An Electrophysiological Method for Examining Lumbosacral Root Compression

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SUMMARY. *The propagation velocities and conduction times of nerve impulses responsible for muscle F-waves were measured in the proximal segments of 60 normal posterior tibial nerves and of 41 normal peroneal nerves. The results were compared with those of 25 patients having confirmed lumbosacral root compression due to disc degeneration. Using the peroneal nerve, 65 per cent of patients had a prolonged proximal conduction time; a similar abnormality was found in 56 per cent of patients when the posterior tibial nerve was studied. The yield of positive results rose to 85 per cent and 76 per cent respectively when the M- and F-latencies in given individuals were compared. It was also shown that in normal subjects the F-response has a longer latency, and slower conduction velocity than the H-reflex when both are obtained using the same stimulating and recording sites. In patients in whom the ankle jerks and H-reflexes are absent, the F-waves may still be recorded, indicating that the latter are mediated through motor fibers*

RÉSUMÉ: *Le temps et la vélocité de conduction proximale F ont été mesurés dans les nerfs tibiaux postérieurs normaux (60 cas) et péronéens normaux (41 cas). Ces résultats furent comparés à ceux obtenus chez 25 patients montrant de façon certaine une compression des racines lombo-sacrées due à une dégénérescence discale. 65 pour cent des patients montraient un temps de conduction proximal allongé lorsque l'on faisait la mesure dans le nerf péronné; ce chiffre était de 56% lorsque le nerf tibial postérieur était utilisé. Ces résultats positifs atteignent 85% et 76% respectivement lorsque, chez un individu donné, les latences M et F étaient comparées. Nous avons aussi montré que chez les sujets normaux la réponse F a une latence plus longue, et une vélocité de conduction plus faible, que le réflexe H lorsque les deux sont mesurés au même site et avec les mêmes points de stimulation et d'enregistrement. Chez les patients sans réflexes achiléens ni réflexe H, il est encore possible d'enregistrer l'onde F, indiquant donc que celle-ci est transportée par les fibres motrices.*

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INTRODUCTION

Electrophysiological testing as an aid to the diagnosis of root compression, especially when due to degenerative disc disease, has chiefly been of value when significant muscle weakness and atrophy have been apparent (Knuttson, 1961; Johnson and Melvin, 1969). At this stage evidence of muscle denervation, such as fibrillation activity, or of collateral re-innervation (motor unit potentials having increased mean durations and amplitudes) can be helpful in the differential diagnosis. However, the measurement of conduction velocity in distal nerve segments, which are those usually examined, is frequently normal since the site of entrapment is proximal.

These limitations have been partially overcome in lumbar and sacral root compression by detection of increased latencies of the knee and ankle jerks (Malcolm, 1951) and of the H-reflex, recorded from the soleus or gastrocnemius muscles (Deschuytere and Rosselle, 1970, 1973). The H-reflex as recorded from the above muscles is mediated predominantly through the S_1 root (Deschuytere and Rosselle, 1973) and gives little or no information regarding the fourth lumbar root. In addition, the H-reflex is difficult to record from upper limb muscles in normal adults (Thomas and Lambert, 1960; Mayer and Mosser, 1973).

In a recent study (Eisen et al., 1977) using a method originally described by Kimura (1974), we were able to demonstrate that proximal slowing of motor nerve impulse conduction, measured by evoking the F-wave response, was helpful in the diagnosis of cervical root compression due to disc degeneration.

METHODS

Control Subjects: Electrophysiological studies (detailed below) were performed on 60 normal subjects aged between 13 and 69 years (mean 35.9 years). Motor (M) nerve and F-wave conduction studies of one posterior tibial nerve were carried out in each subject, and similar studies utilizing the peroneal nerve were performed in 41 instances. In 20 subjects unilateral H-reflex studies were also performed (see below).

Patients: Twenty-five patients aged between 22 and 69 years (mean 49.8 years) were chosen for study on the basis that they all had myelographically-proven root compression due to herniated lumbar and/or sacral intervertebral discs. Six patients had subsequent operative confirmation of their disease. In seven cases the root compressions were bilateral. Motor and F-wave studies were performed in 25 instances on the posterior tibial nerves and in 20 instances on the peroneal nerves.

