRIBERG reported on a review of 24 of 44 patients, who were examined 12—27 months after the operation, and he reported the results to be satisfactory in 84 %.

The following year MALMROS (1942) described a postoperative examination of 54 of 100 patients operated upon for disk herniation. The interval between the operation and the review was 1 year to 6½ years. The results were found to be satisfactory in 70.4 %.

In NORLÉN's (1944) series of 99 patients, 62 were reviewed 1—4 years after the operation. Of these, 52 (83.9 %) were free from sciatic pain, while 10 (16.1 %) still had pain of varying degree.

BRADFORD & SPURLING (1945) reported satisfactory results (good and improved) in 90 %, SENNING & SJÖQVIST (1946) in 92.7 %, FRIBERG & HIRSCH (1946) in 83.8 %, LOVE (1947) in 90.1 %, BARR (1947) in 90 % and LENHARD (1947) in 83 %.

In 1948 WARIS reported a review of 347 patients, who had been operated upon 1—3 years previously, and gave the following results: good 41 %, improved 50 %, unchanged 6 %, worse 1 % and re-operated 2 %. Back pain persisted in 67 %.

In 1950 O'CONNEL published a review of 443 cases, who had been operated upon 1½—6 years previously, with the following results: recovered 60.7 %, good improvement 31.6 %, improvement 4.7 %, no improvement 0.7 %, recurrence 2.3 %.

Finally in 1952 AITKEN gave a report of a review of 200 patients, including 165 in which operation revealed herniation and 35 "no disk" changes and with the following results:

	Disk changes	No disk changes
Excellent	25 %	14 %
Good	20 %	12 %
Fair	21 %	26 %
Poor	27 %	30 %
Bad	6 %	17 %

and ROSS & JELSMA, also in 1952 described 365 patients who had been operated upon 2 years previously. They gave the following results: good 82 %, fair 15.2 %, poor 2.4 %, mortality 0.26 %.

In most of the series, then, the results were described as satisfactory in more than 90 %, as was found in the present material.

II. Clinical findings

The literature contains but scanty data on the persistence or disappearance of neurological signs and symptoms. ALAJOUANINE & PETIT-DUTAILLIS discussed this point as early as 1930 and claimed that one should not expect too much of the possi-

bilities of regeneration. The same year (1930), however, TOWNE & REICHERT described 2 cases of marked hypertrophy of the ligamentum flavum. 1 of these 2 patients had paresis of the legs, weakened patellar reflex, loss of Achilles tendon reflex and marked impairment of sensibility. 16 months after operation, the reflexes and sensibility were normal. In 1937 HOWARD BROWN presented 7 cases with hypertrophy of the ligamentum flavum with the same neurological signs which disappeared after the operation, and in 1939 SPURLING, MAYFIELD & ROGERS presented 6 patients in whom the neurological symptoms disappeared before they left hospital. On the basis of experience with a series from the Mayo Clinic, ADSON (1940) writes that the injury to the nerve root in some cases was so severe that slight symptoms, such as anaesthesia, weakened reflexes and even paresis might persist indefinitely.

MALMROS (1942) found that slight neurological changes (hypaesthesia, slight muscular paresis or weakeness of reflexes) usually disappeared. But marked impairment of sensibility, paralysis of muscle groups or loss of reflexes often persisted for years.

In 1941 FRIBERG found on review of 24 patients that in 3 of them, in whom the patellar reflex was weak before operation, this was normal at the review. 2 of these 3 patients showed a weakened Achilles tendon reflex before operation, but in those patients the reflex had also become normal by the time of review. In a 4th patient the Achilles tendon reflex was also normal at the review instead of weakened before operation. Thus FRIBERG reported recovery of a weakened reflex in 4 cases.

SENNING & SJÖQVIST (1946) reported recovery of the Achilles tendon reflex after complete loss in 11 cases. In their series paresis of the extensors of the great toe usually disappeared within a few weeks, but in 8 cases paresis persisted for more than a year and in 3 cases for more than 3 years.

In 1946 FRIBERG & HIRSCH reviewed 44 patients, who had been operated upon at least 5 years previously. They never found any recovery of the Achilles tendon reflex but regression of the impairment of sensibility in 14 of 33 (42.4 %).

RÖVIG (1949) wrote: "It is emphasized that neurological changes, such as disturbances of the motor and sensory systems and also change in reflexes due to root lesion, may persist for years after the compression has been removed."

This problem received considerable attention by WARIS (1948). He found that of 56 patients, in whom the Achilles tendon reflex had disappeared completely, it returned to normal strength in 12 (21.4 %). In 5 (8.9 %) a weak Achilles tendon reflex was demonstrable, while in 39 (69.6 %), the loss of the reflex was permanent.

Before the operation the Achilles tendon reflex was weak in 18: in 2 (11.1 %) of them the reflex could not be elicited at all at the review, 8 (44.4 %) still had a weak reflex and in 8 (44.4 %) it was normal.

In 2 cases he also found that complete paresis of the dorsal extensors of the great toe had disappeared by the re-examination. 15 patients with weakness of the extensors of the great toe were followed up and in 10 (66.6 %), the extensors recovered normal strength and in 5 (33.3 %) slight weakness persisted.

As to impairment of sensibility WARIS states that of 137 patients, who had had symptom before operation, the symptom persisted unchanged in 53 (38.7 %).

At the review WARIS observed no atrophy except in those cases with definitive muscle weakness. He writes: "This may partly support the assumption that the pain in these cases had caused an atrophy of disuse which fairly soon disappears after the pain is relieved, and that only the atrophy due to muscle paralysis or weakness has been of a permanent nature. On the other hand, this disappearance of atrophy is likewise an objective sign of real recovery; sciatic pain does not limit the use of extremities and cause atrophy any more."

O'CONNEL (1950) found persistent reflex changes in 62 %, persistent muscular weakness in 6.6 % and persistent impairment of sensibility in 30 % and atrophy in 8.4 % at review.

The neurological symptoms and signs observed 1 year after the operation in the present material are summarized below:

a) Achilles tendon reflex.

Of 40 patients with loss of the Achilles tendon reflex before operation, the reflex was still absent at the review in 34 (85 %), while in 5 (12.5 %) it had returned but was still weak. Only in 1 patient (2.5 %) had the reflex returned and recovered normal strength.

Of 69 patients with weakness of the Achilles tendon reflex before operation, the reflex was still weak at the review in 40 (58 %), in 11 (15.9 %) it could not be elicited and in 18 (26.1 %) it had returned to normal.

Of the 4 patients, who were not reviewed, the reflex was normal in 2 and weak in the other 2 before operation.

b) Patellar reflex.

In 4 patients in whom the patellar reflex was absent before operation, it was also absent at the review.

In 29 the patellar reflex was weak before the operation and in 28 it was still weak after the operation, while in 1 it was normal.

Of the 4 patients, who were not reviewed, the patellar reflex could not be elicited in 1 before operation.

c) Paralysis or weakness of the extensors of the great toe.

13 of the patients had paralysis of the extensors of the great toe before operation. Of these, 6 still had paralysis at the review, 4 of them showed weakness of the great toe and in 3 the strength of the toe was normal.

Of the 110 patients with weakness of the gross strength of the extensors of the great toe, 84 (76.4 %) showed normal strength of the toe at the re-examination, while it was still reduced in 26 (23.6 %).

Of the 4 patients, who were not reviewed, 3 had had weakness of the extensors of the great toe.

d) Impairment of sensibility.

Loss of sensibility was noted at the review in 41 (20.3 %) cases, against 61 (29.6 %) before the operation. Of the 4 patients who were not reviewed, impairment of sensibility had been noted in 1.

e) Muscular atrophy.

Atrophy of the lower leg and/or the musculature of the thigh

had been noted before operation in 82 (39.8 %) patients, against 62 (30.7 %) after the operation. Of the 4 patients not reviewed, 2 had had atrophy at the time of the examination before operation.

It must thus be concluded that with the exception of weakness of the dorsal extensors of the great toe, the neurological signs to the greatest part persisted unchanged 1 year after the operation.

III. Electromyographic findings

All the patients in the present material, with the exception of the 4 who were not reviewed, were carefully examined by electromyography 1 year after the operation.

The following findings were made:

Group 1

a) Disk herniation between LV and SI: Of the 60 patients with lumbosacral disk herniation, preoperative examination showed a positive electromyographic finding in 55 (91.7 %). At the review the same electromyographic findings were made in 14 (23.3 %) and in 1 denervation potentials were found only in the medial head of the gastrocnemius.

b) Disk herniation between LV and LVI: The electromyographic findings were normal at the review but had suggested a pathological condition before the operation.

c) Disk herniation between LIV and LV: At preoperative examination electromyography suggested changes in 68 (91.8 %), while at the review such changes were only found in 9 (12.7 %) (3 patients not reviewed). In 3 other cases, in which the preoperative examination showed denervation of LV, electromyography at the time of the review showed denervation only of the extensor hallucis in 2 cases and of the extensor hallucis and peroneus longus in the 3rd case. In 1 case denervation potentials were seen only in the erector trunchi at the review.

d) The 2 patients with disk herniation between LIII and

LIV at the preoperative examination showed LIV-denervation but no such changes at the review.

e) Protrusion between LV and SI: Of these 11 patients, 10 were re-examined and they showed a positive electromyogram in 3 (30 %), while the preoperative examination showed electromyographic abnormalities in 9 (81.8 %).

f) As to protrusions between LIV and LV, all 14 showed electromyographic abnormalities before operation as against only 3 at the review (21.4 %).

g) The 20 cases, in which operation revealed no disk changes, showed electromyographic abnormalities in 14 (70 %) as against 6 (30 %) after operation.

Group 2

In this group 22 of the 24 cases showed electromyographic abnormalities (91.7 %) before operation as against only 7 (29.2 %) at the review.

At the preoperative examination, then, 185 (89.8 %) showed electromyographic changes, against only 42 (20.8 %) after operation, and changes in single muscles in 5 (2.5 %).

Concerning the electromyographic findings, they thus tended to disappear in a great percentage after the operation.

A fairly thorough search of the literature failed to reveal any publication on post-operative electromyographic examinations of patients who had undergone operation for disk herniation.

On the other hand, post-operative electromyographic studies have been carried out on musculus erector trunchi by WEDDELL, FEINSTEIN & PATTLE (1944) and by MACK (1951) whose works, however, fall beyond the scope of the present investigation.

