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# FM latency, FM ratio, F-wave latency versus F-wave index in the diagnosis of diabetic neuropathy

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## Abstract

**Background** Diabetes is one of the most common causes for peripheral neuropathy which warrants early diagnosis and treatment. The conventional nerve conduction studies appear to be normal if few of the nerve roots are escaping the lesion. In view of identifying a better clinical testing method, a late response index comprising most of the parameter of F wave was constructed and compared with the diagnosing ability of other parameters.

**Methods** This hospital-based cross-sectional study was conducted among male diabetics aged 30 to 50 years in a tertiary care hospital. Maintaining an ambient temperature of 28 °C and following a supramaximal stimulation of the median nerve of both upper limbs, using a digitalized nerve conduction/electromyography/EP machine, the F-wave tracing was obtained.

**Results** The F-wave index detected a greater number of subjects with diabetic peripheral neuropathy when compared to F-wave mean latency, F M latency and F–M ratio.

**Conclusion** F-wave index can be used as a surrogate electrophysiological study to detect peripheral neuropathy at an early stage and aids in better prognosis.

**Keywords** F wave, F index, Median nerve, F–M ratio, FM latency

## Introduction

Diabetes mellitus is one of the commonest diseases that is known to affect the peripheral nerves. Studies have shown that roughly 47 to 91% of the diabetics suffer from peripheral neuropathy which if left untreated might lead to complications like pain, foot ulceration, infection, loss of ambulation and results in amputation of the affected

limb [1–3]. These complications might interfere with the quality of one's life by reducing the activities of day to day living and would be of great clinical and economic burden to the society and country. Routine history taking, clinical examination when sandwiched with neurophysiological examination of the peripheral nerves using nerve conduction studies (NCS) would be able to diagnose 74% to 82% of the cases and thereby aid in the successful outcome and improved quality of life among patients with diabetic peripheral neuropathy [1]. Among the NCS used in the detection of proximal nerve lesions, literature has shown greater utility of a late response named F wave which was obtained by applying a supramaximal antidromic stimulus to a motor neuron supplying the muscle. Unlike other conventional NCS which spares certain proximal nerve roots, F waves are resultant small compound muscle action potentials which encompasses

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all nerve roots and are formed as a result of both orthodromic and antidromic stimulation [4–11]. Studies have shown that F-wave abnormalities were evident among 60% of the people with clinical symptoms of diabetic peripheral neuropathy (DPN) and also in those who had no neuropathy at a very earlier stage of clinical diagnosis [12–14]. The various F-wave parameters that can be studied to identify the peripheral nerve lesions are the minimum, maximum, mean latencies, persistence (number of F waves obtained by consecutive stimuli), tachydispersion and chronodispersion (difference between the longest and shortest latencies) [7, 15–17]. However various studies suggest the use minimal latency or persistence and there are still discrepancies that exist as to which particular parameter of F wave should be considered and can be clinically utilized. This study was conducted with the view to construct an index—“F wave index” by taking into account most of the parameters of F wave and then to compare the clinical utility of F-wave index over F–M latency in detecting peripheral neuropathy.

## Methods

Following the ethical clearance obtained by the institutional ethics committee, a written informed consent was taken from the study participants and the study was carried out. The study conducted over a period of one year in the Department of Physiology at a tertiary care hospital. A digitalized nerve conduction/EMG/EP machine (Recorders Medicare Systems, Chandigarh, India) was used for the study procedure and the study was carried out following a standard laboratory temperature of 28 °C.

The sample size was calculated based on an earlier study ( $\alpha$ —5%,  $\beta$ —10%, power—90%, standard deviation—2.79 and precision—2 ms) [18]. This cross-sectional study conducted among 40 clinically diagnosed diabetic males aged between the age group of 30 to 50 years. A thorough neurological examination of both the upper limbs that assessed the presence of symptoms and any other signs of neurological lesion was performed using the Toronto Clinical Scoring system questionnaire. Subjects who were suffering from carpal tunnel syndrome, Guillain–Barre syndrome, myopathy, hypothyroid, neuromuscular injury / disorders, fracture of upper limb bones and subjects with pacemakers were excluded from the study.

Following a supramaximal stimulation of the median nerve, the F-wave recording was obtained from the median nerve (Abductor Pollicis Brevis muscle) of both upper limbs using the routinely used clinical procedure [19–21]. The FM ratio was calculated using the formula:  $(F-M-1) / 2 M$  [22] and FM latency was calculated. The F-wave index [(persistence X arm length) / (latency X

chronodispersion)] was constructed after performing a age, gender matching and adjusting for arm length.

