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RESEARCH ARTICLE

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EVALUATION OF LATE RESPONSE INDICES IN PATIENTS WITH LUMBOSACRAL RADICULOPATHY

Thi Hieu Dung Nguyen[1*], Thi Tuyet Nhung Phan[1], Huu Hung Truong[2], Thanh Minh Nguyen[3], Dinh Toan Nguyen[4]

[1] *Department of Physiology, Hue University of Medicine and Pharmacy*

[2] *Department of Functional Exploration, Hue University Hospital*

[3] *Department of Surgery, Hue University of Medicine and Pharmacy*

[4] *Department of Internal Medicine, Hue University of Medicine and Pharmacy*

*** Corresponding Author**
Thi Hieu Dung Nguyen, Department of Physiology, Hue University of Medicine and Pharmacy
Corresponding Author e-mail: nthdung@hueuni.edu.vn

ABSTRACT

Background: Lumbosacral radiculopathy arises from compression or irritation of spinal nerve roots from L1 to S5. Diagnosis typically combines clinical evaluation, imaging, and electrodiagnosis. F-waves and H-reflexes-late responses in nerve conduction studies-offer functional insight into nerve-root integrity. **Objectives:** To assess the relationship between F-wave and H-reflex parameters and the severity of nerve-root compression on lumbosacral MRI. **Subjects and Methods:** In this cross-sectional study, 41 patients with MRI-confirmed lumbosacral nerve-root compression underwent nerve-conduction studies, F-wave, and H-reflex testing at the EMG Laboratory, Department of Functional Exploration, Hue University Hospital from April to December 2023. **Results:** Patients aged 40-59 years comprised 65.9% of the cohort. Degenerative disc disease accounted for 88.5% of compressive lesions. The L5 root was most frequently involved (40.4%), predominantly at grade 3 compression. The Fmax and Fmean wave indices exhibited significant differences according to the degree of nerve root compression observed on magnetic resonance imaging ($p < 0.05$). The latency and amplitude of the H-wave were prolonged and reduced, respectively, in relation to the severity of compression on lumbar–sacral MRI ($p < 0.05$). **Conclusions:** Late response indices may serve as supportive electrophysiological indicators in the assessment of lumbosacral nerve-root compression, although their diagnostic reliability remains limited.

Key words: *Lumbosacral radiculopathy; F-wave; H-reflex.*

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1. Introduction

Lumbosacral radiculopathy is a common clinical condition, characterized by a pain syndrome resulting from the compression or irritation of nerve roots from L1 to S5, with pain radiating along the course of the nerve. The most frequent etiology is lumbosacral spondylosis causing foraminal or spinal canal stenosis. Additionally, other causes such as ligament hypertrophy, malignancy, or infection have been documented. Epidemiologically, the prevalence is estimated at 3% to 5%, affecting both men and women [1]. Age is a significant risk factor, as the disease typically occurs secondary to lumbosacral spinal degeneration. Diagnosis of lumbosacral radiculopathy typically relies on clinical evaluation, imaging, and electrodiagnostic testing. Among these, nerve conduction studies are an electrodiagnostic method that helps identify which nerve root is compressed and the extent of the lesion, thereby guiding clinicians toward accurate etiologic diagnosis and effective treatment. Furthermore, evaluating late responses, including F-waves and H-reflexes, is a technique that assesses nerve root function and evaluates the severity of damage at various levels in lumbosacral radiculopathy [2]. Specifically, the commonly evaluated late response parameters include latency and wave amplitude. Globally, numerous studies have explored the individual roles of F-wave or H-reflex techniques in lumbosacral radiculopathy in general, or sciatica in particular. However, in Vietnam, research on late responses in this pathology remains limited, necessitating further investigations to refine the early diagnosis of lumbosacral radiculopathy. Therefore, we conducted the study: "Evaluation of late response indices in patients with lumbosacral radiculopathy."

2. Materials and Methods

2.1. Materials

The study included 41 patients diagnosed with lumbosacral radiculopathy who underwent nerve conduction studies at the EMG Laboratory, Department of Functional Exploration, Hue University Hospital from April 2023 to December 2023.

Inclusion criteria:

- Clinical criteria: Patients presenting with one of the following syndromes: lumbosacral syndrome, nerve root compression syndrome, or cauda equina syndrome.

- Subclinical criteria:

+ Electrodiagnostic testing including: Motor conduction of the deep peroneal and tibial nerves; sensory conduction of the superficial peroneal and sural nerves; F-waves, and H-reflexes.

+ MRI showing lumbosacral root compression.

- Consent to participate and cooperate during the study.

Exclusion criteria:

- Patients with a history of lumbosacral spine surgery.

- Patients with a history or presence of neurological diseases affecting nerve conduction (e.g., diabetes, polyneuropathy, alcoholism, acute or chronic poisoning, skin or vascular lesions of the limbs).