Chapter VI

DISCUSSION AND CONCLUSIONS

It is clear from chapt. IV (Table 12) that in those cases in which operation revealed disk lesions, clinical-neurological examination had shown the correct level of the lesion in 77 %, and the corresponding figure for group 2, *i.e.*, patients operated upon previously (Table 13) was 79.2 %, and Table 14 (the 20 cases in which operation revealed no disk changes) shows that clinical-neurological examination had revealed the correct level of the lesion in 55 %. Clinical-neurological examination had thus given a correct diagnosis of the level for the entire material in 76.3 %.

As to the myelographic demonstration of the level of the lesion, the examination indicated the proper level for the entire material in 76.1 % (group 1, disk changes in 75.2 %, group 2, 91.7 %, and group 1 "no disk changes" in 65 %). The corresponding figure for electromyography was 77.6 % (group 1, disk changes in 78.3 %, group 2 in 91.7 % and group 1 "no disk changes" in 55 %). These figures do not include the disk herniation between LV and LVI, because it cannot be fitted into a clinical-neurological and electromyographic scheme. The myelogram in that case was correct.

It is thus obvious that the 3 methods gave a correct diagnosis with largely equal frequency.

In the comparison of the 3 diagnostic methods, the reliability of each method was assessed by comparing each group of operative findings with the diagnostic findings. A more important question from a practical point of view is to what extent the various diagnostic findings can be confirmed at operation.

As to the clinical-neurological examination, group 1 included

95 cases in which *the Achilles tendon reflex* was weak or absent, and in those patients operation revealed a lumbosacral disk herniation in 48 (50.5 %), a lumbosacral protrusion in 8 (8.4 %) osteophytes in the lumbosacral space in 2 (2.1 %), and "varices" in that space in 1 (1.1 %). Of the patients in whom the Achilles tendon reflex was weak or absent in group 1, lumbosacral disk lesions thus were found in 58.9 %, and another explanation for the SI affection in 3.2 %. In group 2 the Achilles tendon reflex was weak or absent in 18 cases and of these patients operation showed a lumbosacral herniation in 5 (27.8 %), a lumbosacral protrusion in 3 (16.7 %) and lumbosacral adhesions in 3 (16.7 %). In the entire material operation thus revealed an affection of SI in the lumbosacral space in 62.8 % of the patients in whom the Achilles tendon reflex was weak or absent.

In many of these patients, however, the Achilles tendon reflex change was combined with weakness of the great toe and/or changed patellar reflex. If only those cases be considered in which the weakness or absence of the Achilles tendon reflex was the only clinical-neurological finding (44 cases in group 1 and 6 in group 2), lumbosacral disk changes were seen in 68.2 % (30 cases) in group 1, and another cause of the affection of SI in 4.5 % (2 cases) *i.e.* a total of 72.7 % (group 1), and of 72 % of the entire material.

Only few authors have described such an analysis of a series. STÅHL (1949), however, did give such an analysis of patients with changed Achilles tendon reflex as the only finding preoperatively, and he found lumbosacral lesions in about 80 % of them at operation. KNUTSSON & WIBERG (1958) gave a corresponding figure of 81 % and FRIBERG & HULT (1951), 77 %.

Weakness of the dorsal extensors of the great toe was seen in 110 of the patients in group 1 and operation revealed a herniation between LIV and LV in 56 (50.9 %) of them, a protrusion between LIV and LV in 10 (9.1 %), osteophytes in the same space in 1 (0.9 %), and "varices" in 1 (0.9 %). In these patients with weakness of the dorsal extensors of the great toe, then, disk lesions were found at operation in the space between

LIV and LV in 60 % of group 1, and in 1.8 % the LV affection could be ascribed to some other cause. In group 2, 15 of the patients had weakness of the great toe and operation revealed a disk herniation between LIV and LV in 1, protrusion between LIV and LV in 1, and adhesions in this space in 2, *i.e.* a total of 4 cases (26.7 %). Of the entire material, then, 57.6 % of the patients with weakness of the great toe had a LV affection in the space between LIV and LV.

Weakness of the great toe was, however, often combined with a change of the Achilles tendon reflex and/or of the patellar reflex. In those cases, in which weakness of the great toe was demonstrated as the only clinical-neurological finding (53 cases in group 1, and 5 in group 2), operation revealed disk changes between LIV and LV in 75.5 % (40 cases) and some other causal factor for the LV affection in the same space in 3.7 % (2 cases), *i.e.* a total of 79.2 % (group 1) and of 79.3 % of the entire material.

In patients with weakness of the great toe as the only clinical-neurological finding, STÅHL found disk lesions between LIV and LV in 83 %, KNUTSSON & WIBERG in 63 %, and FRIBERG & HULT in 83 %.

Weakness of *the patellar reflex* was the only clinical-neurological finding in 4 (group 1), and in 2 of them operation revealed a herniation between LIII and LIV. In the other 2 cases, operation showed no disk changes. In none of the cases in group 2 was a change in the patellar reflex the only neurological abnormality observed.

Myelography. Group 1. In those cases, in which myelography (the primary reports) showed lumbosacral disk herniation (46 cases), the finding was confirmed at operation in 36 and a protrusion was found in 4, thus making a total of 40 (87 %) cases, and osteophytes were found in 2 (4.3 %) in the same space. The diagnosis was thus correct in 42/46 (91.3 %).

Myelography showed changes between LIV and LV in 93 cases, of which operation showed a disk herniation in the same space in 69 cases and a protrusion in 8 cases, thus making a total of 77 (82.8 %) with disk changes, and in 4 (4.3 %) the

changes could be explained by other factors (osteophytes in 2 cases, and "varices" in 2). The diagnosis was thus correct in 81/93 cases (87.1 %).

In 2 cases the myelogram showed changes between LIII and LIV, and in both of them operation showed disk herniation at that level.

Group 2. In 9 cases of group 2 myelography showed lumbosacral lesions, in all of which the diagnosis could be confirmed at operation.

In 8 cases myelography showed changes between LIV and LV and in 7 of them these changes were verified at operation.

Myelographic changes of disk lesions between LIII and LIV were seen in 2 cases, in both of which the changes were verified at operation.

The positive myelographic finding could thus be confirmed at operation in the following percentages:

Lumbosacral in 92.7 %.
Between LIV and LV in 87.1 %.
Between LIII and LIV in 100 %.
The corresponding figures in FRIBERG & HULT's series were:
Lumbosacral in 92.2 %.
Between LIV and LV in 89.9 %.
Between LIII and LIV in 100 %.

Electromyography showed *SI denervation* in 90 of the cases in group 1; 48 (53.3 %) of them had a lumbosacral disk herniation, and 9 (10 %) were found to have protrusion in the same space, the total number of disk lesions was 57 (63.3 %), and another explanation for the SI affection in that space was given in 4 (4.4 %) cases (3 with osteophytes and 1 with "varices"), making a total of 67.7 % (group 1).

13 of the patients in group 2 had a SI denervation and in these cases operation revealed a lumbosacral disk herniation in 6 (46.2 %), a protrusion in that space in 2 (15.4 %), and adhesions there in 4 (30.8 %). In the entire material, thus, of the patients with SI denervation, 70.8 % had a lumbosacral SI affection at operation.

In many of these cases, however, the SI denervation was combined with another denervation and if only cases with a SI denervation only will be considered (70 in group 1, 9 in group 2), it will be found that 68.6 % (48 cases) of these patients in group 1 had lumbosacral disk lesions and another SI affection in the lumbosacral space in 5.7 % (4 cases), making a total of 74.3 % (52 cases) for group 1 and 75.9 % for the entire material.

LV denervation was seen in 89 patients of group 1. Of these, 56 (62.9 %) were found at operation to have disk lesions between LIV and LV, 11 (12.4 %) to have a protrusion in the same space and 4 (4.5 %) to have some other LV affection in the space in question (including 2 with osteophytes, 1 with "varices" and 1 with "varices" and a narrow space). In group 2, LV denervation was noticed in 12 patients, and in 3 (25 %) operation showed disk herniation between LIV and LV, a protrusion in that space in 1 (8.3 %), and adhesions in the space in question in 4 (33.3 %). In the entire material, then, 78.2 % of the patients with LV denervation had a LV affection in the space between LIV and LV.

But here, too, many of the electromyographic findings were combined, and if only those cases be considered with LV denervation only (69 in group 1 and 6 in group 2), the number of patients in group 1 with disk changes in the space between LIV and LV will be 81.2 %, while some other LV affection in the same space was seen in 4.3 %; making a total of 85.5 % for this group and 86.7 % for the entire material.

Denervation of the LIV myotome was demonstrated in 6 cases in group 1, and 2 of these patients had disk herniation between LIII and LIV and 1 had osteophytes between LIII and LIV. In the 2 patients with disk herniation, LIV denervation was the only electromyographic finding, while it was combined with LV and SI denervation, respectively, in the other 4 cases. Thus all of the patients with LIV denervation only, had disk herniation between LIII and LIV. In group 2, 3 patients showed a LIV denervation, 1 of them as the only electromyographic finding and in that patient operation revealed a protrusion between

LIII and LIV. The other 2 showed multiple findings, and in 1 of them operation revealed herniation between LIII and LIV.

Total Group 1		Disk lesions L V — S I	Other S I-affection L V — S I	Total
Achilles tendon reflex change only	44	68.2 $\%_{30}$	4.5 $\%_{2}$	72.7 $\%_{32}$
SI denervation only	70	68.6 $\%_{48}$	5.7 $\%_{2}$	74.3 $\%_{52}$
Myelographic signs of lesions between LV and SI	46	87 $\%_{40}$	4.3 $\%_{2}$	91.3 $\%_{42}$

Thus, in 12 patients with a distinct change in the Achilles tendon reflex operation showed no affection of the SI root in the lumbosacral space. The following findings were made at operation of these patients: disk herniation between LIV and LV in 9 (discussed in chapt. IV: misleading clinical-neurological findings; disk herniation between LIV and LV); protrusion between LIV and LV in 1 (discussed in chapt. IV: misleading clinical-neurological findings; protrusion between LIV and LV) and no disk changes at operation in 2 (discussed in chapt. IV: negative findings).

18 patients with a distinct SI denervation showed no lumbosacral SI affection at operation. Of these 18 patients, the operative findings made were as follows: 12 disk herniations between LIV and LV (discussed in chapt. IV: misleading electromyographic findings; disk herniation between LIV and LV), 3 protrusions between LIV and LV (discussed in chapt. IV: misleading electromyographic findings; protrusion between LIV and LV) and 3 no disk changes at operation (discussed in chapt. IV: neg. operative findings).

