Study on F-waves of median nerve in patients with compressed cervical radiculopathy

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Abstract

Background: Recent research has demonstrated that specific parameters derived from F-wave analysis can aid in the diagnosis of radiculopathy. The objective of this study is to assess the characteristics of F waves in upper extremity nerves of patients diagnosed with compressed cervical radiculopathy and explore the relationship between these F-wave characteristics and the degree of nerve root compression in magnetic resonance imaging. **Methods:** A cross-sectional study was conducted, comprising 16 control individuals and 47 patients with confirmed cervical root compression as determined by MRI. Nerve conduction velocity measurements of upper extremity peripheral nerves were performed in the electrodiagnostic room of the Functional Exploration Department at Hue University of Medicine and Pharmacy Hospital between June 2022 and May 2023. **Results:** Significant differences were observed in five indices - F-wave minimal latency, F-wave maximal latency, F-wave mean latency, F dispersion, and F persistence - between patients with low cervical radiculopathy (24 men and 23 women, mean age: 53.34 ± 10.52) and the control group (7 men and 9 women, mean age: 50.50 ± 16.50). When comparing these F-wave parameters with MRI images, only F-wave mean latency and F maximal latency demonstrated a correlation with the severity of nerve root compression ($p < 0.05$, $r > 0.5$). **Conclusion:** The findings suggest that F-wave parameters can serve as valuable tools in supporting the diagnosis of low cervical radiculopathy, even in the absence of changes in motor and sensory nerve conduction. Specifically, F-wave mean latency and F-wave maximal latency appears to be associated with the severity of cervical root compression.

Key words:

1. INTRODUCTION

The etiology of cervical radiculopathy is multifactorial, with disc herniation and degenerative changes in the cervical spine being the most common causes. Other causes include cervical vertebral fractures, dislocations, and collapse. In addition to comprehensive medical history and neurological examination, paraclinical assessments have significant diagnostic value in identifying cervical root pathologies. Electrophysiological evaluations, including nerve conduction study, offer insights into nerve root function, complementing structural assessments provided by conventional imaging modalities. Despite its lower sensitivity, F-wave analysis, encompassing parameters like F-wave latency, minimal F-wave latency, and F-wave dispersion, has emerged as a diagnostic tool in lumbar radiculopathy, particularly concerning lesions affecting the L5 and S1 nerve roots [1]. However, the utility of F-wave analysis in diagnosing cervical radiculopathy remains relatively unexplored.

The aim of our research is to investigate the F-wave changes on nerve conduction studies in patients with compressive cervical radiculopathy through the following objectives:

1. To evaluate F-wave indices of upper limb nerves in individuals with cervical spinal root compression.

2. To examine the association between F-wave indices of upper limb nerves and severity of cervical spinal root compression observed on MRI imaging.

2. METHODS:

2.1. Study design and population:

This is a cross-sectional study conducted in individuals who underwent electrodiagnosis at the Electromyography Department within the Functional Exploration Unit of Hue University of Medicine and Pharmacy Hospital during the period from June 2022 to May 2023. The study cohort was divided into two distinct groups:

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- Group 1 (control group or disease-free group): Consist of 16 subjects, a total of 32 sides, without peripheral neuropathy and no evidence of nerve root compression on MRI imaging.

- Group 2 (disease group): Consist of 47 patients fulfilling the inclusion criteria detailed in Table 2.1.

Table 1. Criteria for selecting individuals with the targeted disease

Selection criteria included the following prerequisites:
(1) Clinical suspicion of cervical radiculopathy, evidenced by the presence of at least one of the following signs: - Neck pain and/or shoulder pain and/or arm pain, unilaterally or bilaterally, characterized by cervical radicular pain. - Any abnormal upper limb strength or changes in upper limb sensation, accompanied by changes in tendon reflexes.
(2) Abnormal findings in cervical spine MRI indicating low cervical radiculopathy[†]

[†]: This study only focused on F-wave analysis of the median nerve, primarily representing nerve conduction of lower cervical root (C5-T1). Therefore, patients with MRI-confirmed compression exclusively in lower cervical roots (C5-T1) were included, while those with compression solely in high cervical roots (C1-C4) were excluded.

Exclusion criteria: Subjects with any other peripheral nervous system abnormality were excluded.

The sample size was determined based on the spinal radiculopathy detection rate via electrodiagnosis as reported by Dumitru [2]. We estimated the minimum required sample size to be 47 participants.

2.2. Study outcomes:

- Age, gender, and pain assessment was gathered via interviews.

- Superficial sensory disorders were evaluated through clinical examination, which involved assessing for decreased superficial sensation. Muscle strength assessment was in accordance with Medical Research Council (MRC) scale [3], with muscle strength below 5/5 being considered abnormal. Deep tendon reflexes were classified as increased, decreased, or absent. All sensory and motor distribution areas were based on the international standards of the American Spinal Cord Injury Association [4].