Electrophysiological Methods: Studies were carried out with the subjects lying comfortably on a bed in an air-conditioned room, in which the ambient temperature was maintained at between 20 and 22°C.

Motor nerve conduction studies: Maximal stimuli were delivered through a pair of percutaneous needle electrodes (insulated to 2 mm from their tips) which were inserted for proximal stimulation at the level of the popliteal fossa, and for distal stimulation at the ankle. The inter-electrode distance was 30 mm with the cathode being placed distally. The evoked compound action potentials were recorded by gold disc surface electrodes placed over the belly of the abductor digiti minimi muscle for posterior tibial nerve studies, and over the belly of the extensor digitorum brevis muscle for peroneal nerve studies. Reference electrodes were placed over the appropriate muscle tendons, and a ground electrode was positioned between the stimulating and recording sites. The motor (M) nerve conduction velocities for the two nerves were obtained in each case by dividing the distance between the two stimulating points by the difference between the proximal and distal motor latencies.

F-Wave Studies: The stimulus intensity was made supramaximal by 20 per cent. The cathode (now positioned proximally) was applied to the ankle and knee at the sites used for motor nerve conduction studies. The latency of the F-wave response was taken as the time interval between the stimulus artifact and the first deflection of the evoked response. The latency was found to vary slightly in any given individual so that the shortest of 5 responses was chosen. In the majority of cases no difficulty was encountered in eliciting F-waves. When necessary, however, responses could be augmented by slight voluntary contraction of the muscle under study. The F-wave impulse conduction velocity was computed from the following formula (Kimura, 1974):

$$\text{F-wave impulse velocity } (ms^{-1}) = \frac{\left(\begin{array}{c}\text{Distance between stimulation}\\ \text{site and } L_4 \text{ spinous process}\\ (m^{-3})\end{array}\right)}{\text{F conduction time } (s^{-3})} + \frac{\left(\begin{array}{c}\text{Distance between}\\ L_4 \text{ and } L_1 \text{ spinous}\\ \text{processes } (m^{-3})\end{array}\right)}{\text{F conduction time } (s^{-3})}$$

$$\text{where F conduction time } (s^{-3}) = \frac{[\text{F latency } (s^{-3}) - \text{M latency } (s^{-3})] - 1}{2}$$

It is assumed that the central delay of the F-wave response is 1 s^{-3} (Renshaw, 1941).

F-Wave and H-Reflex Studies: In each of 20 normal subjects (mean age 29.8 years), the posterior tibial nerve was stimulated and the M-wave, F-wave and H-reflex were recorded from the soleus muscle (see above). The conduction velocities of the impulses mediating H- and F-waves were then compared by use of the following formula.

$$\begin{array}{c}\text{`H'-reflex afferent impulse}\\ \text{conduction velocity}\\ (ms^{-1})\end{array} = \frac{\left(\begin{array}{c}\text{Distance between popliteal}\\ \text{fossa to } L_4 \text{ spinous process}\\ (m^{-3})\end{array}\right)}{\text{`H' conduction time } (s^{-3})} + \frac{\left(\begin{array}{c}\text{Distance between}\\ L_1 \text{ and } L_4 \text{ spinous}\\ \text{process } (m^{-3})\end{array}\right)}{\text{`H' conduction time } (s^{-3})}$$

where 'H' conduction time (s^{-3}) = (H-latency — M-latency — 1) — (F-conduction time) and F-wave impulse conduction time and velocity were calculated as described above.

F-wave studies (recording from the soleus muscle) were also carried out in 10 patients aged between 33 and 79 years (mean 49.3 years) in whom no H-reflexes could be obtained. These patients also had absent ankle jerks. Four of these patients had compression of the S_1 root from disc disease, 2 had diabetic peripheral neuropathies and 2 had Guillain-Barré syndromes; one of the remaining patients suffered from pernicious anaemia with neuropathy and the other had Hodgkin's disease that had been treated with vincristine.

Statistical Analysis: Student's test was used for comparing the results from the control and patient groups. The regression line prediction bands were computed by a method described by Remington and Schork (1970).