In 4 patients myelographic changes between LV and SI could not be confirmed at operation. 3 of them were found to have herniation between LIV and LV (see chapt. IV: misleading myelographic findings; disk herniation between LIV and LV), and 1 of them a protrusion between LIV and LV (see chapt. IV: misleading myelographic findings; protrusion between LIV and LV).

Total Entire material		Disk lesions L V — S I	Other S I-affection L V — S I	Total
Achilles tendon reflex change only	50	68 $\%_{34}$	4 $\%_{2}$	72 $\%_{36}$
SI denervation only	79	68.4 $\%_{54}$	7.5 $\%_{6}$	75.9 $\%_{60}$
Myelographic signs of lesions between LV and SI	55	83.6 $\%_{46}$	9.1 $\%_{5}$	92.7 $\%_{51}$

Total Group 1		Disk lesions L IV — L V	Other L V-affection L IV — L V	Total
Weakness of the great toe only	53	75.7 $\%_{40}$	3.7 $\%_{2}$	79.2 $\%_{42}$
LV denervation only	69	81.2 $\%_{56}$	4.3 $\%_{3}$	85.5 $\%_{59}$
Myelographic signs of lesions between LIV and LV	93	82.2 $\%_{77}$	4.3 $\%_{4}$	87.1 $\%_{81}$

Thus, 11 with definite weakness of the great toe showed no affection of the LV root in the LIV—LV space at operation. The operative findings made in these 11 patients were as follows: disk herniation between LV and SI in 9 cases (disc. in chapt. IV: misleading clinical-neurological findings; disk herniation between LV and SI), protrusions between LV and SI in 2 (disc. in chapt. IV: misleading clinical-neurological findings; protrusion between LV and SI).

In 10 cases with LV denervations, operation revealed no involvement of the LV root in the space between LIV and LV. The operative findings in these 10 cases were as follows: disk herniation between LV and SI in 7 (disc. in chapt. IV: misleading electromyographical findings; disk herniation between LV and SI), no disk changes in 2 (disc. in chapt. IV: negative findings) and disk herniation between LV and LVI in 1.

Of the cases, in which the myelograms showed changes between LIV and LV, the lesions could not be verified at operation in 12; 9 of them were found to have a lumbosacral disk herniation (see chapt. IV: misleading myelographic findings; disk herniation between LV and SI), 2 a protrusion between LV and SI (see chapt. IV: misleading myelographic findings;

protrusion between LV and SI), and in 1, no disk changes (see chapt. IV: negative findings):

Total Entire material		Disk lesions L IV — L V	Other L V-affection L IV — L V	Total
Weakness of the great toe only	58	74.1 $\%_{43}$	5.2 $\%_{3}$	79.3 $\%_{46}$
LV denervation only	75	80 $\%_{60}$	6.7 $\%_{5}$	86.7 $\%_{65}$
Myelographic signs of lesions between LIV and LV	101	81.2 $\%_{82}$	5.9 $\%_{6}$	87.1 $\%_{88}$

A question of practical importance is to what extent all three diagnostic methods give single or combined or normal findings, respectively, in the same cases, or whether the three methods differ from one another in this respect. The relationship between single, combined and normal findings, respectively, on clinical-neurological and electromyographic examinations is apparent from Tables 19—30 in chapt. IV and therefore need not be discussed again here. The ratio between these findings and the myelographic findings is as follows:

Group 1. a) *Disk herniation between LV and SI:* In 5 patients, in which electromyography showed no signs of pathological condition, the myelogram showed lumbosacral changes in 4 but not in the 5th (in this case, however, the clinical-neurological examination indicated an affection of SI).

In 2 cases the clinical-neurological findings were normal, and in 1 of them the myelogram indicated lumbosacral changes, while in the other case it revealed no signs of a pathological condition (in this case, however, the electromyogram showed SI denervation).

Of the 14 cases in which myelography was of normal appearance in patients with lumbosacral disk herniation found at operation, electromyography and clinical-neurological examination distinctly showed the same lesions in 6 of them. In 3 of the 14 cases electromyography gave clear-cut information, while the clinical-neurological examination gave a combined finding, while in 2 cases it was the converse. In 1 case there were combined findings on electromyographic as well as clinical-neuro-

logical examination, in 1 case distinct electromyographic findings but normal findings on clinical-neurological examination and in 1 case vice versa.

c) *Disk herniation between LIV and LV:* In 6 patients the electromyogram was of normal appearance, and in all of them myelography indicated changes in the space between LIV and LV (in 2 of them the myelographic changes were the only diagnostic findings).

In 8 cases clinical-neurological examination was of normal appearance, and in all of these the myelogram showed changes between LIV and LV (regarding 2 of these, see above).

In 1 case the myelogram was of normal appearance in a patient in whom operation revealed disk herniation between LIV and LV, but in that patient electromyography showed an unequivocal LV denervation and clinical-neurological examination showed a combined finding.

e) *Protrusion between LV and SI:* In 2 of these patients the electromyogram was normal, in 1 of them the myelogram was negative and in the other misleading, but in both of these cases clinical-neurological examination showed an affection of SI only.

In 1 case, in which clinical-neurological examination was of normal appearance, myelography revealed lumbosacral changes.

In the group with protrusions between LV and SI myelography was normal in 4, in 3 of them electromyography distinctly showed SI denervation, and clinical-neurological examination likewise showed a clear-cut affection of SI in 2 of these cases, but a combined finding in the 3rd. In the 4th case electromyography, like myelography, revealed no abnormalities, but the clinical-neurological examination distinctly showed an affection of SI.

In 1 case myelography failed owing to a technical mishap, and in that case both clinical-neurological and electromyographic examination showed a combined LV and SI affection.

f) *Protrusion between LIV and LV:* In 3 cases in this group the clinical-neurological findings were normal, but in all 3 the myelogram indicated changes between LIV and LV.

The group included 3 patients in whom myelography showed no signs of a pathological condition and 1 in which the myelographic findings were suspected, but in all of these cases clinical-neurological and electromyographic examination gave a firm diagnosis.

Group 2. Of the positive findings made at operation in group 2, "re-operated cases", electromyography was of normal appearance in one case: a protrusion between LV and SI but in this case the myelogram suggested lumbosacral lesion, and in 1 case there was a normal clinical-neurological finding, namely, in the subgroup "adhesions between LV and SI" and in that case the myelogram was normal too.

Of the patients (in group 2) in whom operation revealed positive findings, the latter had been missed by myelography in 3, namely, in the one referred to above, in which the electromyogram showed lesion of SI and thus was the only positive finding by the 3 diagnostic methods. In the same subgroup (adhesions between LV and SI) myelography was normal in another case, too, in which the electromyogram indicated lesion of SI, while the clinical-neurological examination suggested affection of both LV and SI. The 3rd case where the myelography was of normal appearance belonged to the subgroup "disk herniation between LV and SI" and in that case the clinical-neurological examination suggested lesion of the LV root, while the electromyogram indicated affection of both the LV and the SI myotomes. This case is described here because reoperation had been done, partly because of the electromyographic findings. The patient was a 30-year old male operated upon on 6.11.1957, when a large herniation of the disk (2.2 ml) was found between the 4th and 5th lumbar vertebrae. The patient, however, was not relieved of his radiating pains and he came back to the hospital in January 1958. Neurological examination showed the same situation as before the first operation, namely: paresis of the great toe, Lasègue's test positive at 50°. Myelography was negative. Electromyography showed denervation fibrillation in both the LV and SI myotomes. A new operation revealed a herniation of the disk (0.6 ml) in the lumbosacral space

and since its removal the patient has been free of pain (case 185/58).

Summarizing, in a few of those cases in which operation revealed changes, only one of the examination methods gave a positive finding. Thus, *clinical-neurological* examination showed: lumbosacral disk herniation in one case and lumbosacral protrusion in another, in which cases both myelography and electromyography had been of normal appearance.

As to the *myelographic* examination, this, in 2 cases, was the only method, which showed disk herniation between LIV and LV.

Finally, *electromyographic* examination was the only method that revealed signs of a pathological condition in 1 case of disk herniation between LV and SI (group 1), in 1 case of protrusion between LV and SI (group 2), and in the described reoperated case with a disk herniation between LV and SI found at the reoperation. In none of the cases in which operation revealed disk changes did all examinations fail to detect the lesions.

The 20 cases (in group 1) with no disk changes found at operation are discussed below.

This group included 8 cases in which operation revealed no changes at all.

In 1 of these patients none of the 3 examination methods had revealed any signs of disease, but the patient had severe pain and atrophy of the thigh and calf muscles, for which reason explorative surgery was decided upon, but the results were negative (apart from a possible thickening of the SI root). At re-examination 1 year after the operation, the patient reported no improvement but still showed no electromyographic or clinical-neurological abnormalities.

In 1 case clinical examination as well as electromyography had shown changes of both the LV and the SI root, while the myelogram suggested a thickened LIV root. The 2 lowermost spaces were explored but revealed nothing of interest. At re-examination the patient felt no better and the clinical and electromyographic changes were still demonstrable.

In 1 of the cases both clinical examination and electromyography showed affection of SI and the myelogram suggested lumbosacral lesions. The 2 lowermost disks were explored, but no changes were found. At re-examination the patient was unimproved and the clinical-neurological and electromyographic changes were still demonstrable.

In 2 other cases, in which the patients were likewise unimproved at the review, 1 of the patients had clinical-neurological symptoms of affection of LIV, but neither myelography nor electromyography showed any abnormalities and in that case the 3 lowermost spaces were explored but nothing of interest was found, and in 1 patient with clinical affection of the LIV and the LV root, myelography showed a thickened LV root, but the electromyogram was normal and in that case exploration of the 2 lowermost spaces revealed no changes either.

In the 5 cases, described above it is possible that the surgeons might have missed a possible cause of root compression.

Of the remaining 3 patients in whom surgical exploration revealed no changes, 2 were improved and 1 had made a complete recovery by the time of the review. One of the improved patients showed clinical and electromyographic evidence of affection of SI but no myelographic changes, and the other patient showed clinical evidence of involvement of the LV and the SI root, electromyographic signs of LV denervation and myelography showed changes in the space between LIV and LV. In both cases the electromyographic changes, as well as the weakness of the great toe in the last case, had disappeared by the time of the review. The patient, who had made a complete recovery, had shown no clinical-neurological signs before operation and the myelogram had been normal, but electromyography had shown SI denervation. The electromyographic abnormality had disappeared by the time of the review.

In these 3 last-mentioned cases there had either been spontaneous restitution or some compression might have been present which could not be demonstrated at operation but which was, nevertheless, relieved by the decompressive henilaminectomy.