- Nerve conduction study: Neurowerk EMG-2 2-channel system was used. Motor and sensory conduction of the median and ulnar nerves were performed bilaterally with antidromic technique for sensory. F-waves of the median nerve were elicited on both sides. A minimum of 10 F-wave recordings was performed.

- MRI images depicting nerve root compression were graded according to Pfirrman [5], and categorized into 4 grades: grade 0 (normal) , grade 1 (contact), grade 2 (deviation), and grade 3 (compression) [5]. MRI was performed using a standardized cervical protocol (sagittal and transverse T1- and T2- weighted sequences with a 4-mm slice thickness) with a 1.5T MR scanner (Siemens Magnetom Amira, Erlangen, Germany).

- Motor conduction indices include distal motor latency (DML), motor amplitude (mAmp), and motor conduction velocity (MCV). Sensory conduction indices include distal sensory latency (DSL), sensory amplitude (sAmp) and sensory conduction velocity (SCV). All indices were compared against established normal values as per the guidelines provided by David C. Preston [6].

- F-wave indices include minimal F-wave latency (Fmin), maximal F-wave latency (Fmax), mean F-wave latency (Fmean), F-wave dispersion (Fd), and F-wave persistence (Fp).

2.3. Statistical Analysis

- Data were presented as mean, standard deviation for quantitative variables with normal distribution or as median, interquartile range for quantitative variables with non-normal distribution.

- The Mann-Whitney U test and T-test were used to compare between the disease group and the control group, regarding the differences in the indicators of motor and sensory nerve conduction of median and ulnar nerves, along with F-wave characteristics of the median nerve on the affected side. Data from both sides were included for comparative analysis in cases where bilateral involvement was observed.

- Correlation analysis: The association between F-wave indices and the degree of nerve root compression on MRI was examined utilizing One-way ANOVA or Kruskal-Wallis test. Additionally, Spearman or Pearson coefficients were calculated to determine correlation strength, with a coefficient greater than 0.5 indicating a robust correlation.

- Data was processed using SPSS 26.0 software.

3. RESULTS:

3.1. General characteristics

Table 2. Clinical characteristics and symptoms of study participants

Characteristics		The disease group (n = 47)	Percent %	The control group (n = 16)	Percent %
Gender	Male	24	51.1	7	54.38
	Female	23	48.9	9	56.3
Age		53.34 ± 10.52		50.50 ± 16.50	
Pain	Neck pain	38	81.3		
	Arm pain	28	60.4		
	Shoulder pain	20	43.8		
Upper limb superficial sensation abnormality		6	12.8		
Upper limb weakness		18	38.3		
Reflex disorders		19	38.8		

There was no significant difference in gender distribution between the cervical radiculopathy group (n = 47) and the control group (n = 16). The average age was 53.34 ± 10.52 years in patient group. Neck pain was most common symptom (81.3%). Reflex disorders accounted for 38.8%, closely followed by weakness at 38.3%, whereas superficial sensory symptoms or signs were the least prevalent (12.8%).

3.2. Nerve conduction study in patients with cervical radiculopathy

Table 3. Motor conduction characteristics of median and ulnar nerves

	The affected-side motor conduction (n = 73)	The control group (n = 32)	P
The median nerve			
DML	3.61 ± 0.70	3.28 ± 0.48	< 0.05†
mAmp	9.58 ± 3.38	11.62± 2.90	< 0.05‡
MCV	56.16 ± 5.17	55.8± 5.00	> 0.05†
The ulnar nerve			
DML	2.39 ± 0.5	2.19 ± 0.3	< 0.05†
mAmp	10.02 ± 3.05	9.45 ± 1.73	> 0.05‡
MCV	57.37 ± 10.05	56.83 ± 10.5	> 0.05†

†: The Mann-Whitney U test; ‡: T-test

Motor conduction parameters of the median and ulnar nerves were within normal limits in comparison with reference values. However, when compared to the control group, there was a significant prolongation ($p<0.05$) in motor latency time and reduction in motor amplitude of the median nerve.

Table 4. Sensory conduction findings of the median and ulnar nerves

	The affected-side sensory conduction (n = 73)	The control group (n = 32)	P
The median nerve			
DSL	2.46 ± 0.6	2.16 ± 0.3	< 0.05†
sAmp	37.35 ± 17.65	44.58 ± 28.48	> 0.05†
SCV	60.28 ± 11.67	66.82 ± 13.15	< 0.05‡
The ulnar nerve			
DSL	2.03 ± 0.3	1.91 ± 0.4	< 0.05†
sAmp	34.61 ± 22.65	33.45 ± 23.15	> 0.05†
SCV	61.49 ± 11.35	65.88 ± 11.84	> 0.05†

†: The Mann-Whitney U test; ‡: T-test

In comparison with reference values, sensory conduction parameters of median and ulnar nerves were within normal range. Nevertheless, when compared to the control group, there was a significant increase ($p < 0.05$) in sensory latency time and decrease in sensory conduction velocity of the median nerve.