TABLE 1

F- and H-responses in 20 normal subjects
(means ± 2.5 standard deviations)

	Latency, popliteal fossa to soleus muscle (s^{-3})	Conduction time, popliteal fossa to cord (s^{-3})	Conduction velocity, popliteal fossa to cord (ms^{-1})
H response	27.2 ± 1.3	8.9 ± 1.1	73.85 ± 9.75
F response	31.2 ± 1.6	12.9 ± 0.8	50.6 ± 2.9
Significance	$p<0.001$	$p<0.001$	$p<0.001$

RESULTS

F-versus H-responses: The mean values for the H- and F-responses recorded from the soleus muscle in 20 normal subjects are summarized in Table 1. There was a significantly shorter mean conduction time, and a higher mean conduction velocity between the knee and spinal cord, for impulses mediating the H-reflex than for those mediating the F-wave. This difference was also reflected in the significantly shorter mean latency of the H-reflex compared to that of the F-response (27.2 ± 1.3 s^{-3} and 31.2 ± 1.6 s^{-3} respectively; $p < 0.001$). These differences can be explained by the fact that the H-response is evoked by impulses travelling along 1a afferent fibers whereas the F-wave is largely mediated by motor fibers and these have lower impulse conduction velocities (Fig. 1). The F-response could also be recorded from the soleus muscle in 10 patients with various peripheral neuropathies in whom H-reflexes and ankle jerk could not be obtained. The mean F-wave impulse conduction time and conduction velocity from the popliteal fossa to spinal cord in these patients were 14.05 ± 1.9 s^{-3} and 47.0 ± 4.81 ms^{-1} respectively, whilst the mean F-latency from the popliteal fossa to the soleus muscle was 33.8 ± 3.9 s^{-3}. None of these values were significantly different from those of the control group (see Table 1). The F-wave impulse conduction velocities measured between the popliteal fossa and spinal cord were similar when recordings were made from the soleus and the abductor digiti minimi muscles (50.6 ± 2.9 ms^{-1} and 50.4 ± 6.1 ms^{-1} respectively). In both groups the stimulus was applied to the posterior tibial nerve at the knee.

In order to obtain additional information concerning the possibility that the F-response is entirely mediated by motor nerve fibers, the M- and F-wave conduction times between the knee and ankle for the posterior tibial and peroneal nerves were measured in the control group (Table 2). It can be seen that the differences in the latencies for the two types of response, obtained by stimulation at the knee and ankle respectively, were very similar. For the posterior tibial nerve the mean conduction time between the knee and the ankle, as determined by the F-wave response, was 0.3 ± 1.7 s^{-3} longer than the value when determined by the M-response. Similarly, for the peroneal nerve, the mean impulse conduction time between the knee and ankle for the F-wave was found to be only 0.1 ± 1.8 s^{-3} less than that for the M-response. The small differences in the conduction times, determined by both methods, indicate the impulses mediating the responses travel along the same motor fibers.

TABLE 2

Conduction times between knee and ankle measured by M- and F-responses (Mean ± 2.5 standard deviations)

	Latency (s^{-3}), Stimulating at ankle	Latency (s^{-3}), Stimulating at knee	Difference = Conduction time (s^{-3}) between knee and ankle
	Posterior Tibial Nerve (N = 60)		
M response	5.85 ± 0.9	13.15 ± 1.5	7.3 ± 1.05
F response	47.4 ± 3.3	39.7 ± 2.95	7.6 ± 1.8
	Peroneal Nerve (N = 41)		
M response	5.2 ± 0.8	11.65 ± 1.2	6.4 ± 0.9
F response	44.6 ± 3.6	38.2 ± 3.1	6.3 ± 1.8

STUDIES IN NORMAL CONTROLS AND PATIENTS WITH ROOT LESIONS:

The motor and F-response parameters that were measured in controls and in patients with lumbar root lesions are summarized in Table 3. When comparing the control and patient groups there were no significant differences between the mean motor nerve impulse conduction velocities or between the mean latency measurements from the knee to the abductor digiti minimi muscle (for the posterior tibial nerve), or to the extensor digitorum brevis muscle (for the peroneal nerve). In contrast, the mean F-wave impulse conduction velocity and conduction time between the cord and knee were respectively lower and longer in the patients. Similarly, the mean F-wave latencies, representing the time for impulse conduction from the popliteal fossa through the spinal cord and back to the abductor digiti minimi muscle (posterior tibial nerve), or to the extensor digitorum brevis muscle (peroneal nerve), were significantly longer in the patients. These findings indicate, for the patient group as a whole, dysfunction of proximal nerve segments