In 7 cases osteophytes were seen that could explain the root compression.

In 1 of these cases the change was only demonstrable by myelography, while clinical-neurological examination and electrography revealed nothing of interest. The patient had improved by the time of the review.

In 4 cases all 3 examination methods showed root compression; 2 of these patients had completely recovered by the time of the re-examination and by them the electromyographic changes had disappeared, while the other 2 were unimproved and still showed electromyographic abnormalities.

In a 6th case myelography showed abnormalities, while the compression produced both clinical-neurological and electromyographic signs. At the review this patient had improved and then both the clinical-neurological sign (weakness of the great toe) and the denervation had regressed.

In the 7th case the clinical-neurological examination revealed no abnormalities, while myelography and electromyography suggested the same lesions. The patient felt better at the review but the denervation was still demonstrable.

From the observations made in these 7 cases it may be concluded that the osteophytes *may* cause root compression and that their removal *may* be followed by improvement or even by complete recovery.

Of the 20 cases (group 1) in which operation revealed no disk changes, there were still 5 in which the operative findings were described as "varices" in 4 and as "varices"+narrow space in the 5th. Before operation the last mentioned patient showed LV denervation and myelography suggested a change in the space between LIV and LV, while the clinical-neurological examination showed weakness of the patellar reflex. At the review the patient had made a complete recovery and the LV denervation had disappeared. Unless this recovery had been spontaneous, the LV root might have been compressed by the very narrow space observed at operation, where according to the surgeon, the arches almost contacted one another and where large varicose veins were seen.

Of the 4 patients in whom "varices" were seen, 1 of the patients had made a complete recovery by the time of the review. At the preoperative examination, there were clinical signs of weakness of the great toe, myelography had failed owing to a technical mishap and the electromyogram showed no abnormalities. At the review the strength of the great toe was normal. 2 patients had improved by the time of the review. One of them had clinical-neurological and electromyographic signs of involvement of SI before operation, while the SI denervation had disappeared after the operation. In the other case there was preoperatively an affection of the LIV and the LV root, while the myelogram and electromyogram showed no abnormalities. The clinical changes persisted after the operation. In the 4th case the patient showed clinical signs of involvement of the LIV and the LV root, while electromyography showed LV denervation. Myelography revealed no abnormalities. At the review the patient was unimproved and the LV denervation persisted as did the clinical findings. The patient had pronounced muscular atrophy which had increased since the operation. The patient was re-operated upon later, but re-operation revealed only markedly varicose veins.

In all of these 4 cases the surgeon had observed relatively wide, tortuous veins but no other signs of a pathological condition. It is probable that these varicose veins do not themselves compress the roots but they are obviously a sign of stasis or some other cause of the root compression. HANRAETZ (1959) surveyed the literature on the cause of the occurrence of such varicose epidural veins. He first divides the varicose changes into primary and secondary. He ascribes the primary to a disontogenetic disturbance of the mesoderm. The secondary varicose changes in the epidural veins may, according to HANRAETZ, be the result of:

a) a local lesion in the vertebral canal itself.

b) inflammation within the spinal canal.

c) plethora of the plexus may result from hyperaemia *outside the spinal canal* such as following upon tumours and inflammation in the abdomen and gynecological disorders.

d) Varicosis may be the result of over-abundant blood supply *e.g.* through vascular tumours, angiomatosis of the central nervous system and haemangiomatosis vertebrae.

In 1 case in group 2 surgical exploration revealed no changes at all. Before operation the Achilles tendon reflex was possibly somewhat weak but neither electromyography nor myelography had shown any signs of a pathological condition. 6 years previously the same space had been explored, and neither then had operation revealed any changes. By the time of the review, 1 year after the last operation, the patient had recovered and the Achilles tendon reflex was normal.

Also among some of those cases, in which operation revealed no disk changes, only one of the methods had suggested disease, namely: the clinical-neurological examination in 2 cases, in which the operator found only "varices" and in which one of the patients made a partial recovery and the other complete recovery after explorative surgery and in 2 cases, in which operation revealed no changes at all. In one of these cases (group 2) the patient had recovered and in the other (group 1) he showed no improvement at all by the time of the review.

The myelographic examination revealed changes in 1 case in which operation showed osteophytes and in which the patient improved after the operation.

Electromyography showed lesions in 1 case in which exploration revealed no changes at all and in which the patient made a full recovery with disappearance of the electromyographic changes after the operation.

In 1 case none of the diagnostic methods showed any signs of disease and surgical exploration provided no explanation either. At the review that patient was unimproved.

As is apparent from chapt. V, the postoperative regression was considerable as far as electromyographic changes are concerned, while the clinical-neurological findings to a large degree persisted. For practical reasons myelography was not done after the operation. No correlation was found between the postoperative regression of the electromyographic changes and the size of the disk hernia or the results of operation.

The findings described above suggest the following conclusions:

I. Neurological examination and electromyography cannot always give an exact diagnosis. The reasons for this inexactitude are as follows:

a) The LV root can be compressed also by a lateral prolapse in the *LV and SI space*, as shown by the 4 patients in which the disk had herniated far laterally in the lumbosacral space (see chapt. IV).

b) The SI root can be compressed by a medial prolapse in the *LIV—LV space*. The present material included 4 cases of medial disk herniation between LIV and LV with clinical as well as electromyographic changes suggesting only involvement of SI. And this also applies to a medial protrusion between LIV and LV (see chapt. IV).

c) One and the same prolapse can compress two roots and thus give combined findings (see analyses in chapt. IV). There are for example cases with clinical-neurological as well as electromyographic signs of affection of both the LV and the SI root, and in which the electromyographic changes had disappeared by the time of the review.

d) The lowerwost disk is not always the 24th from the atlas. For example, 1 patient, may have 7 cervical vertebrae, 12 thoracic vertebrae and 6 lumbar vertebrae, such as the patient, who was classified as having a disk herniation between LV and LVI.

e) Individual variations occur in the nervous system. In the present material there was 1 case of lumbosacral disk herniation at the usual place in the space with clinical and electromyographic findings suggesting only involvement of LV and 1 case of disk herniation between LIV and LV at the usual place in the disk with only clinical and electromyographic signs of involvement of SI (see chapt. IV). In both these cases the electromyographic changes had disappeared by the time of the review.

II. In certain cases, 2 or 3 roots may produce clinical-neurological signs while the electromyographic examination may show only involvement of 1 root and vice versa. This is illustrated by Tables 19—30 in chapt. IV.

III. Myelography is not exact either, because lateral prolapses can compress a root without causing any defect in the contrast column in the dural sac or root pockets. It was pointed out in the section on the myelographic findings that at the level of the disk between LV and SI, the dural sac often tapers so that large lateral prolapses may be present despite a normal myelogram.

In view of the above considerations, it appears that electromyography is valuable in the diagnosis of the lumbar root compression syndrome and, on the basis of the analysis performed in the present material, its importance may be summarized as follows:

1) The electromyogram may show changes in the absence of clinical-neurological findings (see Tables 19—30 in chapt. IV).

2) The electromyogram may show involvement at one level when combined clinical-neurological symptoms may suggest changes at two levels (see Tables 19—30 in chapt. IV).

These 2 conclusions are illustrated by Tables 19—30 in chapt. IV.

3) The electromyogram may show abnormalities when the myelogram is normal.

Of the 14 patients, in whom myelography showed no changes but in which operation revealed lumbosacral disk herniation, the electromyogram showed changes in 13, and of the 4 patients with normal myelograms but with the operative findings: protrusion between LV and SI, 3 showed a positive electromyogram. As to the space between LIV and LV, the myelograms were normal in 4, 1 in whom operation revealed disk herniation, and 3 in which operation showed protrusion. In all of these 4 cases electromyographic changes were noted. The degree of accord between myelography on one hand and electromyography and clinical-neurological examination on the other hand among patients in whom no disk changes could be found at operation were discussed in a previous section. Group 2 included 2 patients in whom operation revealed lesions that had not been demonstrated in the myelogram but in the electromyogram.

4) The electromyographic changes regress considerably after operation and can therefore be used with advantage for demonstration of so-called recurrences. This is apparent from the postoperative examination, which is accounted for in chapt. V. The clinical-neurological changes, with the exception of weakness of the great toe, were still demonstrable in a high degree 1 year after the operation, while the electromyographic changes persisted in only about one fourth of the patients.

The disadvantages of electromyography are as follows:

1) The electromyographic denervation potentials do not appear until 18—21 days after onset of the disease.

2) Every muscle must be examined very carefully requiring the insertion of the needle a relatively large number of times.

There appears to be general agreement on the value of electromyography for the diagnosis of lumbar nerve root compression syndrome. SHEA & WOODS (1955) write: "Perhaps the commonest and most practical clinical use of the EMG is as an aid in the diagnosis of a compression lesion of a specific nerve root (most frequently by a protruded intervertebral disk)." MARINACCI (1955) writes: "The EMG has proved itself to be a definite significance in determining and localizing nerve root lesions." "The clinical findings when correlated with the EMG aids the surgeon in selecting his cases for opaque myelography." And in his book on "Clinical Electromyography", MARINACCI (1955) concludes: "In the diagnosis of nerve root compression syndrome the EMG is slowly but surely replacing subjective uncertainty with objective reality. Nevertheless, the EMG is a laboratory procedure and its findings must always be correlated with the history and the clinical picture."

It is clear from the present investigation that electromyography is not superior to the other two methods, but that it is a good supplementary method.

Chapter VII

SUMMARY

A series of 206 cases (205 patients) operated upon for lumbar nerve root compression syndrome, was studied with respect to the diagnostic value of clinical-neurological, myelographic and electromyographic examination.

The operative findings, made in the material, were:

Group 1	(patients not operated upon previously)	182
	a) Disk herniation between LV and SI	60
	b) Disk herniation between LV and LVI	1
	c) Disk herniation between LIV and LV	74
	d) Disk herniation between LIII and LIV	2
	e) Protrusion between LV and SI	11
	f) Protrusion between LIV and LV	14
	g) No disk changes	20,
	consisting of 4 subgroups:	
	1) No pathological findings at operation	8
	2) Osteophytes	7
	3) "Varices"	4
	4) Very narrow interspace+"varices"	1
Group 2	(previously operated cases)	24 (23 patients)
	a) Disk herniation between LV and SI	6
	b) Disk herniation between LIV and LV	4
	c) Disk herniation between LIII and LIV	1
	d) Protrusion between LV and SI	3
	e) Protrusion between LIV and LV	1
	f) Protrusion between LIII and LIV	1
	g) Adhesions between LV and SI	3
	h) Adhesions between LIV and LV	2
	i) Adhesions between LV and SI+LIV and LV	2
	j) No pathological findings at operation	1

An account is then given of projected pain in the different groups. Projected pain into the heel was noted in 20 % of the

patients with disk herniation between LV and SI (group 1) and projection of pain into the great toe was noted in 21.6 % of the patients with disk herniation between LIV and LV.