Table 5. F-wave latency, F-wave dispersion, and F-wave frequency of the median nerve

	F waves on the affected side (n = 73)	The control group (n = 32)	P
Fmin	25.5 ± 2.2	23.41 ± 2.5	< 0.01
Fmax	28.41 ± 4.0	24.7 ± 2.2	
Fmean	26.63 ± 2.2	24.04 ± 2.2	
F dispersion	2.92 ± 2.1	1.38 ± 0.6	
F persistence	83.56 ± 30	94.38 ± 0.0	

All F-wave parameters showed statistically significant differences between the disease and the control group. In particular, F-wave latency and dispersion significantly prolonged in patients with cervical radiculopathy compared to controls, indicating a decrease in F-wave frequency among individuals with the condition.

3.3. MRI findings of nerve root compression

Table 6. Distribution of nerve root compression severity and localization by MRI imaging

	The nerve root compression severity			Total
	Grade 1 (n = 46)	Grade 2 (n = 23)	Grade 3 (n = 4)	
Compression at C4 root	11.0%	2.7%	0.0%	13.7%
Compression at C5 root	24.7%	4.1%	0.0%	28.8%
Compression at C6 root	53.4%	16.4%	0.0%	69.8%
Compression at C7 root	28.8%	9.6%	2.7%	41.1%
Compression at C8 root	0.0%	1.4%	0.0%	1.4%
Compression at T1 root	0.0%	1.4%	0.0%	1.4%

Grade 1 compression was the most observed, accounting for 63.1% of cases. A majority of patients with cervical root compression (69.8%) displayed compression at the C6 root level, followed by the C7 root level, at 41.1%.

Table 7. Correlation between median nerve F-wave indices and severity of nerve root compression detected via MRI imaging.

	Grade 0	Grade 1	Grade 2	Grade 3	p	R
F min	23.41 ± 1.57	25.09 ± 2.17	25.87 ± 1.73	27.98 ± 3.45	$< 0.05^{‡}$	$0.49^{£}$
F max	24.7 ± 2.2	27.94 ± 3.5	28.57 ± 3.3	32.85 ± 11.2	$< 0.05^{†}$	$0.59^{§}$
F mean	24.04 ± 2.2	26.15 ± 2.9	27 ± 2.9	30.05 ± 8	$< 0.05^{†}$	$0.56^{§}$
Fd	1.38 ± 0.6	2.87 ± 2.3	2.7 ± 1.5	4.88 ± 8.9	$< 0.05^{†}$	$0.44^{§}$
Fp	94.38 ± 0.0	85.22 ± 22.5	84.78 ± 30	57.5 ± 42.5	$< 0.05^{†}$	$0.35^{§}$

†: Kruskal-Wallis test; ‡: The One-way Anova; £: Pearson coefficient; §: Spearman coefficient

Statistically significant differences were observed across all parameters of the median nerve F-wave regardless of levels of nerve root compression ($p < 0.05$). There was a robust positive correlation ($p < 0.05$) observed between Fmax and Fmean values and the severity of root compression on MRI.

Both Fmax and Fmean demonstrated substantial positive correlations with the degree of root compression, with statistical significance ($p < 0.05$).

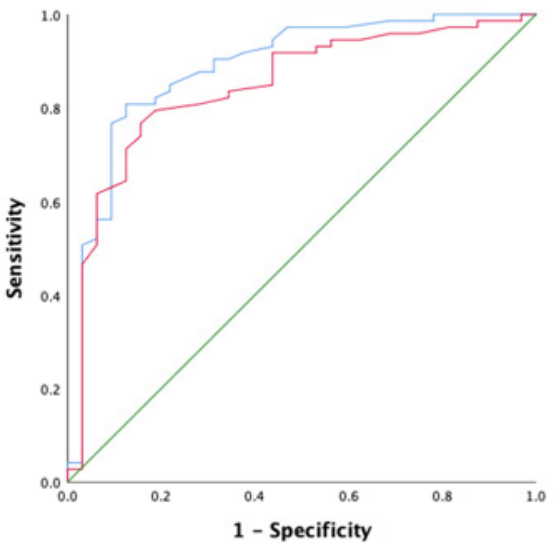

Figure 1. The Receiver Operating Characteristic (ROC) curve illustrating the value of Fmax and Fmean in the diagnosis of cervical spinal root compression. The area under the ROC curve for Fmax and Fmean was calculated as 0.886 and 0.846, respectively. Optimal cutoff points for Fmax and Fmean values in detecting cervical root compression were identified as 26.05 ms (Sensitivity: 80.8%; Specificity: 87.5%) and 25.05 ms (Sensitivity: 79.5%; Specificity: 81.2%), respectively.

