Clinical utility of F wave parameters in unilateral S1 radiculopathy

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ABSTRACT

الأهداف: اختبار معايير موجة إف (مدة الموجة، وفترة الكمون القصوى، وفترة الكمون الدنيا، ومتوسط فترة الكمون، والتبدد الزمني للموجة، واستمراريتها) التي تستهدف العصب الظنبوني المصاب بالاعتلال الأحادي الجانب للجذور العصبية إس1. بالإضافة إلى تقييم الفروق الإحصائية لهذه المعايير بين الجزء المصاب وغير المصاب في مجموعة الحالة من جهة، وبين مجموعة الحالة والشاهد من جهة أخرى.

الطريقة: أُجريت هذه الدراسة في مختبر التخطيط الكهربائي الفيسيلوجي التابع لجامعة مارمارا، أسطنبول، تركيا، واستمرت خلال الفترة من سبتمبر 2007م إلى يناير 2008م. شملت الدراسة 20 مريضاً مصاباً بالاعتلال الأحادي الجانب للجذور العصبية إس1 (مجموعة الحالة)، و20 مشاركاً من الأصحاء (مجموعة الشاهد). لقد تم الحصول على موجة إف الثنائية للعصب الظنبوني، وبعد ذلك تم تعديل كلاً من: مدة الموجة، وفترة الكمون القصوى، وفترة الكمون الدنيا، ومتوسط فترة الكمون للموجة وذلك اعتماداً على طول المشاركين في الدراسة. وتمت الاستعانة بالتخطيط الكهربي العضلي في مجموعة الحالة، ولقد تم استثناء المرضى الذين لديهم تاريخ بمرض السكري، أو تعاطي الكحول، أو أي من الاضطرابات التي تؤثر على الأعصاب المحيطية.

النتائج: أشارت النتائج إلى عدم اختلاف معايير موجة إف في مجموعة الشاهد، وبالمقابل فقد كان طول هذه المعايير في مجموعة الحالة والمتمثلة في مدة الموجه، وفترة الكمون القصوى/ساعة، وفترة الكمون الدنيا/ساعة، ومتوسط الكمون/ساعة، والتبدد الزمني (الفرق بين القيم القصوى والدنيا لفترة الكمون) أعلى في الجزء المصاب مقارنة بالجزء السليم. لقد كانت مدة موجة إف في مجموعة الحالة أطول من مجموعة الشاهد وذلك في كلي الجزئين المصاب وغير المصاب، وكانت مدة التبدد الزمني لموجة إف أطول في مجموعة الحالة مقارنة بمجموعة الشاهد وذلك في الجزء المصاب. لقد أُصيب 15 مريضاً من أصل 20 مريض في مجموعة الحالة بزوال العصب أو الجهد المتعدد الأطوار وذلك بعد خضوعهم لتخطيط كهربية العضل.

خاتمة: أثبتت هذه الدراسة فائدة استخدام موجة إف في تقييم وتشخيص اعتلال الجذور العصبية وخاصة في المراحل البسيطة والأولى من المرض. لقد كان تشخيص المرض بواسطة مدة موجة إف وتبددها الزمني أعلى قيمةً من تشخيصه بواسطة فترة الكمون الدنيا للموجة وخصوصاً بين الحالات التي كانت نتائجها طبيعية بعد التخطيط الكهربي للعضل.

Objective: To investigate the F wave parameters (F duration, F minimum latency, F maximum latency, F mean latency, F chronodispersion, and F persistence) of the tibial nerve with unilateral S1 radiculopathy. We evaluated the differences of these parameters between the affected and unaffected sides and also with the control group.

Methods: The study was performed from September 2007 to January 2008 in the Electrophysiology Laboratory of Marmara University Medical Faculty, Istanbul, Turkey. Bilateral tibial F waves were obtained from 20 normal control subjects (control group) and 20 patients with unilateral S1 radiculopathy (patient group). Minimum, maximum, and mean F latency values were corrected by the subject's height (F min/H, F max/H, F mean/H). Needle electromyography was performed in the patient group. The patients with a history of diabetes, alcoholism, or other abnormality known to affect peripheral nerves were excluded.

Results: In the control group, no significant differences were found in any of the F-wave parameters between the 2 sides. In the patient group, there were significant prolongations of F duration, F min/H, F max/H, F mean/H, and F chronodispersion on the lesion side. Patients' F durations of the affected and unaffected side were significantly longer than the control group. The F chronodispersion also showed significant prolongation on the affected side in the patient group compared with the control group. Among 20 patients, 15 had evidence of denervation or polyphasic potentials on needle electromyography.