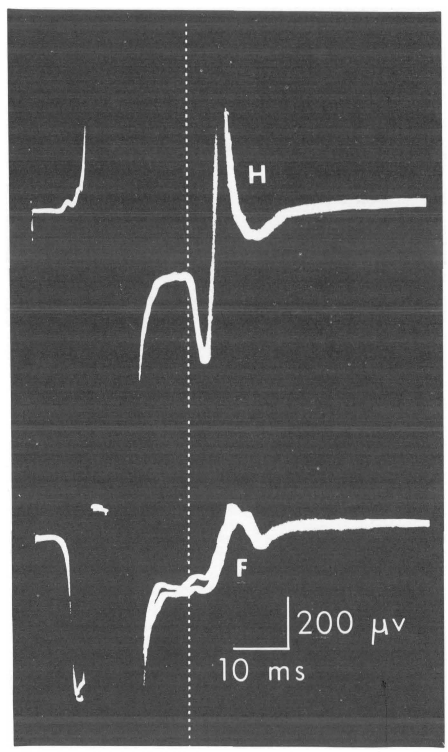

Figure 1—Top is the direct motor (M) wave followed by the H reflex. Recording is from the soleus, the posterior tibial nerve was stimulated submaximally at the knee. Bottom is the M and F waves recorded from the same normal subject with supramaximal stimulation. The recording and stimulating sites were the same in both instances. The dotted line runs through the onset of the H reflex and shows that the F response is of a longer latency.

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TABLE 3

Motor (M) and F-wave studies in normal posterior tibial and peroneal nerves and patients with lumbar root lesions
(Means ± 2.5 standard deviations)

		Motor conduction velocity (ms^{-1}) Knee to ankle	M latency (s^{-3}) Knee to muscle	F conduction velocity (ms^{-1}) Knee to cord	F latency (s^{-3}) Knee to muscle	Conduction time (s^{-3}) Knee to cord
Posterior Tibial nerve	Control (M = 60)	53.2 ± 5.7	13.15 ± 1.5	50.4 ± 6.1	39.7 ± 3.0	12.7 ± 1 1
	Patients (N = 25)	53.9 ± 9.2	13.4 ± 1.5	45.0 ± 9.2	45.4 ± 6.0	15.5 ± 2.9
Significance		NS	NS	$p < 0.01$	$p < 0.001$	$p < 0.001$
Peroneal Nerve	Control (N = 41)	51.2 ± 5.9	11.65 ± 1.2	55.6 ± 5.5	38.2 ± 3.1	12.7 ± 1.3
	Patients (N = 20)	53.3 ± 9.5	12.1 ± 0.9	45.9 ± 8.2	46.1 ± 7.5	16.5 ± 3.5
Significance		NS	NS	$p < 0.001$	$p < 0.001$	$p < 0.001$

NS = not significant

(between the knee and spinal cord) but normal distal (knee to ankle) impulse conduction.

If the patients with lumbar root lesions who showed abnormalities in their electrophysiological studies (Table 4) are considered, a prolonged F-wave impulse conduction time between the cord and knee was found to be the most useful diagnostic parameter. Even then, slightly less than one half of the patients had normal impulse conduction times between the cord and knee as measured in the posterior tibial nerve, and one third showed no abnormality in this parameter when measured in the peroneal nerve.