- Current or past neuromuscular diseases (e.g., myositis, muscular dystrophy).

- Prolonged or current use of neurosuppressive drugs (e.g., anesthetics) or drugs with a risk of causing neuropathy (e.g., Isoniazid, Metronidazole).

- Patients with psychiatric illnesses preventing cooperation.

2.2. Methods

Study design: Cross-sectional study with a convenience sample of 41 eligible patients.

Study variables:

- Demographic characteristics: Age, gender, occupation, diagnosis.

- Clinical variables: Pain characteristics, motor dysfunction, sensory dysfunction, sphincter disorders, reflex changes, nerve stimulation tests.

- Subclinical variables:

+ MRI findings: were obtained using a 1.5 Tesla Siemens Magnetom Amira scanner. Location, cause of nerve root compression, degree of compression, compressed root per Pfirrmann criteria [3].

+ Motor conduction parameters: performed using the Neurowerk_EMG2 system (Germany). DML, mAmp, MCV. Sensory conduction parameters: DSL, sAmp, SCV. These were compared with normal reference values by David C. Preston [2].

+ Tibial nerve F-wave parameters:

Fmin, Fmax, Fmean: From all elicited F-waves, three parameters are determined: the shortest latency (F-wave minimal latency, Fmin), the longest latency (F-wave maximal latency, Fmax), and the mean latency (F-wave mean latency, Fmean). In a given patient, prolonged F-wave latency indicates slowed conduction along the entire length of the nerve, although it does not specify the exact site of the lesion.

Fd: F-wave dispersion is calculated as the difference between the longest and shortest latencies. It reflects the range of conduction properties among the motor fibers activated.

Fp: is expressed as the number of F-waves elicited in response to each train of supramaximal stimuli. Typically, a minimum of 10 stimuli is sufficient for most latency and persistence assessments.

+ Tibial nerve H-reflex parameters:

Hmean latency: Latency is defined as the time interval from the moment of stimulation to the appearance of the H-wave.

Hmax amplitude: is measured from the first negative peak to the first positive peak. From all elicited H-waves, the maximal amplitude (H-wave maximal amplitude, Hmax) is determined.

2.3. Statistic

Data were analyzed using standard medical statistical methods with the support of SPSS 26.0 software.

3. Results

3.1. General Characteristics

Table 3.1. Distribution of epidemiological characteristics of the study cohort (n=41)

Characteristics	Bilateral	Unilateral	Total	Ratio (%)
Age Group				
20-39 years	5	1	6	14.6%
40-59 years	12	15	27	65.9%
> 60 years	4	4	8	19.5%
Mean Age ± SD	50.54 ± 10.5			
Gender				
Male	7	4	11	26.83%
Female	14	16	30	73.17%
Occupation				
Manual labor	29	-	-	70.7%
Intellectual labor	12	-	-	29.3%

The cohort comprised 41 patients (11 males, 30 females). The majority of patients were in the 40-59 age group (65.9%); the mean age was 50.54 ± 10.5. The manual labor group accounted for 70.7% of the participants.

3.2. MRI Characteristics and Lower Limb Nerve Conduction

3.2.1. MRI Characteristics

Table 3.2. Lumbosacral spine lesions on MRI

Severity / Lesion	Number of Patients	Ratio (%)
Foraminal Stenosis		
Grade 0	4	15.39%
Grade 1	12	46.15%
Grade 2	10	38.46%
Disc Degeneration		
Yes	23	88.46%
No	3	11.54%
Vertebral Body Degeneration		
Yes	17	65.39%
No	9	34.61%

Degenerative disc disease was the most common cause of lumbosacral nerve root compression in the study cohort.