Conclusion: The F wave study can be clinically useful in the evaluation of S1 radiculopathies, especially in patients with mild and early stage of the disease. Both F duration and F chronodispersion have a higher diagnostic value as compared to F min in the diagnosis of lumbosacral radiculopathy, especially in cases with normal findings on needle electromyography.

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F-waves are distally recorded late responses evoked by antidromic activation of motor neurons. The routine evaluation of F-wave is usually limited to the latency measurements.[1] However, the sensitivity of minimum F-wave latency (F min) in radiculopathy is found to be disappointing.[2,3] The diagnostic yield with F waves was found to be only 18% (5/28 patients) with L5 or S1 radiculopathies.[2] Tonzola et al[3] found late response abnormalities in 26% (15 of 57 lumbosacral radiculopathy patients). Therefore, other F-wave parameters including chronodispersion (F chr), duration (F dur), persistence (F pers), maximal (F max) and mean (F mean) latencies have been examined to increase the sensitivity of F-waves in detecting radiculopathy.[4-11] Additionally, comparison of F-wave parameters between the 2 sides was also found to be informative in patients with unilateral root compression.[12] The aim of this study was to investigate the F wave parameters of the tibial nerve with unilateral S1 radiculopathy. We evaluated the differences in these parameters between the affected and unaffected sides and also compared the results with the control group.

Methods. The study was performed from September 2007 to January 2008 in the Electrophysiology Laboratory of Marmara University Medical Faculty, Istanbul, Turkey. All electrophysiological data were recorded with a Medelec Synergy Electroneuromyography machine (VIASYS Healthcare, Old Woking, Surrey, UK). Bilateral tibial F waves were obtained from 20 normal subjects (aged 32-65 years, mean 46.2 years; 8 men, 12 women) and 20 patients (aged 27-70, mean 46.05; 9 men, 11 women) with unilateral S1 radiculopathy (**Table 1**). The diagnosis of unilateral S1 radiculopathy required a clear history of low back pain, which radiated in a S1 segmental distribution, dermatomal sensory loss or numbness, ankle reflex loss, or S1 segmental weakness.[9] All patients had at least one of these clinical pictures. Intervertebral disc herniation (L5/S1) was also established by MRI in all patients. Motor nerve conduction studies of the tibial nerve were carried out to exclude a peripheral nerve lesion. There was no abnormality in the nerve conduction study. The patients with a history of diabetes, alcoholism, or other abnormality known to affect the peripheral nerves were excluded.

The F wave parameters (F dur, F min, F max, F mean, F chr, and F pers) of the tibial nerve were investigated in the control and patient groups. Subjects were asked to relax and not to move their extremities. No facilitation technique was used. For the F response, 20 stimuli were given at a frequency of 0.5 Hz. Filter settings were 2-3 kHz, sensitivity was 1 mV, and sweep speed was 100ms. The onset and ending components of the F wave were accepted as the first and the last F wave components with at least 40 micromV of peak to peak amplitude other than A waves. The evaluated F wave parameters were: (a) persistence, or the number of definable F waves divided by the number of stimuli, (b) minimum latency, or the shortest latency to the onset of the first deflection from baseline, (c) maximum latency, defined as the longest F-wave latency of the 20 consecutive stimuli, (d) mean latency, or the mean F latency of all traces, (e) chronodispersion, defined as difference between minimum and maximum latency values, and (f) duration of the F-waves from the take off to return to the baseline. All F wave latency parameters were adjusted according to the subject lengths [the data (ms)/ length (m)]. Minimum, maximum, and mean F latency values were corrected by the subjects' height (Fmin/H, Fmax/H, Fmean/H). Needle electromyography (EMG) was performed in all patients. Spontaneous electrical activity, polyphasic motor unit potentials, recruitment, and maximal interference patterns were evaluated subjectively. Skin temperature was maintained to be above 32°C.

The study was approved by the local Research Ethics Committee of Marmara University Medical Faculty and was conducted in compliance with ethical standards. Written informed consent was obtained in all cases, and the study was designed according to principles of the Helsinki Declaration.

The Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA) for windows version 10.0 was used for evaluation of the data. Student's paired t test, Fisher's exact test, and chi square, ANOVA, and Dunnet tests were used for comparisons. The statistical significance limit was accepted as $p<0.05$.