We have, however, previously shown (Eisen et al., 1977) that for a given stimulation and recording site the M- and F-wave latencies vary in a linear fashion, providing that body stature and limb length are normally proportional. Regression lines with 99 per cent prediction bands were therefore constructed, relating the latencies of the M- and F-responses obtained by stimulation at the popliteal fossa and by recording from the abductor digiti minimi for the posterior tibial nerve, and from the extensor digitorum brevis for the peroneal nerve. The bands are based upon results from 60 control subjects for the posterior tibial nerve (Fig. 2) and from 41 control subjects for the peroneal nerve (Fig. 3). A point outside the upper prediction band indicates, for the given individual, that the F-wave latency is increased and that the impulse slowing is due to a lesion between the knee and spinal cord. For the posterior tibial nerve (Fig. 2), 19 (76 per cent) of the patients (solid circles) had disproportionally prolonged F-wave latencies. For the peroneal nerve (Fig. 3), 17 (85 per cent) of the patients showed the same abnormality. In one instance in the peroneal studies no F-wave could be obtained, and this too was considered as abnormal.

TABLE 4

Number and (percentage) of patients having abnormal motor (M)- and F-wave studies*

Parameter	Posterior Tibial nerve (25 patients)	Peroneal nerve (20 patients)
Decreased motor (M) conduction velocity (knee to ankle)	1 (4)	0 (0)
Increased motor (M) latency stimulating at knee	0 (0)	0 (0)
Decreased F conduction velocity (cord to knee)	2 (8)	6 (30)
Increased F latency Stimulating at knee	7 (28)	11 (55)
Increased F conduction time from cord to knee	14 (56)	13 (65)
Prolonged F latency in relation to M latency	19 (76)	17 (85)

*Values are those $\lessgtr$ 2.5 standard deviations of normal

DISCUSSION

The application of the F-wave response to clinical electromyography has been relatively recent. Kimura (1974) showed that in Charcot-Marie-Tooth disease the marked slowing of impulse conduction velocity, usually encountered in the distal segments of a limb, could be equally well documented in the proximal segments of the median and ulnar nerves. Also of interest has been the ability to demonstrate slowing of impulse conduction in proximal segments of the upper limb nerves in patients with the Guillain-Barré syndrome in whom the conduction velocity was normal distally (Kimura and Butzer, 1975; King and Ashby, 1976). This finding is particularly important since as many as 25 per cent of patients with Guillain-Barré syndrome have normal distal conduction velocities (Eisen and Humphreys, 1974; McLeod et al., 1976). By measuring the F-wave impulse velocity along proximal segments of the peroneal

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nerve, Panayiotopoulos and Scarpalezos (1976), were able to show that nerve as well as muscle was involved in myotonic dystrophy.

In the present study we have been able to demonstrate that measurement of the F-wave impulse velocity (or preferably the F-wave impulse conduction time), is often abnormal in patients having myelographically-confirmed lumbar and/or sacral root compression as a result of disc disease. Conduction time is considered to be the more reliable parameter since it avoids any errors in the measurement of distance from the stimulating site to the L_4 or L_5 spinous process. It should be stressed that measurement of F-wave impulse conduction times gave falsely negative results in 35 per cent of cases for the peroneal nerve and in 44 per cent for the posterior tibial nerve. However, a direct comparison of the motor and F-wave latencies in any given individual, using the same stimulus and recording sites when eliciting both responses, gives a substantially higher yield of positive results. Such a comparison is justifiable under these circumstances because the motor and F-wave latencies vary in a linear fashion, providing that body stature and limb length are proportional (Eisen et al., 1977). Thus, a