## Statistical analysis

Data analysis was carried out using Statistical Package of Social Sciences (SPSS) version 21.0. (SPSS Inc, Chicago, USA). Descriptive statistics: mean, standard deviation of the mean latencies, F–M latency and median, IQR of F-wave index were tabulated. Since the data of F-wave index followed a non-normal distribution, Mann–Whitney *U* test was used to compare the mean score of F-wave index between right and left arm. Also, the comparison between the diagnosing ability of the mean latency, F-index and F–M latency was analyzed using independent sample *t*-test.

## Results

The mean age of the subjects was  $42.70 \pm 6.02$  years. They had a mean height of  $160.18 \pm 24.13$  cm and the mean body mass index of the study participants was  $23.31 \pm 3.45$ . The results obtained are displayed in Table 1 and Fig. 1, respectively.

The present study showed that the F-wave mean latency in the right arm was 31.64 ms and in the left arm was 32.83 ms. The F–M latency in the right and left arm were 22.86 and 23.33, respectively, and the median F-wave index in the right and left arm 35.85 and 39.49, respectively. The FM ratio were calculated for both the arms (Rt arm –  $4.73 \pm 2.55$ ; Lt arm-  $4.89 \pm 2.63$ ).

It showed that in the right arm, the F-wave index diagnosed more (85%) subjects with DPN as compared to FM latency (14.3%), F min latency (7.5%), and FM ratio (12.6%). Similarly, in the left arm of DPN subjects, the F-wave index had better diagnostic ability (80%) when compared to FM latency (11.9%), F min latency (32.5%), and FM ratio (10.2%).

**Table 1** F-wave parameters in the median nerve of both upper limbs

Parameters	Right upperlimb		Left upperlimb	
	Mean	SD	Mean	SD
F mean latency	31.64	2.32	32.83	5.09
F–M latency	22.86	3.86	23.33	2.79
F–M ratio	4.73	2.55	4.89	2.63
	Median	IQR	Median	IQR
F index	35.85	35.26	39.49	39.49

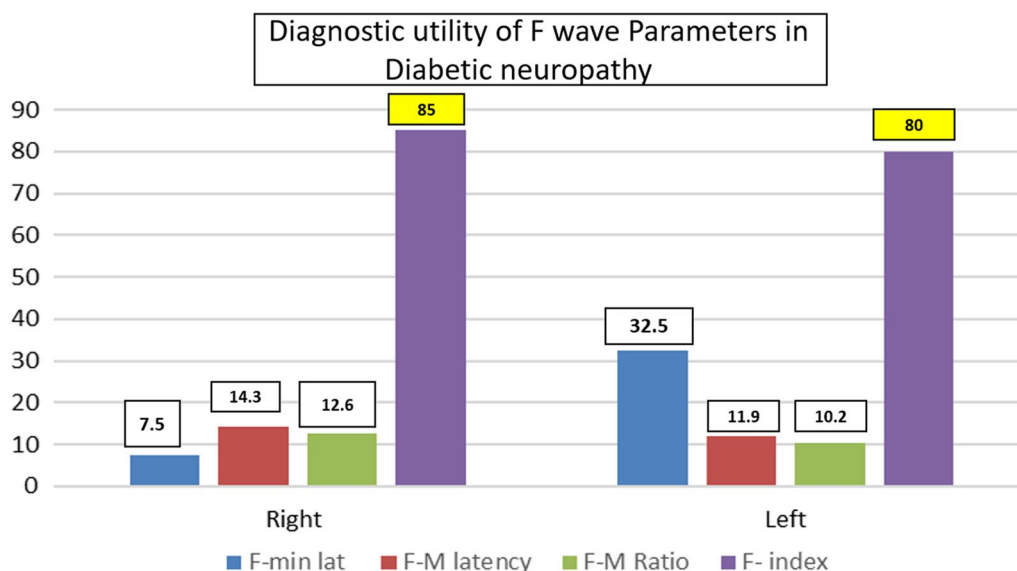


Fig. 1 Comparison of diagnosing ability of various parameters of F wave

**Discussion**

Diabetic peripheral neuropathy still remains as a clinical condition which is underdiagnosed despite the availability of conventional NCS [23, 24]. Various studies have shown that with the advent of expanded access to computerized electrodiagnostic instruments in the area of NCS, there has been a great potential in the early diagnosis and better outcomes in the field of peripheral nerve lesions. Also, studies have suggested NCS as gold standard in the diagnosis diagnostic test among the electrophysiological studies. There are better NCS that can be easily performed by diabetologists, internal care physicians, orthopedicians and primary care physicians [24–27].

Assessment of the proximal conduction status of a nerve is best accomplished by tracing the late response like the F wave. F-wave studies from a motor or a mixed nerve is rather a simple and non-invasive method of diagnosing DPN, radiculopathy and other polyneuropathy [15, 25]. F wave has the credit of identifying lesions even at the exit site of the nerve root when compared to the conventional NCS.