Results. There were no statistical differences between the patient and control groups for age, gender, and height ($p>0.05$) (**Table 1**). For testing the normal distribution of electrophysiological findings, we used Kolmogorov-Smirnov test. As p was >0.05 for all the tested parameters, normal distribution was confirmed and electrophysiological parameters of the both sides of

Table 1 - Gender, age, and height values of the patients with unilateral S1 radiculopathy and control groups.

Characteristics	Patient group	Control group	*T*-value	*P*-value
Age (years)	46.05 ± 9.62	46.2±9.29	t:-0.05	0.960
Gender			x^2:0.102	0.749
Men	9 (45%)	8 (40%)		
Women	11 (55%)	12 (60%)		
Height (meters)	1.67±0.06	1.63±0.07	t:1.60	0.118

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Table 2 - F-wave values of the patients with unilateral S1 radiculopathy (on the affected side and unaffected side).

Variable	Affected side (n=20)	Unaffected side (n=20)	*T*-value	*P*-value
F duration (msec)	15.22±2.49	14.34±2.28	2.792	0.012
F minimum/ Height(msec)	28.39±3.08	27.97±2.97	2.081	0.050
F maximum/ Height(msec)	29.68±3.54	29.05±3.18	2.681	0.015
F mean/ Height (msec)	28.99±3.21	28.54±3.00	2.371	0.028
Chronodis-persion (msec)	2.3±1.27	1.68±0.91	3.715	0.001
Persistence	99±4.47	100±0.00	-1	0.330

Table 3 - F-wave values of the control group and patients with unilateral S1 radiculopathy (on the affected side).

Variable	Patient group affected side (n=20)	Control group (n=40)	*T*-value	*P*-value
F duration (msec)	15.22±2.49	12.45±1.35	5.61	0.0001
F minimum/ Height(msec)	28.39±3.08	28.56±1.35	-0.12	0.907
F maximum/ Height(msec)	29.68±3.54	29.59±1.58	0.12	0.908
F mean/ Height (msec)	28.99±3.21	29.07±1.44	-0.01	0.991
Chronodis-persion (msec)	2.3±1.27	1.68±0.66	2.13	0.037
Persistence	99±4.47	100±0	-1.43	0.159

Table 4 - F-wave values of the control group and patients with unilateral S1 radiculopathy (on the unaffected side).

Variable	Patient group unaffected side (n=20)	Control group (n=40)	*T*-value	*P*-value
F duration (msec)	14.34±2.28	12.45±1.35	4.06	0.0001
F minimum/ Height(msec)	27.97±2.97	28.56±1.35	-0.87	0.388
F maximum/ Height(msec)	29.05±3.18	29.59±1.58	-0.91	0.367
F mean/ Height (msec)	28.54±3.00	29.07±1.44	-0.80	0.425
Chronodis-persion (msec)	1.68±0.91	1.68±0.66	-0.49	0.623
Persistence	100±0.00	100±0.00		

the control group were evaluated in the same pool. The upper limits of normal values for F-wave parameters were obtained from the control group by calculating mean ±2 standard deviations (SD). The values not within this range were considered as abnormal. In the patient group, there was significant prolongation of F dur, F min/H, F max/H, F mean/H, and F chr on the lesion side (**Table 2**). The F dur on the affected

Table 5 - The number of patients with unilateral S1 radiculopathy showing F wave values in the normal range, and number of patients showing values above the normal range, N=20.

Variable	Affected side		Unaffected side	
	Normal	Above	Normal	Above
F duration (msec)	10	10	17	3
F minimum/ Height(msec)	17	3	18	2
F maximum/ Height(msec)	17	3	17	3
F mean/ Height (msec)	18	2	18	2
Chronodis-persion (msec)	14	6	17	3
Persistence	20		20	

and unaffected sides of the patients were significantly longer than the control group (**Tables 3 & 4**). The F chr also showed significant prolongation on the affected side in the patient group when compared with the control group (**Table 3**). Among 20 patients, 15 (75%) had evidence of denervation or polyphasic potentials on EMG. In those patients, 9 of them (60%) showed prolongation in at least one of the F-wave parameters on the affected side. Seven of them (7/15) had abnormal F dur, and 5 of them had prolonged F chr. Prolongation only in F dur was observed in 3 patients, prolongation only in F chr was observed in 2 patients. Prolonged F dur with chr was observed in one patient. Prolonged F dur with F min was observed in one patient. All of the F-wave parameters were prolonged in 2 patients. In addition, 3 of those 9 patients with abnormality of F-wave parameters on the affected side had prolonged F-wave parameters on the non affected side. Two patients showed prolongation in all F-wave parameters and the other one had an abnormality only in F dur. In the remaining 5 patients with mild S1 radiculopathy on MRI and normal findings on EMG, the F dur was found to be significantly prolonged in 2 patients on the affected side. There was prolongation in F dur, F max, and chr in one patient. No significant differences were found in the other 2 patients (**Table 5**).

