FROM THE ORTHOPAEDIC CLINIC, LUND. CHIEF: PROF. GUNNAR WIBERG

ELECTROMYOGRAPHIC STUDIES IN THE DIAGNOSIS OF LUMBAR DISC HERNIATIONS

By

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The diagnosis "herniated disc" is based primarily on the presence of symptoms and signs caused by the hernia pressing on a nerve root. The symptoms and signs vary according to the nerve root affected, or, in other words, according to the level of the hernia. The level is mainly diagnosed by clinical neurological examination, and, if the results of this examination for some reason are doubtful, such as when the symptoms suggest compression of two nerve roots, or if no neurological signs are demonstrable, the level may be diagnosed by myelography. In recent years a third diagnostic method has become available, namely the electromyography.

The application of electromyography in human neurological disorders was described in 1938 by *Denny-Brown* and *Pennybacker*. Among the first to report the use of electromyography in the diagnosis of intervertebral nerve root pressure were *Shea, Woods* and *Werden* (1950). They showed that of 60 operated lumbar disc herniations, electromyography had proved the diagnosis in 90 per cent and had failed in 10 per cent. Myelography was done in 55 cases with a correct diagnosis in 87.3 per cent. The same authors published (1956) a larger material: 354 cases with a correct electromyographic diagnosis in 91.8 per cent. Myelography was performed in 287 cases with a correct diagnosis in 79.7 per cent. *Marinacci* (1955) reported 71 cases of lumbosacral herniations of the intervertebral disc in which the electromyographic findings agreed with the operative findings in 94.3 per cent. He also described 57 cases of herniations of the disc between the 4th and 5th lumbar vertebrae in which electromyography had shown the exact location of the lesion in 92.9 per cent. None of these authors

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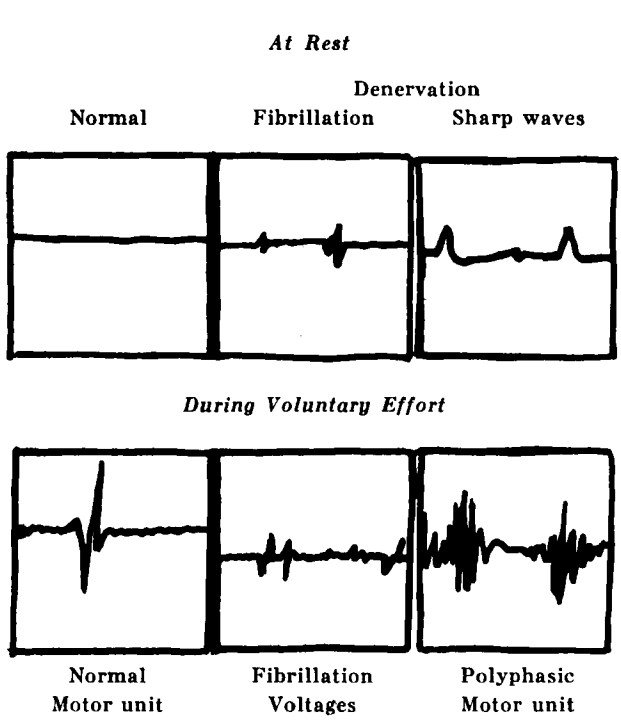

Fig. 1.
Electromyograms, showing characteristic voltages of normal and denervated voluntary muscle.

draw comparisons with the clinical neurological findings. Myelography is not done routinely but only in part of the cases. Nor are the incorrect electromyograms discussed.

The clinical electromyograph is an instrument containing a high gain, low noise, balanced amplified system, driving a cathode ray oscilloscope and a loud speaker. Connected to this system are needle electrodes, which are inserted directly into the muscle fibers to be tested. The examinations are conducted in a darkened room, so as better to visualize the wave forms on the oscilloscope screen. The patient is placed on an examination table in a comfortable position, no premedication is given. The skin is prepared with an antiseptic, and the needle electrodes are inserted into the muscle to be tested.