The present study recorded the F-wave parameters from the median nerve of both upper limbs. Median nerve was preferred for conducting the study because of

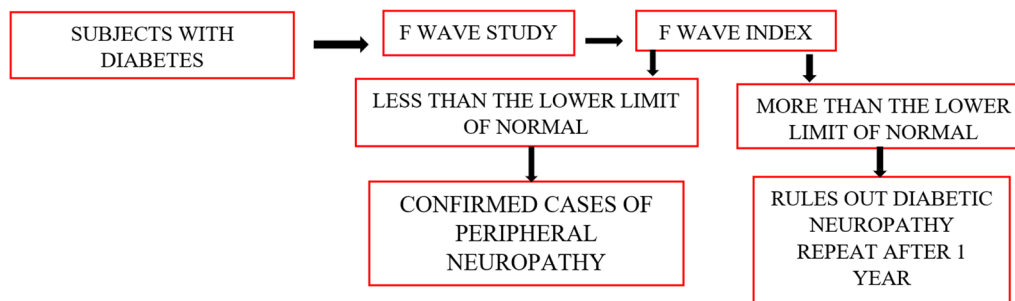
some of the following mentioned reasons: better accessibility, ease of stimulation using surface electrodes, most common nerve affected in individuals with neuropathy and most of all median nerve is better used to study the proximal nerve lesions.

This study attempted to analyze the mean latency, F–M latency, FM ratio and F-wave index among the diabetics. Also, the study also tried to analyze which of the above parameters had a better diagnostic ability among diabetics with peripheral neuropathy.

Studies have shown prolonged F-wave minimum latency among subjects with DPN [9, 26].

The part of the present study in healthy individuals yielded the following results: F-wave mean latency in the right arm:  $27 \pm 2.06$  ms; left arm:  $28.66 \pm 3.79$  ms. F–M latency in the right arm:  $19.05 \pm 2.02$  ms; left arm:  $20.36 \pm 2.07$  ms. FM ratio in the right arm:  $1.93 \pm 1.04$  ms; left arm:  $2.38 \pm 1.68$  ms. A difference of more than 2 ms from the healthy individuals suggests a diagnosis of peripheral nerve injury [6]. F-wave index in the right arm:  $109.01 \pm 63.71$  left arm:  $90.22 \pm 50.64$ .

The present study was conducted with the following notion:



Based on the cut-off value derived from the healthy controls, the diagnosis of DPN was confirmed if the F-wave latency in the right upper limb was beyond 30.84 ms and 32.24 ms in the left arm. The upper limit of the F-wave mean latency among healthy individuals was considered. The lower limit of the F-wave index from the healthy population was considered to diagnose DPN and in the subjects with right arm F-wave index less than 35.85 and 39.49 in the left arm were considered as confirmed cases of peripheral neuropathy.

Considering the above cut-off limits, the study also compared the diagnostic ability of the above parameters. The study concluded that the F-wave index was able to identify a greater number of individuals with diabetic peripheral neuropathy when compared to the conventional F-wave parameters.

#### Limitations of the study

The study was carried out in a small group of individuals and only the male population. Also, the sub-group analysis based on insulin dependent and non-insulin dependent diabetics were not done. The F-wave data were obtained only from the median nerve of both upper limbs. Also, in the present study due to the fact that the study was conducted in a small group of individuals and also only the symptom score was studied, the correlation between the F-wave parameters and clinical outcome was not assessed. Future studies which would be carried out among both the genders in a larger scale and including the nerves of all the limbs will be appreciated.

#### Conclusion

Diabetic peripheral neuropathy still remains as a condition of intractable and stubborn nerve damage. The F index detected a larger proportion of diabetics with peripheral neuropathy as compared to the conventional F-wave minimum latency and F–M latency. Hence, it

would be better to consider the F-wave index as a surrogate investigation which is reliable and accurate form of NCS that will definitely aid in the early detection of peripheral neuropathy. This will go a long way in providing a better standard of living among diabetics.

#### Abbreviations

NCS	Nerve conduction studies
DPN	Diabetic peripheral neuropathy
FM ratio	F-wave motor wave ratio
F–M latency	F-wave motor wave latency
F min latency	F-wave minimum latency

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#### Author contributions

GRS: Conceptualization, methodology, formal analysis, investigation, data curation. JA: Conceptualization, methodology, formal analysis, investigation, data curation. JV: Data curation and data analysis.

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#### Availability of data and materials

The authors will provide the data if required. The data ensure that confidentiality was maintained.

#### Declarations

##### Ethics approval and consent to participate

The study was carried out after obtaining institutional ethical clearance and properly signed informed consent from the study individuals.

##### Consent for publication

The authors consent to give the publisher, the exclusive rights to publish and sell the research findings in all languages, in whole or in part.

##### Competing interests

The authors declare that they do not have any competing interests.

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