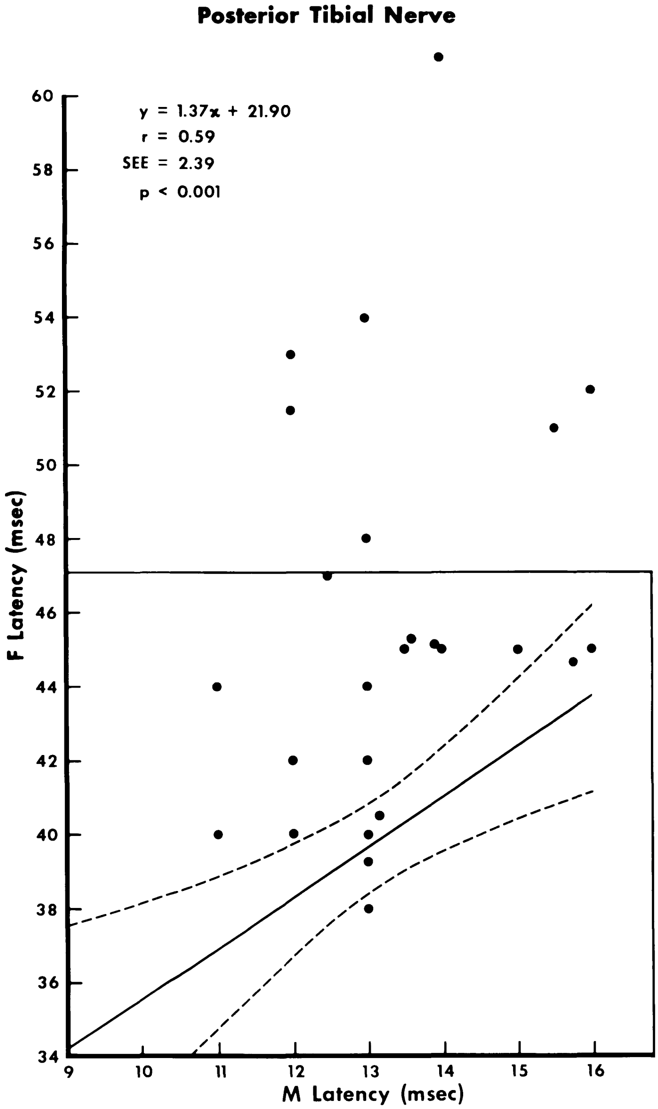

Figure 2—The regression line and its 99 percent confidence bands (broken lines) were computed from 60 normal subjects, by comparing the M and F latencies recorded from the abductor digiti minimi upon stimulation of the posterior tibial nerve at the knee. The horizontal and vertical lines mark 2.5 standard deviations above the normal means for the F and M latencies (47.1 msec and 16.8 msec respectively). The solid circles represent points plotted for 25 patients with lumbar-sacral root compression.

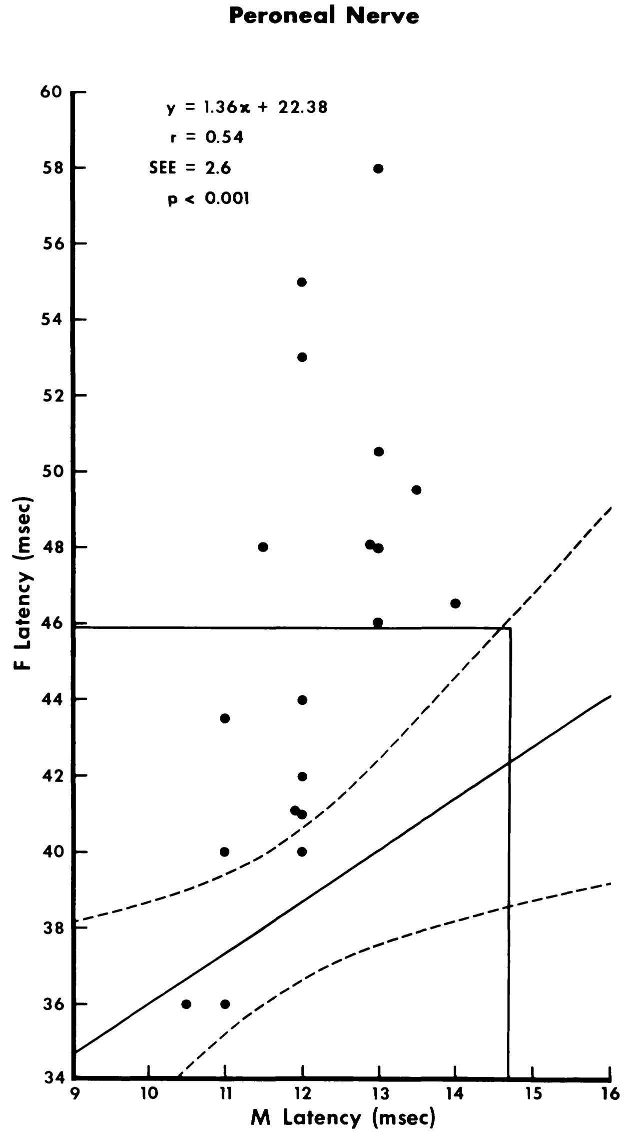

Figure 3—Same as figure two computed from 41 normal subjects. Recording was from the extensor digitorum brevis upon stimulating the peroneal nerve at the knee. The upper 2.5 standard deviations for the M latency (vertical line) and F latency (horizontal line) are 14.7 msec. and 45.9 msec. respectively). Nineteen points (solid circles) are plotted for patients with lumbar-sacral root compression.

disproportionally prolonged F-wave latency in comparison to the motor latency would be indicative of a proximally-situated lesion (see Figs. 2 and 3).