When a normal muscle at rest is tested by electromyography (EMG) no electrical activity is recorded visually or acoustically. If, however, a skeletal muscle has been denervated for example by compression of the spinal nerve root innervating that muscle, abnormal action poten-

tials are observed. Approximately three weeks after a nerve root has been injured, a physiological phenomenon known as fibrillation occurs in the resting muscle. These spontaneous abnormal action potentials are visualized in the cathode ray oscilloscope as monophasic and diphasic spikes or as sharp waves. They recur rhythmically. In addition to the unmistakable wave forms seen on the screen, there is a characteristic high-pitched, clicking sound which is heard through the loud speaker.

Muscles	Myotome
Quadriceps femoris Tibialis anterior Erector spinae (at the level of L IV–L V vertebrae)	The L IV-myotome
Tibialis anterior Extensor hallucis and digitorum longus Lateral head of gastrocnemius The peronealgroup Hamstrings Tensor fascia lata Gluteus medius Erector spinae (at the level of the lumbosacral interspace)	The L V-myotome
Medial head of gastrocnemius Soleus Hamstrings Gluteus maximus Erector spinae (at the level of S I–S II vertebrae)	The S I-myotome

Fig. 2.
The myotomes.

With active contraction a normally innervated muscle will yield a simple wave (monophasic, diphasic, triphasic). This apparently results from the synchronous contraction of the motor unit. A degenerated muscle on the contrary will contract in an asynchronous manner and thereby produce an unmistakable polyphasic, or complex wave. Waves of this form produce a characteristic sound resembling the strained, chugging sound of an old four-cylinder automobile engine.

The basis of the electromyographic localization of a single nerve root lesion is the finding of denervation fibrillation in those muscles supplied specifically by the nerve root involved and in no other muscles.

An isolated muscle may have multiple nerve root innervation, it will, however, show denervation fibrillation only together with those other muscles that are innervated by the same compressed nerve root. This group of muscles is called a myotome. It is thus necessary to test the entire myotome.

Electromyographic Localization of Lesions of Lumbosacral Nerve Roots.

Muscles tested	Root innervation	Location of lesion as indicated by degree of denervation fibrillation		
		L IV	L V	S I
Quadriceps femoris	L IV	+++	—	—
Tibialis anterior	L IV, L V	++	+++	—
Extensor hallucis long.				
Peroneus long.	L IV, L V	+	++	—
Lateral head of gastrocnemius	L V, (S I)	—	+++	(+)
Medial head of gastrocnemius	(L V), S I	—	(+)	+++
Soleus	S I	—	—	+++

Fig. 3.
Electromyographic Localization of Lesions of L IV-, L V- and S I-Nerve Roots.

To illustrate this, let us assume that the first sacral nerve root is compressed by a herniated disc. The needle electrode is placed successively into the quadriceps femoris (L IV) and no evidence of denervation is found. Progressing, the tibialis anticus (L IV, L V) is tested and again no denervation fibrillation voltages are picked up. However, in the gastrocnemius (L V, S I) numerous denervation fibrillation voltages are demonstrated. Similarly in the soleus (S I, S II) the EMG reveals evidence of denervation. Since we have demonstrated that the muscles supplied by the 4th and 5th lumbar nerve root are not involved, whereas the muscles partially innervated by S I are, the lesion must be compressing this root. Finally, denervation is found in the erector spinae thus proving that the root and not a portion of the lumbosacral plexus is implicated.

At the Department of Orthopaedics, Lund, EMG has now been used routinely in the examination of patients with herniated intervertebral disc since the first of January 1958. Electromyographic examination is made independently and without previous knowledge of the clinical or myelographic diagnosis. In other words the decision of the electromyographer is not influenced by previous diagnostic procedures. The

clinical neurologic, myelographic and electromyographic signs are then compared with the operative findings.

In 24 patients with lumbosacral disc herniation the electromyogram was correct in all the 24 cases and myelography was correct only in 14 of the cases, and among the neurological signs the Achilles tendon reflex was weak or absent in 18 cases.