4. DISCUSSION

F-wave analysis, a non-invasive method to assess nerve conduction, is commonly utilized in diagnosing nerve root compression. In our study, we investigated the F-wave indices of both median nerves of 16 healthy individuals and 47 patients diagnosed with low cervical root compression. We included a control group because of expected variations in F-wave characteristics due to factors such as race, age, height, and gender. Certainly, it is recommended that each electromyography department should establish their own normal reference values [7].

F-wave indices of the median nerve in the control group differed significantly from those reported by Hoang Thu Soan et al. [8] ($p < 0.05$). This discrepancy may be attributed to the predominance of middle-aged individuals in our study, in contrast to a younger study population targeted by Hoang Thu Soan et al. Clinical findings revealed a high prevalence of neck pain among patients (81.3%), with 38.8% exhibiting abnormal tendon reflexes and 38.3% demonstrating radicular weakness upon physical examination. Conversely, the incidence of superficial radicular sensory sign or symptoms were relatively lower (12.8%).

The motor and sensory conduction of median and ulnar nerves yielded results within normal limits compared to those of healthy individuals. However, significant differences were observed in motor latency times and M-wave amplitude of the median nerve ($p < 0.05$), which might be an indicator of nerve damage associated with cervical radiculopathy. Similarly, changes in sensory conduction parameters (the latency times and conduction velocities of median and ulnar nerves) observed in our study align with the pathophysiology of nerve root compression. As commonly acknowledged in the literature, the motor latency time reflects nerve tip conduction impairment, motor conduction velocity assesses myelin sheath integrity, and amplitude indicates myelin sheath and axonal damage. Consequently, variations in motor conduction indices among patients with cervical radiculopathy may be indicative of more severe and involved root compression-induced damage, including herniation or bone spur-related injuries to myelin sheath and axons.

Results from our study revealed significant prolongation of F-wave latency of median nerves on both sides, including Fmin, Fmax, and Fmean, along with increased F-wave dispersion; while

there was a notable decrease in F-wave frequency among the disease group compared to the control group. This finding is consistent with prior research by Hoang Thu Soan et al. [8], who reported similar significant prolongation of Fmin and Fmean in patients with cervical root compression compared to healthy individuals. On the other hand, a study conducted in Taiwan by Lin Chu-Hsu and colleagues [9] demonstrated significant reduction solely in Fp compared to the control group. Y.L. Lo and colleagues [10] proposed a combined assessment of F-wave parameters, including Fmin, Fp, Fd, and inter-lateral differences, resulting in higher sensitivity in detecting cervical root compression cases validated by MRI imaging. F-wave latency might stay normal in cases of single root compression possibly due to a phenomenon called the 'dilution' effect [11]. This underscores the necessity of evaluating multiple F-wave indices across both ulnar and median nerves to enhance diagnostic sensitivity for upper limb nerve root compression.

MRI findings predominantly indicated compression at the C6 level followed by C7, well aligning with previous literature suggesting a predilection for C6-C7 involvement in cervical radiculopathy. Notably, cervical root compression primarily stems from causes such as disc herniation or osteophyte formation, as demonstrated by our research with 97.9% of patients exhibiting cervical disc herniation.

Comparison of F-wave parameters of the median nerve with the degree of nerve root compression on MRI revealed significant differences across all indices. However, Spearman and Pearson correlation analyses identified Fmax and Fmean as having a strong positive correlation ($p < 0.05$) with cervical root compression severity, suggesting the presence of longer F-wave latency in more severe compression cases. Similarly, Phan Viet Nga [12] reported a significant increase in Fmin and Fmean proportional to spinal stenosis severity, particularly in mild and severe stenosis cases, while Fmax was not investigated. Our study also demonstrated a moderate correlation between Fmin and root compression severity on MRI ($r = 0.49$; $p < 0.05$). Further investigations with larger sample sizes and comprehensive assessment of F-wave indices are warranted to elucidate these findings.

Furthermore, ROC curve analysis utilizing Fmax and Fmean as diagnostic parameters exhibited good discriminatory ability (> 0.8 AUC), with optimal cutoff points identified at 26.05 ms for Fmax and 25.05 ms for Fmean. Notably, Fmax demonstrated a sensitivity of 80.8% and specificity of 87.5%, while Fmean exhibited a sensitivity of 79.5% and specificity of 81.2%.

5. CONCLUSION

In patients with cervical radiculopathy, F-wave analysis is a valuable adjunctive diagnostic tool to MRI imaging, and needle emg. Fmean and Fmax are promising parameters aiding in disease diagnosis and severity assessment, and therefore should be used routinely to improve diagnostic accuracy.

Conflicts of Interest: The authors declare no conflicts of interest.

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