There is good evidence to indicate that the F-response is predominantly the result of antidromic stimulation of spinal motor neurons. Thus, it persists in man or in the experimental animal despite dorsal root rhizotomy or transverse myelotomy (Magladery and McDougal, 1950; Gassel and Weisendanger, 1965; Thorne, 1965; McLeod and Wray, 1966; Mayer and Feldman, 1967; Miglietta, 1973). Also the F-wave can be obtained by stimulating the facial nerve, which is purely motor (Sawnhey and Kayan, 1970; Trontelj and Trontelj, 1973). In the present and in previous studies, impulse conduction time in a given segment of nerve is very similar when measured by the F-wave and by the direct motor (M) response (Kimura, 1974; Kimura and Butzer, 1975; Eisen et al., 1977). In addition, Trontelj (1973), using single fiber electromyography, has shown a high degree of correlation between the latencies of consecutive M- and F-responses, indicating that both responses are mediated by the same nerve fibers.

Further evidence that the F-wave is mainly induced via motor fibers has come from the present study of H-reflexes and F-responses. It was shown that when the stimulus intensity was increased to a supramaximal value the H-reflex could no longer be elicited but the F-response appeared. The latency of the F-wave and the calculated impulse conduction velocity between the spinal cord and soleus muscle were respectively longer and slower than the H-reflex values obtained at submaximal stimuli; similar observations were previously made by Magladery and McDougal (1950). It was also possible to obtain the F-response in patients with absent ankle jerks in whom no H-reflexes could be evoked. Fra and Bignolio (1968) and Upton et al. (1971) showed that both types of response could be obtained from the small muscles of the foot. The authors felt that the latencies of the two responses were 'similar', but definitive latency and velocity measurements were not performed.

It is concluded that the measurement of impulse conduction in proximal segments of nerve and the comparison of F- and M-wave latencies in any given individual are useful means of documenting disease at the root level. In this study all the patients had radiological evidence of lumbar and/or sacral root compression and it remains to be seen if the technique described will be equally valuable in patients having suspected, but not previously confirmed, root pathology.

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REFERENCES

DESCHUYTERE, J. and ROSSELLE, N. (1970). Electromyographic and neurophysiological investigation in root compression syndromes in man. Electromyography, 10, 339-340.

DESCHUYTERE, J. and ROSSELLE, N. (1973). Diagnostic use of monosynaptic reflexes in L5 and S1 root compression. In: New Developments in Electromyography and Clinical Neurophysiology, vol. 3, pp. 360-366, edited by J. E. Desmedt. Karger· Basel.

EISEN, A. A., WOODS, J F and SHERWIN, A. L. (1974). Peripheral nerve function in long-term therapy with diphenylhydantoin. Neurology, (Minneapolis). 24, 411-417

EISEN, A. and HUMPHREYS, P (1974). The Guillain-Barré syndrome. A clinical and electrodiagnostic study of 25 cases. Archives of Neurology (Chicago), 30, 438-443.

EISEN, A., SCHOMER, D. and MELMED, C. (In press). The application of F wave measurements in the differentiation of proximal and distal upper limb entrapments, Neurology (Minneapolis).

FRA, L. and BIGNOLIO, F (1968). F and H responses elicited from muscles of the lower limb in normal subjects. Journal of the Neurological Sciences, 7, 251-261.

GASSEL, M. M. and WIESENDANGER, M. (1965). Recurrent and reflex discharges in plantar muscles of the cat. Acta Phsyiologica Scandinavica, 65, 138-142.