Herniated or protruded disc found at operation between:	EMG		Myelography		Neurological signs		
	Correct	Incorrect	Correct	Incorrect	Correct	Misleading	Normal
L V – S I	24	–	14	10	18	4	2
L IV – L V	27	4*	26	4	18	6	7
L III – L IV	1	–	1	–	1	–	–
No herniation found at operation	3	1	4	–	1	3	See correct
Total	55	5	45	14	38	13	9

* 3 of the incorrect electromyograms showed denervation of the S I-myotome. In all these 3 cases a herniation was found between L IV- L V vertebrae but it was the S I-nerve root that was affected.

1 of the incorrect electromyograms did not show any denervation but in this case the patient had had symptoms only 10 days.

Fig. 4.
Comparison of Electromyographic, Myelographic, Neurological and Operative findings.

In 31 cases of intervertebral disc herniation between the 4th and 5th lumbar vertebrae I found a correct electromyogram in 27 cases, but an incorrect one in 4 cases. Myelography had demonstrated herniation between the 4th and 5th lumbar vertebrae in 26 of 30 cases but missed in 4. Myelography was not done in one case. In 18 out of 31 cases I found among the neurological signs a paresis of the great toe. Now to the 4 incorrect electromyograms:

In 3 of the incorrect cases, the electromyogram suggested involvement of the first sacral nerve root, whereas myelograms as well as the operative findings showed the compressive lesion to be at the level of the 4th lumbar intervertebral space. On reviewing the myelographic and the operative observation, a fairly obvious reason was found for the false anatomic localization by the EMG. In these cases the lesion was a herniated nucleus pulposus which had protruded medially and inferiorly at the 4th lumbar space without involving the 5th nerve

root, but actually compressing the first sacral nerve root. The EMG, then correctly localized the involved nerve root, but the compression instead of being at the lumbosacral space was actually at the 4th lumbar interspace. Therefore, when the EMG shows the first sacral nerve root to be involved, the surgeon must bear in mind that the lesion may be situated either in some few cases medially, at the 4th lumbar interspace, or laterally at the lumbosacral space.

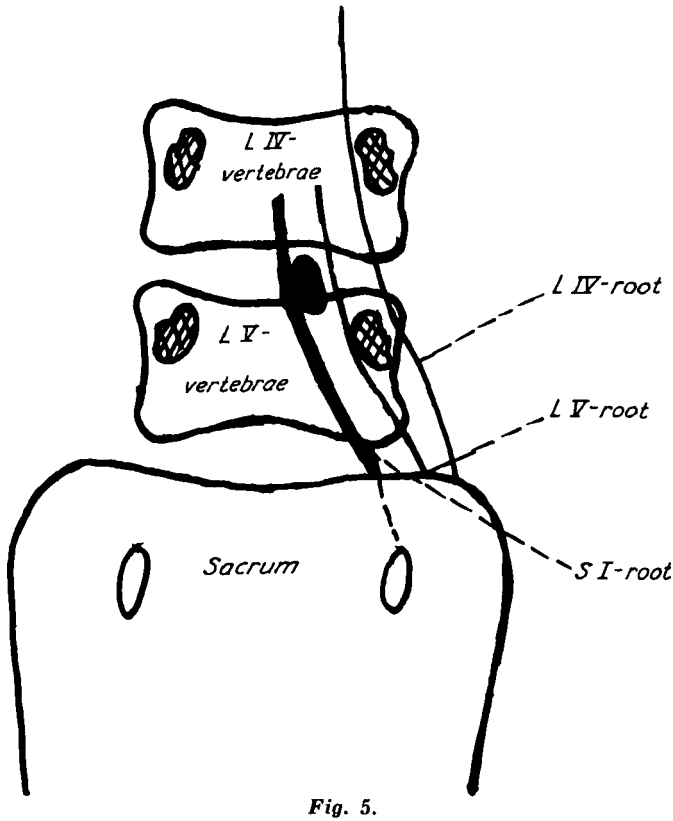

Fig. 5.
Diagram showing how a medially and inferiorly herniated nucleus pulposus at the fourth lumbar interspace may compress the first sacral nerve root.