The Achilles tendon reflex was found to be weak or absent in 80 % of the patients with disk herniation between LV and SI (group 1), in 37.8 % of those with a herniation between LIV and LV, in 72.7 % of those with a protrusion between LV and SI, and in 21.4 % of those with protrusion between LIV and LV.

In group 1 the patellar reflex was found to be changed in 100 % (2/2) of the patients with disk herniation between LIII and LIV, in 15 % of those with disk herniation between LV and SI, and in 12.2 % of those with disk herniation between LIV and LV.

Weakness of the extensors of the great toe was noted in 75.7 % of patients with disk herniation between LIV and LV in group 1, and in 46.7 % of those with disk herniation between LV and SI, and in 71.4 % of those with a protrusion between LIV and LV, and in 45.5 % in those with protrusion between LV and SI.

Atrophy of m. ext. dig. brev. was found in 14.9 % of cases of disk herniation between LIV and LV and in 15 % of those with disk herniation between LV and SI.

Impairment of sensibility was noted in 29.2 % of group 1 and in 29.6 % of the entire material. The extent of the impairment of sensibility was analyzed in the various groups.

A short account is given on the occurrence of muscular atrophy and of the results of Lasègue's test.

The clinical findings were compared with findings by earlier investigators.

As to the myelographic findings, an account is given of the primary reports and of the postoperative check examination of the preoperative myelograms and comparisons are made with myelograms in previous materials.

The electromyographic examination is described and the electromyographic findings in the patients grouped according to the operative findings are presented. Electromyographic data published by earlier authors, are also reviewed.

In chapter IV the results of the examinations by the 3 diagnostic methods are compared with the operative findings and it was found, among other things, that of the cases in which operation revealed disk herniation or protrusion in group 1, the clinical-neurological diagnosis was correct in 77 %, the myelographic diagnosis was correct in 75.2 %, the electromyographic diagnosis was correct in 78.6 %.

The corresponding figures for group 2 were: clinical-neurological examination 79.2 %, myelography 91.7 %, electromyography 91.7 %, and for the group in which operation revealed no disk changes the figures were: clinical-neurological examination 55 %, myelography 65 %, electromyography 55 %.

The same chapter also gives an account of the ratio between single and combined clinical findings and single and combined electromyographic findings.

Misleading clinical, myelographic and electromyographic findings are then discussed.

Chapter V gives an account of a review of the patients 1 year after the operation with special reference to the results of the operation and the disappearance of the clinical and electromyographic signs. It was found that the results of operation were satisfactory in 93.2 % of group 1 and in 93.1 % of the entire material. At the review it was also found that in only 1 case had the Achilles tendon reflex returned after complete absence and that a weak Achilles tendon reflex became normal again in 26.1 %. As to the patellar reflexes, if they had disappeared completely, they never became normal again, while of 29 in which the reflex was weak, one recovered normal strength. Of the 13 with a paralytical great toe, the toe recovered normal strength in 3, and of the 110 with weakness of the extensors of the great toe before operation 76.4 % recovered normal strength after the operation.

Of the 185 patients, who had electromyographic changes before operation, only 42 had persistent electromyographic changes at the review and 5 had signs of denervation in a single muscle.

In chapter VI an account is given of the ratio between un-

equivocal, positive, diagnostic findings and the operative findings and it was found that in group 1 operation revealed lumbosacral changes in 72.7 % of all patients (44) with an unequivocal Achilles tendon reflex change, or in 72 % of the entire material; operation revealed lumbosacral changes in 74.3 % of all patients (70) in group 1 with definite SI denervation, or in 75.9 % of the entire material; and that if the myelogram showed lumbosacral changes, these changes were confirmed at operation at the same level in group 1 in 91.3 %, or in 92.7 % of the entire material; and that operation revealed changes between LIV and LV in group 1 in 79.2 % of all patients with paresis of the great toe or in 79.3 % of the entire material; operation revealed changes between LIV and LV in 85.5 % of all patients with unequivocal LV denervation in group 1 or in 86.7 % of the entire material. Myelographic changes between LIV and LV were confirmed at operation in the same space in 87.1 % of group 1 and in 87.1 % of the entire material.

In addition, those cases in which operation revealed no disk changes are analysed. Finally, it is given an account of the possibilities of the various diagnostic methods.

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REFERENCES

ABBOT, W. D.: Compression of cauda equina by the ligament flavum. J.A.M.A. 1936, 106, 2129—2130.

ACCORNEO, A.: Observation sur le réflexe achilléen dans la sciatique. Rev. neurol. 1914, 27 (II), 805—807.

ADRIAN, E. D. and BRONK, D. W.: The discharge of impulses in motor nerve fibres: II. The frequency of discharge in reflex and voluntary contractions. J. Physiol. 1929, 67, 119—151.

ADSON, A. W.: Bandscheibenzerreissung mit Prolaps des Nucleus pulposus in den Wirbelkanal als Ursache rezidivierender Ischiae. Der Chirurg 1940, 12, 501.

ADSON, A. W. and OTT, W. O.: Results of the removal of tumors of the spinal cord. Arch. Neurol. & Psychiat. 1922, 8, 520—538.

AITKEN, A.: Rupture of the intervertebral disc in industry, further observations on the end results. Am. J. Surg. 1952, 84, 261—267.

AITKEN, A. P. and BRADFORD, C. H.: End result of ruptured intervertebral discs in industry. Am. J. Surg. 1947, 73, 365—380.

ALAJOUANINE, T. et PETIT-DUTAILLIS, D.: Compression de la queue de cheval par une tumeur d'un disque intervertébral, ablation suivie de guérison. Bull. et mém. Soc. nat. de chir. 1929, 55, 937—945.

— La nodule fibrocartilagineux de la face postérieure des disques intervertébraux. Presse méd. 1930, 38, 937—945.

ANDERSEN, T. och CHROM, S. A.: Luftmyelografi hos ischiaspatienter. Nord. Med. 1942, 14, 1619—1626.

ANDRAE, R.: Über Knorpelknötchen an hinteren Ende der Wirbelbandscheiben im Bereich des Spinalkanals. Beitr. path. Anat. 1929, 82, 464—474.

ARNELL, S.: Weitere Erfahrungen über Myelographie mit Abrodil. Acta Radiol. 1944, 25, 408—413.

— Myelography with water-soluble contrast. Acta Radiol. 1948, suppl. 75.

ARNELL, S. and LIDSTRÖM, F.: Myelography with Skiodan (Abrodil). Acta Radiol. 1931, 12, 187—289.

AYERS, C. E.: Lumbo-sacral backache. New England J. Med. 1929. 200. 592—608.

BABINSKI, J. 1896; quoted by Norlén.

BADGLEY, C. E.: Clinical and roentgenological study of low back pain with sciatic radiation; clinical aspects. Am. J. Roentgenol. 1937, 37, 454—460.

BADGLEY, C. E.: Articular facets in relation to low back apinand sciatic radiation. J. Bone & Joint Surg. 1941, 23, 481—496.

BARR, J. S.: "Sciatica" caused by intervertebral disc lesion. J. Bone & Joint Surg. 1937, 19, 323—342.

— The relationship of the intervertebral disc to back strain and peripheral pain (sciatica). Surgery 1938, 4, 1—12.

— Ruptured intervertebral disc and sciatic pain. J. Bone & Joint Surg. 1947, 29, 429—437.

— Low-back and sciatic pain. Results of treatment. J. Bone & Joint Surg. 1951, 33 A, 633—649.

BARR, J. S., HAMPTON, A. O. and MIXTER, W. J.: Pain low in back and "sciatica" due to lesions of intervertebral discs. J.A.M.A. 1937, 109, 1265—1270.

BARR, J. S. and MIXTER, W. J.: Posterior protrusion of lumbar intervertebral discs. J. Bone & Joint Surg. 1941, 23, 444—456.

BAUMAN, G. I.: The cause and treatment of certain types of low back pain and sciatica. J. Bone & Joint Surg. 1924, 6, 909—914.

BEATON, L. E. and ANSON, B. J.: Sciatic nerve and piriformis muscle; their interrelation possible cause of coccycodynia. J. Bone & Joint Surg. 1938, 20, 686—688.

BIRO, M.: Neuritis ischiadica, neuralgia ischiadica und hysterie. Deutsche Ztschr. f. Nervenh. 1897, 11, 207—229.

BONNER, F. J. and SCHMIDT, W. H.: Electromyography in disc disease. Arch. Phys. med. 1957, 38, 689—691.

BRADFORD, F. K. and SPURLING, R. G.: Intraspinal causes of low back pain: results in sixty consecutive low lumbar laminectomies. Surg., Gynec. & Obst. 1939, 69, 446—459.

— The intervertébral disc. With special reference to rupture of the annulus fibrosus with herniation of the nucleus pulposus. Charles C. Thomas, Springfield, III. II Ed. 1945.

BRAIN, W. R.: Diseases of the nervous system. Humphrey Milford, London 1933, 899 pp.

BRAZIER, M. A. B., WATKINS, A. L. and MICHELSEN, J. J.: Electromyography in differential diagnosis of ruptured cervical disk. Arch. Neurol. & Psychiat. 1946, 56, 651—658.

BROCHER, J. E. W.: Lumbago und Ischias. Eine Pathogenetische Studie. Ztschr. f. klin. Med. 1936, 130, 575—587.

— La sciatique d'origine vertébrale et nerveuse. Helvet. med. acta. 1940, 7, 355—420.

BROWN, G. L.: The actions of acetylcholine on denervated mammalian and frogs muscle. J. Physiol. 1937, 89, 438—461.

BROWN, H. A.: Enlargement of ligamentum flavum; cause of low back pain with sciatic radiation. J. Bone & Joint Surg. 1938, 20, 325—338.

BUCHTAHL, F.: An introduction to electromyography. Kbhvn. Gyldendal. 1957.

BUCY, P. C.: Chondroma of intervertebral disc. J.A.M.A. 1930, 94, 1552—1554.

BUNTS, A. T.: Surgical aspects of ruptured intervertebral disc. Radiol. 1941, 36, 604—616.