JOHNSON, E. W and MELVIN, J. L. (1969). The value of electromyography in the management of lumbar radiculopathy Archives of Physical Medicine, 50, 720,

KIMURA, J. (1974). F-wave velocity in the central segment of the median and ulnar nerves. A study in normals and in Charcot-Marie-Tooth disease. Neurology (Minneapolis), 24, 539-546.

KIMURA, J. and BUTZER, J F (1973). F-wave conduction velocity in Guillain-Barré syndrome. Assessment of nerve segment between axilla and spinal cord. Archives of Neurology (Chicago), 32, 524-529.

KING, D. and ASHBY, P (1976). Conduction velocity in the proximal segments of a motor nerve in the Guillian-Barré syndrome. Journal of Neurology, Neurosurgery and Psychiatry, 39. 538-544.

KNUTTSON, B. (1961). Comparative value of electromyographic, myelographic and clinical-neurological examinations in the diagnosis of lumbar root compression syndrome. Acta Orthopaedica Scandinavica (Suppl.) 49, 1-135.

MAGLADERY, J. W and McDOUGAL, D. B. (1950). Electrophysiological studies of nerve and reflex activity in normal man. 1. Identification of certain reflexes in the electromyogram and the conduction velocity of peripheral nerve fibers. Bulletin of the Johns Hopkins Hospital, 86, 265-290.

MALCOLM, D. S. (1951). A method of measuring reflex times applied in sciatica and other conditions due to nerve-root compression. Journal of Neurology, Neurosurgery and Psychiatry, 14, 15-24.

MAYER, R. F and FELDMAN, R. G. (1967). Observations on the nature of the F wave in man. Neurology (Minneapolis) 17, 147-156.

MAYER, R. F and MOSSER, R. S. (1973). Maturation of human reflexes. Studies of electrically evoked reflexes in newborns, infants and children. In: New Developments in Electromyography and Clinical Neurophysiology, vol. 3, pp. 294-307, edited by J. E. Desmedt. Karger· Basel.

McLEOD, J. G. and WRAY, S. H. (1966). An experimental study of the F wave in the baboon. Journal of Neurology, Neurosurgery and Pschiatry, 29, 196-200.

McLEOD, J. G., WALSH, J C., PRINEAS, J. W and POLLARD, J. D. (1976). Acute idiopathic polyneuritis. A clinical and electrophysiological follow-up study. Journal of the Neurological Sciences, 27, 145-162.

MIGLIETTA, O. E. (1973). The F response after transverse myelotomy. In: New Developments in Electromyography and Clinical Neurophysiology, vol. 3, pp. 323-327, edited by J. E. Desmedt. Karger: Basel.

PANAYIOTOPOULOS, C. P. and SCARPALEZOS, S. (1976). Dystrophia myotonica: peripheral nerve involvement and pathogenic implications. Journal of the Neurological Sciences, 27, 1-16.

REMINGTON, R. D. and SCHORK, M. A. (1970). Statistics with application to the biological and health sciences, pp. 259-272. Prentice Hall Inc: New Jersey.

RENSHAW, B. (1941). Influence of discharge of motorneurons upon excitation of neighbouring motorneurons. Journal of Neurophysiology, 4, 167-183.

SAWNHEY, B. B. and KAYAN, A. (1970). A study of the F wave from the facial muscles. Electromyography, 10, 287-295.

THOMAS, J. E. and LAMBERT, E. H. (1960). Ulnar nerve conduction velocity and H-reflex in infants and children. Journal of Applied Phsyiology, 15, 1-9.

THORNE, J. (1965). Central responses to electrical activation of the peripheral nerves supplying the intrinsic hand muscle. Journal of Neurology, Neurosurgery and Psychiatry, 28, 482-495.

TRONTELJ, J. V (1973). A study of the F response by single fiber electromyography In: New Developments in Electromyography and Clinical Neurophysiology, vol. 3, pp. 318-322, edited by J E. Desmedt. Karger: Basel.

TRONTELJ, J V and TRONTELJ, M. (1973). F-responses of human facial muscles. A single motorneuron study Journal of the Neurological Sciences, 20, 211-222.

UPTON, A. R. M., McCOMAS, A. J and SICA, R. E. P (1971). Potentiation of 'late' responses evoked in muscles during effort. Journal of Neurology, Neurosurgery and Psychiatry, 34, 699-711.