Discussion. In the current study, we found that detailed assessment of F-wave parameters, especially F dur and F chr, might help the detection of abnormality in patients with S1 radiculopathy. The utility of needle EMG is a well-known entity in the electrophysiological examination of radiculopathies. A complementary profit can be obtained by investigation of F-wave parameters in patients with mild radiculopathy in whom needle EMG shows no denervation.[11] Reports on the sensitivity of F-wave parameters for lumbosacral radiculopathy (LSR) have ranged from 18% to 80-90%.[2,10]

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In the study with the lowest sensitivity, Aminoff et al,[2] compared the diagnostic utility of needle EMG and late responses in 28 patients with L5 or S1 radiculopathy. They found the diagnostic yield for F-wave as 18%, and reported that with the evaluation of H-reflex, the sensitivity of the electrophysiological tests had been increased to 41% (9/22 with S1 radiculopathy). On the other hand, EMG showed denervation potentials in 75% of the patients.[2] Tonzola et al[3] found late response abnormalities in 15 of 57 LSR patients. In another study that investigated the utility F-wave latencies in L5 root compression, needle EMG showed abnormalities in all of the 24 patients. On the other hand, at least one of the different F-wave parameters was found to be abnormal in only 7 patients (29.2%).[4] However, F dur and F chr were not studied in those reports and the diagnostic utility of F-wave investigations was found to be higher when more than one of the F-wave parameters were studied (namely, duration, and chronodispersion).[8,13] In our study, by assessment of different F-wave parameters, we found significant abnormalities in the patient group.

Toyokura et al[11] investigated F min/H, and F dur of the tibial nerve in 27 patients with mild S1 radiculopathy patients and in 46 healthy subjects. Similar with our findings, they found no significant differences between the 2 sides in any of the F-wave parameters in the control group. Additionally, they reported longer F min/H and F dur on the affected side than the non-affected side and the control group. The differences were more evident in F dur.[11] In a recent report, combined utilization of F min, F chr, F pers, and side to side differences resulted in 55% sensitivity and 100% side concordance for detecting cervical radiculopathy, 4/31 (13%) of the cases had at least one abnormal F wave parameter, despite normal electromyography findings.[14] In another report, differences in several F wave parameters between the injured and normal side of patients with unilateral lumbosacral radiculopathy were found.[15]

Interpretation of F dur abnormalities is generally not simple. It generally shows no great difference between the sides and does not correlate with age and gender. The F dur is thought to be modulated by the number of motor units and motor conduction properties driven by central excitability and increased F dur has been reported in several upper and lower motor lesions.[16-18] Prolonged F dur with normal F min in S1 radiculopathy might be explained by the coexistence of fibers with normal conduction time and fibers with prolonged conduction time caused by conduction delays at the root lesion and axonal loss of large fibers. The F dur is also influenced by the size of the individual motor unit. Enlargement of the motor unit following collateral reinnervation may prolong F dur in patients with radiculopathy.[11] Chronodispersion, which is defined as the difference between F min and F max latency values, was found to be prolonged in our patient group. Panayiotopoulos and Chroni[17] noted that prolonged F dur might precede the appearance of increased F chr in mild neuropathy. In another report, the results indicated a high diagnostic sensitivity of F chr, at least in radiculopathies of the lower limbs.[10] The sensitivity of F chr seems to depend on the length of the nerve. This is in line with the concept that F chr is a measure of the variability of conduction in different axons in the whole nerve. This underscores the usefulness of F chr for detecting mild abnormalities.[10] The prolongation of F chr is most likely due to the effect of focal demyelination, which results in root lesions in differential slowing.[19]

The main limitation of our study is the small sample size. In addition, there was no blinding of the patients from the evaluators. For future research, F wave parameters, especially F dur, and F chr can be examined in patient groups that contain more subjects.

In conclusion, according to our findings, we conclude that F dur and F chr have a higher diagnostic value than the other F-wave parameters for the diagnosis of LSR. Additionally, assessment of F-wave parameters is complementary in the evaluation of L5/S1 radiculopathy and may have a diagnostic utility especially in patients with mild and early stages of the disease, and particularly in cases with normal findings on needle EMG.

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