BUONO DEL, M. S.: Die lumbale Myelographie zur Diagnose der Diskushernie. Fortschr. Röntgenstr. 1957, 87, 334—342.

BURT, J. B.: Problems in the study of sciatica. Brit. M. J. 1934, 2, 788—789.

BUSCH, E.: Om luftmyelografi ved lumbosacral discusprolaps og ligamentær compression. Ugeskr. f. læger. 1940, 102, 899—902.

BUSCH, E. und CHRISTENSEN, E.: Die lumbalen Pulposushernien. Zentralbl. f. Neurochir. 1936, 1, 53—58.

CAPUA, A.: Encephalography with subarachnoidal injection of thorotrast Radiol. med. 1933, 20, 1376—1378.

CHAMBERLAIN, E. W. and YOUNG, B. R.: The diagnosis of intervertebral disc protrusion by intraspinal injection of air. J.A.M.A. 1939, 113, 2022—2024.

CLARK, D. A.: Muscle counts of motor units; A study in innervation ratios. Am. J. Physiol. 1931, 96, 296—304.

COTUNNII, D.: De ischiade nervosa commentarius. Rudolphum Gräffer, Viennae 1770 (1764).

CRAIG, W. McK.: The present status of the protruded disc. Compt. rend. III Congrès Neurolog. Intern. Copenhagen 1939, 752—754.

CRAIG, W. McK. and WALSH, M. N.: Neuro-anatomical and physiological aspects and significance of sciatica. J. Bone & Joint Surg. 1941, 23, 417—434.

CRUE, B. L., PUDENZ, R. H. and SHELDEN, C. H.: Observations on the value of clinical electromyography. J. Bone & Joint Surg. 1957, 39 A, 492—500.

DANDY, W. E.: Ventriculography following injection of air into cerebral ventricles. Ann. Surg. 1918, 68, 5.

— Loose cartilage from intervertebral disc simulating tumour of the spinal cord. Arch. Surg. 1929, 19, 660—672.

— Concealed ruptured intervertebral discs. J.A.M.A. 1941, 117, 821—823.

— Improved localization and treatment of ruptured intervertebral discs. J.A.M.A. 1942, 120, 605—660.

— Recent advances in the treatment of ruptured (lumbar) intervertebral discs. Ann. Surg. 1943, 118, 639—645.

— Recent advances in diagnosis and treatment of ruptured intervertebral discs. Am. J. Surg. 1947, 115, 514—520.

DANFORTH, M. S. and WILSON, P. D.: The anatomy of the lumbosacral

region in relation to sciatic pain. J. Bone & Joint Surg. 1925, 7, 109—160.

DAUM, H. F., SMITH, A. B., WALKER, J. W., CHAPMAN, S. B. and EVERSMAN, G. H.: Protrusions of the lumbar disc; A correlation of the radiographic diagnoses and surgical findings. Southern Med. J. 1959, 52, 1479—1484.

DEJERINE, J.: Les radiculites. Rev. neurol. 1916, 29, 321—348.

— Semiologie des affections du système nerveux. Masson et Cie, Paris 1926, 1219 pp.

DEJERINE, J. et REGNARD, M.: Sciatique radiculaire avec paralysie dissociée des muscles antero-externes de la jambe droite. Intégrité du jambier antérieur. Anesthésie dans le territoire de S.-I. Rev. neurol. 1912, 23, 288—290.

DENNY-BROWN, D.: On the nature of postural reflexes. Proc. Roy. Soc. London, 1929, 61, 99—128.

DENNY-BROWN, D. and PENNYBACKEER, J. B.: Fibrillation and fasciculation in voluntary muscle. Brain. 1938, 61, 311—334.

DUBARRY, L. C. L. R.: Contribution à l'étude de la sensibilité cutanée dans la névralgie sciatique. P. Cassignol, Bordeaux 1902, 94 pp.

ECCLES, J. C. and SHERRINGTON, C. S.: Numbers and contraction-valves of individual motor-units examined in some muscles of the limb. Proc. Roy. Soc. London. 1930, 106, 326—357.

EKVALL, S.: Enquête clinique, au printemps de 1938, sur les cas de sciatique observés durant les années 1933 et 1934. Acta Med. Scand. 1939, 101, 1—33.

ELSBERG, C. A.: Experiences in spinal surgery. Surg., Gynec. & Obst. 1913, 16, 117—132.

— Diagnosis and treatment of surgical disease of the spinal cord and its membranes. N. B. Saunders & Co, Philadelphia and London 1916.

— Tumours of the spinal cord. Paul B. Hoeber, New York 1925.

— Extradural ventral chondromas (ecchondroses), their favorite sites, spinal cord and root symptoms they produce, and their surgical treatment. Bull. Neurol. Inst. New York 1931, 1, 350—388.

— Surgical diseases of the spinal cord, membranes and nerve roots. H. K. Lewis and Co, London. 1942, 598 pp.

FASSBENDER, C. W., HÄUSSLER, G. und STÖSSEL, H. G.: Über die Ergebnisse der Abrodil-Myelographie beim lumbalen Bandscheibenvorfall. Fortschr. Röntgenstr. 1958, 89/5, 574—578.

FELTSTRÖM, E.: Myelografi med abrodil. Nord. Med. 1942, 14, 1652—1655.

FERNET, C.: De la sciatique et de sa nature. Arch. gén. d. méd. 1878, 1, 385—403.

FINCHER, E. F.: Neurologic aspects of low back pain and sciatica. Ann. Surg. 1939, 109, 1028—1033.

FLORES, A.: Compression médullaire progressive à 6 ans de durée par

hyperplasie du ligament jaune consécutive à fracture d'une lame vertébrale; Laminectomie guérison. Rev. neurol. 1923, 30, 664—667.

FOERSTER, O.: Symptomatologie der Erkrankungen des Rückenmarks und seiner Wurzeln. Im Bunke und Foerster, Handbuch der Neurologie 1936, 5, 1—403.

FORD, L. T. and KEY, J. A.: An evaluation of myelography in the diagnosis of intervertebral disc lesions in the low back. J. Bone & Joint Surg. 1941, 23, 417—434.

FORD, L. T., RAMSEY, R. H., HOLT, E. P. and KEY, J. A.: An analysis of 100 consecutive lumbar myelograms followed by disc operations for relief of low-back pain and sciatica. Surgery 1952, 32, 961—966.

FORESTIER, M. H.: Pathogénie sacro-vertébrale de certaines sciatiques. Bull. gén. de thérap. 1914, 167, 484—492.

FREIBERG, A. H.: Sciatic pain and its relief by operations on muscle and fascia. Arch. Surg. 1937, 34, 337—350.

FREIBERG, A. H. and VINKE, T. H.: Sciatica and sacro-iliac joint. J. Bone & Joint Surg. 1934, 16, 126—136.

FRIBERG, S.: Low back and sciatic pain caused by intervertebral disc herniation. Acta Chir. Scand. 1941, 85, suppl. 64, 1—114.

FRIBERG, S. and HIRSCH, C.: On late results of operative treatment for intervertebral disc prolapses in the lumbar region. Acta Chir. Scand. 1946, 93, 161—168.

FRIBERG, S. and HULT, L.: Comparative study of abrodil myelogram and operative findings in low back pain and sciatica. Acta Orthop. Scand. 1951, 20, 303—314.

GALVANI, L.: De viribus electricitatis in motu musculari commentarius. Memoirs of the Institute of Sciences, Bologna, Italy 1791, 7.

GARA, S.: Über ein bisher unbekanntes pathognomonisches Symptom der Ischias. Wien med. Wchnschr. 1907, 57, 1135—1139.

GHORMLEY, R. K.: Low back pain. J.A.M.A. 1933, 101, 1773—1777.

GOLDTHWAIT, J. E.: The lumbo-sacral articulation. An explanation of many cases of lumbago, sciatica and paraplegia. Boston Med. and Surg. J. 1911, 164, 365—372.

GOLDTHWAIT, J. E. and OSGOOD, R. B.: A consideration of the pelvic articulations from an anatomical, pathological and clinical standpoint. Boston Med. and Surg. J. 1905, 152, 593—601, 634—638.

GOLSETH, J. G.: Diagnostic contributions of the electromyogram. Calif. Med. 1950, 73, 355—357.

GOLSETH, J. G. and FIZZELL, J. A.: Electromyographic studies on cats after section and suture of the sciatic nerve. Am. J. Physiol. 1947, 150, 558—567.

GOWERS, W. R.: A manual of diseases of the nervous system. London J. & A. Churchill 1892, vol. I, 101—108.

GUINON, G. and PARMENTIER, E.: Sur une complication peu connue de la sciatique. Arch. d. neurol. 1890, 20, 145—186.

VON HAGEN, K. O.: The clinical application of electromyography to lower motor neuron and muscular disorders. Bull. Los Angeles Neur. Soc. 1955, 20, 131—138.

HAGGART, G. E.: Sciatic pain of unknown origin, effective method of treatment. J. Bone & Join Surg. 1938, 20, 851—859.

HANRAETZ, P. R. M. J.: The degenerative back. Elsevier Publ. Co. Amsterdam 1959.

HELLEDAY, U.: On myitis chronica. Nord. Med. Ark. 1876, 8, 1—17.

HELWEG, J.: Ischias, en klinisk studie. Koebenhavn, Henrik Koppel, 1920, 272 pp.

HERRLIN, L.: The lateral fifth lumbar root syndrome in sciatica. Opusc. Med. 1958, 3, 85—91.

HEUMAN, G.: Muskelreumatism. Sv. läk.tidn. 1920, 17, 185—194.

— Än en gång sjukdomar i ryggraden såsom orsak till lumbago och ischias. Sv. läk.tidn. 1920, 17, 457—460.

HIBBS, R. A. and SWIFT, W. E.: Developmental abnormalities at the lumbosacral juncture causing pain and disability. Surg., Gynec. & Obst. 1929, 48, 604—612.

HIRSCH, C.: Intervertebral foraminotomy. Acta Chir. Scand. 1946, 94, 75—80.

— The clinical evaluation of sciatica. Acta Orthop. Scand. 1958, 27, 210—218.

HOEFER, P. F. A. and GUTTMAN, S. A.: Electromyography as a method for determination of level of lesions in the spinal cord. Arch. Neurol. & Psychiat. 1944, 51, 415—422.

HOEFER, P. F. A. and PUTNAM, T. J.: Action potentials of muscles in normal subjects. Arch. Neurol. & Psychiat. 1939, 42, 201—218.

HUBERT-VALLEROUX, 1870; quoted by Dubarry.