The fourth of the incorrect electromyograms did not show any denervation, but in this case the patient had had symptoms only 10 days. The EMG did not turn positive until after about 21 days.

One patient had a herniated disc between the 3rd and 4th lumbar vertebrae. In this case I found a correct EMG and myelography and a weakness in the patellar reflex, too.

In 4 cases no herniation was found at the operation. Here EMG was correct, it means negative, in 3 of the cases. In the 4th case EMG showed denervation of the first sacral myotome. The patient has been followed-up and has been found to have been definitely relieved of his sciatic pain. This would seem to indicate that root compression had actually existed (as shown by the electromyogram alone) and was relieved by a simple laminectomy with decompression of the nerve root.

In all the 4 patients explored the myelograms were negative. The neurological examination was misleading in 3 of the 4 cases, but correct in one.

Finally, a few interesting cases.

Case 1. A 36-year-old male had since 1955 attended three other hospitals because of "back trouble" and left sciatica. Neurological examination was not convincing. Myelography was reported to be negative and the patient was considered hysterical. Neurological examination at the Orthopaedic Clinic in Lund was normal and so was the myelography too. An EMG was done and revealed severe left first sacral root involvement. Operation confirmed a protruded lumbosacral disc and the first sacral nerve root was found to be greatly enlarged. The patient recovered and returned to work.

Case 57. A 50-year-old male, who had been diagnosed elsewhere as hysterical, came to the Orthopaedic Clinic in Lund because of radiating pain into the left leg and great toe. Lasègue's sign was positive at 90°. Neurological examination was normal. Myelography was essentially negative. (Perhaps an enlarged S I-nerve root). An EMG revealed denervation fibrillation of the 5th lumbar myotome. Operation revealed a large lateral herniation in the space between the 4th and 5th lumbar vertebrae. Now the patient is free from pain.

Case 5. A 36-year-old male was operated upon 6/11 1957, when a large herniation of the disc (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: a paresis in the great toe, Lasègue's sign 50°. Myelography was negative. EMG showed denervation fibrillation in both the L V- and S I-myotomes. A new operation revealed a herniated disc (0.6 ml) in the lumbosacral space and since its removal the patient has been free of pain.

The electromyogram is of real value in substantiating or eliminating suspected root compression syndrome. In the cases just described, the patients were not only given proper treatment, but the suspected diagnosis of hysteria or malingering was excluded. I believe that when the clinical findings are uncertain, electromyography should be done before submitting the patient to myelography. Electromyography, however, is not necessary when the clinical findings give a clear-cut dia-

gnosis, but it has been found to be of definite value for excluding the possibility of root compression if the myelogram is negative. In acute, severe intervertebral disc herniations EMG is of no value. It is often impossible to wait three weeks before instituting treatment.

SUMMARY

The author reports the method of electromyography as an aid in the diagnosis of lumbar disc herniations.

In an analysis of the electromyographic, clinical, myelographic and operative findings in a series of 60 patients operated upon at the Department of Orthopaedics, University Hospital, Lund, the following observations of interest were made.

In 24 patients with lumbosacral disc herniation the electromyogram was correct in all the 24 cases and myelography was correct only in 14 of the cases and the Achilles tendon reflex was weak or absent in 18 cases.

In 31 cases of intervertebral disc herniation between the 4th and 5th lumbar vertebrae the author found a correct electromyogram in 27 cases but an incorrect one in 4 cases. Myelography had demonstrated herniation between the 4th and 5th lumbar vertebrae in 26 of 30 cases but missed in 4. (Myelography was not done in one case). A paresis of the great toe was found in 18 out of the 31 cases. The 4 "incorrect" electromyograms are discussed and a fairly obvious reason for them is given.

A few interesting cases are reported.

RESUME

L'auteur rapporte la méthode de l'électromyographie comme une aide dans le diagnostic de la hernie discale lombaire.