HUDDLESTON, O. L. and GOLSETH, J. G.: Electromyographic studies of paralyzed and paretic muscles in anterior poliomyelitis. Arch. Phys. Med. 1948, 29, 92—98.

INGVAR, S.: On the nature of myalgia. Acta Rheum. 1936, 8, 30—31.

JACOBI, W., LÖHR, W., and WUSTMAN, O.: Über die Darstellung des zentralen und peripheren Nervensystems im Röntgenbild. Leipzig, J. A. Barth 1934.

JASPER, H. H.: Report to Associate Committee on Army Medical Research, National Research Council, C-6239. Canada Montreal Neurological Institute, McGill University 1945.

JASPER, H. H. and JOHNSTON, R. H.: A portable clinical electromyograph: Report to Associate Committee on Army Medical Research, National Research Council. Canada Montreal Neurological Institute, McGill University 1945.

JOHANSSON, C. E.: Discusprolapser ur röntgenologisk synpunkt. Nord. Med. 1947, 36, 249.

— Results of myelographies with water soluble media. Acta Chir. Scand. 1949, 99, 560—567.

KEEGAN, J. J.: Dermatome hypalgesia associated with herniation of intervertebral disc. Arch. Neurol. & Psychiat. 1943, 50, 67—83.

KELLGREN, J. H.: Preliminary account of referred pains arising from muscle. Brit. M. J. 1938, 1, 325—327.

KEY, C. A.: On paraplegia depending on the ligaments of the spine. Guy's Hosp. Rep. 1838, 17, 37.

KIMBERLEY, A. G.: Low back pain and sciatica, its etiology, diagnosis and treatment. Surg., Gynec. & Obst. 1937, 65, 195—216.

KLEINBERG, S.: Sciatic scoliosis due to low backache. Am. J. Surg. 1929, 7, 89—94.

KNUTSSON, B.: Electromyographic studies in the diagnosis of lumbar disc herniations. Acta Orthop. Scand. 1959, 28, 290—299.

KNUTSSON, B. and WIBERG, G.: On surgically treated herniated intervertebral discs. Acta Orthop. Scand. 1958, 28, 108—123.

KNUTSSON, F.: Lumbar myelography with water-soluble contrast in cases of disc prolapse. Acta Orthop. Scand. 1951, 20, 294—302.

KOCHER, T.: Die Verletzungen der Wirbelsäule zugleich als Beitrag zur Physiologie des menschlichen Rückenmarks, Mitt. Grenzgeb. Med. und Chir. 1896, 1, 415—480.

KOLSTAD, P. og SOLEM, G. H.: Myelografi med vannopplöselig kontrastmiddel, en analyse av 427 myelografier. Nord. Med. 1959, 61, 306—309.

KUGELBERG, E.: Electromyograms in muscular disorders. J. Neurol., Neurosurg. & Psychiat. 1947, 10, 122—128.

KUGELBERG, E. and PETERSÉN, J.: Muscle weakness and wasting in sciatica due to fourth lumbar or lumbosacral disc herniations. J. Neurosurg. 1950, 7, 270—277.

LANDOUZY, L.: De la sciatique et de l'atrophie musculaire qui peut la compliquer. Arch. gen. d. méd. 1875, 1, 303—325, 424—443, 562—578.

LANGLEY, J. N. and KATO, T.: The physiological action of physostigmine and its action on denervated skeletal muscle. J. Physiol. 1915, 49, 410—431.

LANSCHE, W. E. and FORD, L. T.: Correlation of the myelogram with clinical and operative findings in lumbar disc lesions. J. Bone & Joint Surg. 1960, 42 A, 193—206.

LASEGUE, C.: Considérations sur la sciatique. Arch. gén. d. méd. 1864, 2, 558—580.

LASSILA, Y.: Luftmyelographische Befunde bei Ischiassyndrom verursachenden Bandscheiben Prolapsen. Acta Soc. Medic. fenn. Duodecim. Ser. B. 1942, 32, 3, 1—79.

LEKSELL, L.: Thorotrastmyelografi. Nord. Med. 1943, 20, 2453—2454.

LENHARD, R. E.: End-result study of the intervertebral disc. J. Bone & Joint Surg. 1947, 29, 425—428.

LÉRI, A. et SCHAEFFER: Sciatiques et lymphocytose; la sciatique vulgaire, rheumatismale, est généralement d'origine radiculaire; le rôle des canaux sacrés antérieurs. Bull. et mém. Soc. méd. d. hôp. de Par. 1916, 40, 680—686.

LEWIS, T.: Pain. New York, Macmillan Co 1942, 192 pp.

LINDBLOM, K.: Eine anatomische Studie über lumbale Zwischenwirbelscheibenprotrusionen und Zwischenwirbelscheibenbrüche in die Foramina intervertebralia hinein. Acta Radiol. 1941, 22, 711—721.

— Lumbala diskprolapser vid foramina intervertebralia. Nord. Med. 1942, 16, 3597—3598.

— Lumbar myelography by Abrodil. Acta Radiol. 1946, 27, 1—7.

LINDGREN, E.: On the diagnosis of tumours of the spinal cord by the aid of gasmyelography. Acta Chir. Scand. 1939, 82, 303—318.

— Myelography with air. Acta psychiat. et neurol. 1939, 14, 385—388.

LINDSLEY, D. B.: Electrical activity of human motor units during voluntary contaction. Am. J. Physiol. 1935, 114, 90—99.

LINDSTEDT, F.: Über Ätiologie und Pathogenese der Ischias. Acta Med. Scand. 1920, 53, 318—380.

— Über Ätiologie und Pathogenese der Ischias und Lumbago nebst einer neuen Anschauungsweise dieser Neuralgien. Ztschr. f. klin. Med. 1922, 93, 179—216.

— Om ischias- och myalgiproblemet och därmed sammanhängande frågor om neuralgiernas natur. Sv. läk.tidn. 1937, 34, 457—468.

LJUNGDAHL, M.: Nerv- och muskelsymptom vid deformerande arthriter. Sv. läk.tidn. 1919, 16, 833—849.

LOOFBOURROW, G. N.: Electrographic evaluation of mechanical response in mammalian skeletal muscle in different conditions. J. Neurophysiol. 1948, 11, 153—167.

LORTAT-JACOB, L. et SABARÉANU, G.: Sciatique radiculaire unilatérale. Presse méd. 1904, 2, 633—635.

LOVE, J. G.: Protruded intervertebral discs; with note regarding hypertrophy of ligamentum flavum. J.A.M.A. 1939, 113, 2029—2034.

— The disc factor in low back pain with or without sciatica. J. Bone & Joint Surg. 1947, 29, 438—447.

LOVE, J. G. and CAMP, J. D.: Root pain resulting from intraspinal protrusion of intervertebral discs: diagnosis and surgical treatment. J. Bone & Joint Surg. 1937, 19, 776—804.

LOVE, J. G. and WALSH, M. N.: Protruded intervertebral discs. J.A.M.A. 1938, 111, 396—400.

— Intraspinal protrusion of intervertebral discs. Arch. Surg. 1940, 40, 454—484.

LOVE, J. G. and WALSH, M. N.: Protruded intervertebral discs. Surg., Gynec. & Obst. 1943, 77, 497—504.

LUCHERINI, T.: Radiculomyelography with thorotrast. Riv. osp. 1934, 24, 475—484.

LUSCHKA, H.: Die Halbgelenke des menschlichen Körpers. Berlin, Georg Reimer, 1858, 144 pp.

MACEY, H. B.: Clinical aspects of protruded intervertebral disk. Arch. Surg. 1940, 40, 433.

MACK, E. W.: Electromyographic observations on the postoperative disc patient. J. Neurosurg. 1951, 8, 469—472.

MACKENZIE, J.: Some points bearing on the association of sensory disorders and visceral disease. Brain, 1893, 16, 321—354.

MALMROS, R.: Den lumbale discusprolaps og ligamentære rodkompression. Kbh Munksgaard 1942.

MARINACCI, A. A.: The value of electromyography in neurology. Calif. Med. 1954, 80, 314—315.

— Clinical electromyography. Calif. San Lucas Press 1955.

— The use of electromyography in the differential diagnosis of lumbar herniated disks. Bull. Los Angeles Neurol. Soc. 1958, 23, 65—71.

MAYERDING, H. W.: Spondylolisthesis as an etiologic factor in backache. J.A.M.A. 1938, 111, 1971—1976.

— Low backache and sciatic pain associated with spondylolisthesis and protruded intervertebral disc: incidence, significance and treatment. J. Bone & Joint Surg. 1941, 23, 461—470.

MENDEHLSOHN, R. A. and SOLA, A.: Electromyography in herniated lumbar disks. A. M. A. Arch. Neur. Psychiat. 1958, 79, 142—145.

MIDDLETON, G. S. and TEACHER, J. H.: Injury of the spinal cord due to ruptures of an intervertebral disc. Glasgow Med. J. 1911, 76, 1—6.

MIXTER, W. J. and BARR, J. S.: Rupture of intervertebral disc with involvement of spinal canal. New England J. Med. 1934, 211, 210—215.

NAFFZIGER, H. C., INMAN, V. and SAUNDERS, I. B.: Lesions of the intervertebral disc and lig. flava. Surg., Gynec. & Obst. 1938, 66, 288—299.

NICHOLS, B. H. and NOSIC, W. A.: Myelography with the use of thorium dioxid solution (thorotrast) as a contrast medium. Radiol. 1940, 35, 459—466.

NORDENTOFT, J. M.: Om myelografi med abrodil. Nord. Med. 1944, 21, 255—257.

NORLÉN, G.: On the value of the neurological symptoms in sciatica for the localization of a lumbar disc herniation. Acta Chir. Scand. 1944, 91, suppl. 95.

— Om behandling av artrosis deformans coxae med rotavskärning. Sv. läk.tidn. 1944, 41, 661—665.

NOTTA, A.: Mémoire sur les lésions functionelles qui sont sous la dépendance des névralgies. Arch. gén. d. méd. 1854, 2, 552—557.

O'CONNELL, J. E. A.: Sciatica and mechanism of production of clinical syndrome in protrusions of lumbar intervertebral discs. Brit. J. Surg. 1943, 30, 315—327.

— Clinical diagnosis of lumbar intervertebral disc protrusions with indications for their operative removal. Brit. M. J. 1946, 4438, 119.

— The indication for and results of the excision of lumbar intervertebral disc protrusions: A review of 500 cases. Ann. Roy. Coll. Surg. Engl. 1950, 6, 403—412.

ODIN, M., RUNSTRÖM, G. and LINDBLOM, A.: Iodized oil as an aid to the diagnosis of lesions of the spinal cord and a contribution to the knowledge of adhesive circumscript menigitis. Acta Radiol. 1929, suppl. 7.

OLIVECRONA, H.: The operative procedure in intervertebral disc protrusions. Acta Radiol. 1941, 22, 743—748.

OPPENHEIM, H.: Lehrbuch der Nervenkrankheiten. Berlin, S. Karger. 1908, 1, 695 pp.

OPPENHEIM, H. and KRAUSE, F.: Über Einklemmung bzw. Strangulation der Cauda equina. Deutsche med. Wchnschr. 1909, 35, 697—700.

PENNYBACKER, J.: Sciatica and the intervertebral disc. Lancet 1940, 1, 771—777.

PETIT-DUTAILLIS, D. and DE SÈZE, B.: Sciatiques et lombalgies par hernie postérieure des disques intervertébraux. Masson, Paris 1945.

PETRÉN, K.: Några erfarenheter om ischias och malum coxae senile samt deras behandling. Nord. tidskr. f. terapi. 1908, 7, 3—16, 33—50.

— De perifera nervernas sjukdomar. I Faber, Holst, Petrén: Lärobok i intern medicin. Köpenhamn Gyldendalske Boghandel 1916, II: 2, 234—305.

PHULPIN, E.: La sciatique. Paris, G. Steinheil. 1895, 87 pp.

PITKIN, H. C. and PHEASANT, H. C.: Sacarthrogenetic telalgia. J. Bone & Joint Surg. 1936, 18, 111—133, 365—374, 706—716.

PROEBSTER, R.: Über Muskelaktionsströmme am gesunden und kranken Menschen. Ztschr. f. ortopäd. Chir. 1928, 50, 1.

PUTTI, V.: New conceptions in pathogenesis of sciatic pain. Lancet, 1927, 2, 53—60.

PUUSEPP, L.: Kompression der Cauda equina durch das verdickte ligamentum flavum. Tumorsymptome, Operation, Heilung. Folia neuro-path. Estonania 1932, 12, 38—48.

RADOVICI, A. and MELLER, O.: Encephalomyelography with subarachnoid and epidural injections of thorotrast. Experimental studies. Compt. rend. Soc. de biolog. 1932, 109, 1392—1394.

REFSLUND POULSEN, B.: Luftmyelografi ved den lumbale discusprolaps. Nord. Med. 1943, 18, 776—788.

VON REIS, G.: Pain in the distribution-area of the 4th lumbar root. Acta Psychiat. et Neurol. 1945, suppl. 36, 135 pp.

VON REIS, G., SAHLGREN, E. and SJÖQVIST, O.: En operationsmetod vid arthrosis deformans coxae. Nord. Med. 1944, 21, 557—559.

ROGER, H.: Les sciatiques; formes cliniques et traitement des sciatiques rhumatismales. Rev. neurol. 1930, 1, 1032—1096.

ROGERS, M. H.: Sciatica: etiology and treatment. Boston M. & S. J. 1911, 165, 760—762.

ROMBERG, M. H.: Lehrbuch der Nervenkrankheiten. Berlin, Alexander Duncker. 1853, I: 1, 327 pp.

ROSS, P. and JELSMA, F.: Postoperative analysis of 366 consecutive cases of herniated lumbar discs. Am. J. Surg. 1952, 84, 657—662.

ROUSSET, 1804; quoted by Dubarry.

RÖVIG, G.: Rupture of lumbar discs with intraspinal protrusion of the nucleus pulposus. Acta Chir. Scand. 1949, suppl. 144.

SAHLGREN, E.: Beror ischias alltid på lokal affektion av rot eller nerv? Sv. läk.tidn. 1942, 39, 1137—1146.

— Nye synpunkter på lumbago-ischiasproblemet. Nord. Med. 1946, 29, 505.

SASHIN, D.: Critical analysis of anatomy and pathologic changes in sacro-iliac joints. J. Bone & Joint Surg. 1930, 12, 891—910.

SCHIFF, M.: Über motorische Lähmung der Zunge. Arch. f. Physiol. Heilkunde. 1851, 10, 579—593.

SCHMORL, G.: Über die an den Wirbelbandscheiben vorkommenden Ausdehungs- und Zerreissungsvorgänge und die dadurch an ihnen und der Wirbelspongiosa hervorgerufenen Veränderungen. Verhandl. d. deutsch. path. Gesellsch. 1927, 22, 250—262.

— Über Knorpelknötchen an der Hinterfläche der Wirbelbandscheiben Fortschr. Röntgenstr. 1929, 40, 629—634.

SCHMORL, G. und JUNGHANS, H.: Die gesunde und kranke Wirbelsäule im Röntgenbilde. Leipzig, Georg Thieme 1932.

SCHOBER, P.: Kritische Betrachtungen über das Laseguesche Zeichen und die sogenannte Ischias. Deutsche med. Wchnschr. 1940, 66, 1269—1271.

SCOTT, W. G. and FURLOW, L. T.: Myelography with pantopaque and a new technique for its removal. Radiol. 1944, 43, 241—249.

SENNING, Å. och SJÖQVIST, O.: Senresultaten vid diskbråck. En efterundersökning av 400 opererade fall. Nord. Med. 1947, 34, 1128—1129.

DE SÈZE, S.: Sciatique «basale» et disques lombo-sacrés. Presse méd. 1940, 48, 570—575.

SHEA, P. A. and WOODS, W. W.: Electromyography as an aid in clinical diagnosis. A. M. A. Arch. Int. Med. 1955, 96, 787—793.

— The diagnostic value of the electromyograph. Brit. J. Phys. Med. 1956, Febr., 1—8.

SHEA, P. A., WOODS, W. W. and WERDEN, D. H.: Electromyography in

diagnosis of nerve root compression syndrome. Arch. Neurol. & Psychiat. 1950, 64, 93—104.

SHERRINGTON, C. S.: Note on the knee-jerk and the correlation of action of antagonistic muscles. Proc. Roy. Soc. 1893, 52, 556.

SHINNERS, B. M. and HAMBY, W. B.: The results of surgical removal of protruded lumbar intervertebral discs. J. Neurosurg. 1944, 1, 117—122.

SICARD, J. A.: Névrodocites et funiculites vertébrales. Presse méd. 1918, 26, 9—11.

SICARD, J. A. et FORESTIER, J. E.: Méthode radiographique d'exploration de la cavité epidurale par le lipiodol. Rev. neurol. Par. 1921, 28, 1264—1266.

SJÖQVIST, O.: De lumbala diskbråckens klinik, diagnos samt exstirpation utan laminectomi. Nord. Med. 1942, 13, 687—693.

SMITH, A. DE F.: Posterior displacement of fifth lumbar vertebra. J. Bone & Joint Surg. 1934, 16, 877—888.

SMITH-PETERSEN, M. N. and ROGER, W. A.: End-result study of arthrodesis of the sacro-iliac joint for arthritis, traumatic and nontraumatic. J. Bone & Joint Surg. 1926, 8, 118—131.

SPURLING, R. G. and BRADFORD, F. K.: Neurologic aspects of herniated nucleus pulposus at the fourth and fifth lumbar interspace. J.A.M.A. 1939, 113, 2019—2022.

SPURLING, R. G. and GRANTHAM, E. G.: Neurologic picture of herniations of nucleus pulposus in lower part of lumbar region. Arch. Surg. 1940, 40, 375—388.

SPURLING, G. R., MAYFIELD, F. H. and ROGERS, J. B.: Hypertrophy of ligamenta flava as cause of low back pain. J.A.M.A. 1937, 109, 928—933.

STAINDLER, A.: Interpretation of sciatic radiation and syndrome of low back pain. J. Bone & Joint Surg. 1940, 22, 28—34.

STENSTRÖM, R.: Widening of the root defect in lumbar myelogram by abrodil. Acta Radiol. 1948, 29, 303.

STENSTRÖM, T.: Eine klinische Studie über „Neuritis"-Symptome bei Ischias. Acta psychiat. et neurol. 1931, 6, 593—644.

STERNBERG, 1893; quoted by Norlén.

STURSBERG, H.: Über Wurzelischias. München. med. Wchnschr. 1910, 57, 1776—1780.

STÅHL, F.: Clinical diagnosis of lumbar disc herniations. Acta Orthop. Scand. 1949, 18, 141—152.

TOWNE, E. B. and REICHERT, F. L.: Compression of lumbosacral roots of spinal cord by thickened ligamenta flava. Ann. Surg. 1931, 94, 327—336.

WAGNER, L. C.: Congenital defects of lumbosacral joints, with associated nerve symptoms. Am. J. Surg. 1935, 27, 311—327.

WALK, L.: Slight myelographic deformities in sciatica. Acta Radiol. 1958, 50, 226—229.

VALLEIX, F. L. I.: Traité des neuralgies. Paris, J. B. Baillière. 1841, 480—647.

WARIS, W.: Lumbar disc herniation. Acta Chir. Scand. 1949, suppl. 140.

WEDDELL, G., FEINSTEIN, B. and PATTLE, R. E.: The electrical activity of voluntary muscle in man under normal and pathological conditions. Brain. 1944, 67, 178—257.

WERTHEIM-SALOMONSON, J. K. A.: Neuralgie und Myalgie. In Lewandowsky, Handbuch der Neurologie. 1911, 2, 1—50.

WIBERG, G.: Prolaps av intervertebraldisken som orsak till ischias. Uppsala läkaref. förh. 1943, 48, 415—431.

WILLIAMS, P. C.: Reduced lumbosacral joint space; its relation to sciatic irritation. J.A.M.A. 1932, 99, 1667—1682.

WORINGER, E., THOMALSKE, G. und BAUMGARTNER, J.: Die Myelographie mit wasserlöslichem Kontrastmittel in der Diagnose des lumbo-sacralen Bandscheibenprolapses. Bericht über 600 Fälle. Nervenartzt. 1956, 27, 547—552.

YASKIN, C. and FINKELSTEIN, A.: Low back and leg pains; clinical considerations. Clinics 1944, 3, 261—308.

YEOMAN, W.: Relation of arthritis of sacro-iliac joint to sciatica. Lancet, 1928, 2, 1119—1122.

YOUNG, B. R. and SCOTT, M.: Air myelography, substitution of air for lipiodol in roentgen visualization of tumours and other structures in spinal canal. Am. J. Roentg. 1938, 39, 187—192.

ÅKERBLOM, N. V.: Bidrag till diskussion om behandling av ischias. Nord. tidsskr. f. terapi. 1908, 7, 148—151.