Dans l'analyse des trouvailles électromyographiques et opératoires chez une série de 60 malades opérés à la Clinique d'Orthopédie de l'Hôpital de l'Université de Lund, les observations suivantes présentant de l'intérêt ont été faites:

Chez 24 malades souffrant de hernie discale lombo-sacrée, l'électromyogramme était correct dans tous les 24 cas et la myélographie n'était correcte que dans 14 de ces cas, le réflexe achilléen étant faible ou aboli dans 18 cas.

Dans 31 cas de hernie discale intervertébrale entre les 4ème et 5ème

vertèbres lombaires, l'auteur a trouvé un électromyogramme correct dans 27 cas et incorrect dans 4 cas. Le myélogramme a décelé la hernie entre la 4ème et la 5ème vertèbre lombaire dans 26 cas sur 30, mais a fait défaut dans 4. (Il n'a pas été pratiqué de myélogramme dans un cas). Une parésie du gros orteil a été trouvée dans 18 cas sur 31. Les quatre électromyogrammes « incorrects » sont discutés; une explication paraissant plausible est donnée.

L'auteur rapporte quelques cas intéressants.

ZUSAMMENFASSUNG

Der Verfasser berichtet über die Methode der Elektromyographie als ein Hilfsmittel in der Diagnose des Vorfalles von Lendenwirbelzwischenscheiben.

Die Analyse der elektromyographischen und operativen Befunde in einer Reihe von 60 Patienten, die an der orthopedischen Abteilung des Universitetskrankenhauses in Lund operiert wurden ergab die folgenden interessanten Beobachtungen.

Bei 24 Patienten mit lumbosakralem Scheibenvorfall war das Elektromyogram in allen 24 Fällen richtig und die Myelographie nur in 14 der Fälle, während der Achillessehnenreflex in 18 Fällen geschwächt oder abwesend war.

In 31 Fällen von Scheibenvorfall zwischen dem 4. und 5. Lendenwirbel fand der Verfasser ein richtiges Elektromyogram in 27 Fällen, ein unkorrektes jedoch in 4 Fällen. Das Myelogram hatte einen Vorfall zwischen dem 4. und 5. Lendenwirbel in 26 von 30 Fällen aufgezeigt, hatte aber in 4 Fällen versagt. (In einem Falle wurde keine Myelographie vorgenommen). Eine Parese der Grosszehe wurde in 18 von 31 Fällen gefunden. Die vier „fehlerhaften" Elektromyogramme werden besprochen und eine ziehmlich naheliegende Erklärung für ihr Entstehen wird gegeben.

Einige interessante Fälle werden berichtet.

REFERENCES

Buchtahl, Fritz: Electromyography in the diagnosis of central and peripheral lesions of the nervous system. IVe Congrès Neurologique International, Paris 1949. 1: 35–46.

– An Introduction to Electromyography. Gyldendal, København 1957.

Denny-Brown, D. and *Pennybacker, J. B.:* Fibrillation and Fasciculation in Voluntary Muscle. Brain. 1938. 61: 311–334.

Golseth, James G.: Diagnostic Contributions of the electromyogram. California Med. 1950. 73: 355–357.

von Hagen, Karl O.: The clinical application of electromyography to lower motor neuron and muscular disorders. Bull. Los Angeles Neurol. Soc. 1955. 20: 131–138.

Huddleston, O. L., Austin, E. and *Marinacci, A. A.:* Diagnostic features of electromyography. Arch. Phys. Med. 1951. 32: 579–584.

Kugelberg, Eric: Electromyograms in muscular disorders. J. Neurol., Neurosurg. and Psychiat. 1947. 10: 122–128.

Marinacci, A. A.: Clinical Electromyography. California, San Lucas Press 1955.

Shea, Paul A., Woods, Ward W. and *Werden, Delbert H.:* Electromyography in diagnosis of nerve root compression on syndrome. Arch. Neurol. & Psychiat. 1950. 64: 93–104.

Shea, Paul A. and *Woods, Ward W.:* Electromyography as an Aid in Clinical Diagnosis. A. M. A. Arch. of Internal. Med. 1955. 96: 787–793.

– – The diagnostic value of the electromyograph. Brit. J. phys. med. 1956, February.