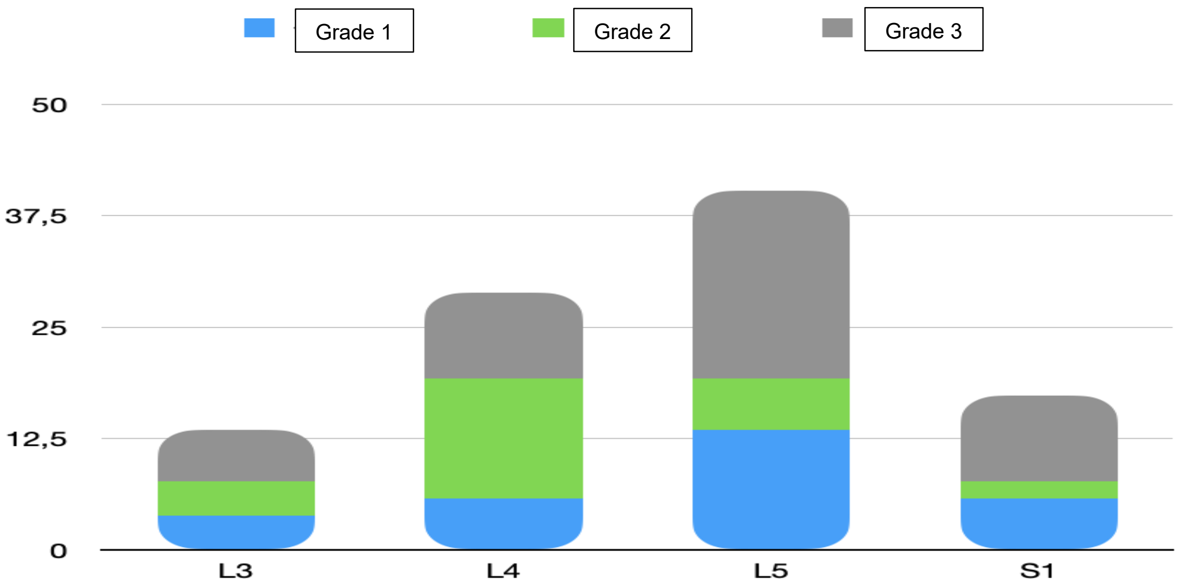

Chart 3.1. Distribution of compressed nerve roots by degree of compression on MRI

Among the compressed roots, the L5 root had the highest prevalence (40.38%), predominantly featuring grade 3 compression. L4 root compression accounted for 28.85% (most frequently grade 2, nearly 50%); and S1 root compression was observed in 17.31% of cases.

3.2.2. Lower Limb Nerve Conduction Characteristics

Table 3.3. Motor and sensory conduction parameters of lower limb nerves

Parameter (Mean ± SD)	Tibial N.	Deep Peroneal N.	Superficial Peroneal N.	Sural N.
Latency (ms)				
Unaffected Side (n=20)	5.98 ± 0.73	5.87 ± 0.82	1.99 ± 0.66	2.61 ± 0.60
Affected Side (n=62)	6.90 ± 0.88	7.00 ± 1.31	2.22 ± 0.76	2.93 ± 0.74
p-value	p = 0.0001	p = 0.0001	p = 0.146	p = 0.084
Conduction Velocity (m/s)				
Unaffected Side (n=20)	53.73 ± 5.56	51.98 ± 1.39	64.29 ± 14.57	57.04 ± 9.78
Affected Side (n=62)	51.36 ± 6.93	49.03 ± 8.86	62.93 ± 13.51	57.82 ± 10.61
p-value	p = 0.11	p = 0.008	p = 0.783	p = 0.681
Amplitude (mV / uV)				
Unaffected Side	15.19 ± 5.11	4.47 ± 1.75	12.60 ± 7.93	10.50 ± 5.94
Affected Side	14.08 ± 6.38	4.14 ± 2.20	19.60 ± 34.64	9.70 ± 3.96
p-value	p = 0.248	p = 0.305	p = 0.897	p = 0.771

The latencies of the tibial and deep peroneal nerves showed a statistically significant difference compared to the healthy side ($p < 0.05$). The amplitudes and motor conduction velocities of the tibial and deep peroneal nerves, along with the sensory conduction of the superficial peroneal and sural nerves, were within normal limits (when compared to standard values [3]), showing no statistically significant differences ($p > 0.05$).

3.3. Characteristics of Late Responses in Lumbosacral Radiculopathy

3.3.1. F-wave and H-reflex Parameters

Table 3.4. F-wave and H-reflex indices of the tibial nerve

Parameter	Unaffected Side (n=20) (Mean ± SD)	Affected Side (n=62) (Mean ± SD)	p-value
F-wave			
Fmin	44.53 ± 2.61	44.11 ± 8.66	p > 0.05
Fmax	45.95 ± 3.26	46.85 ± 9.21	p > 0.05
Fmean	44.54 ± 2.87	45.28 ± 8.91	p > 0.05
F dispersion (Fd)	2.44 ± 1.30	2.72 ± 1.17	p > 0.05
F persistence (Fp)	100	97.32 ± 15.56	p > 0.05
H-reflex			
Latency	30.36 ± 4.10	32.10 ± 7.32	p > 0.05
Amplitude	2.43 ± 2.20	2.72 ± 2.16	p > 0.05

The differences in these indices between the healthy and affected sides were not statistically significant.

3.3.2. Relationship between Tibial F-wave Indices and MRI Root Compression

Table 3.5. Relationship between tibial F-wave and degree of root compression on MRI

Parameter	Grade 0	Grade 1	Grade 2	Grade 3	p-value
Fmin	43.12 ± 3.58	44.06 ± 2.53	45.12 ± 1.69	42.90 ± 13.22	0.127
Fmax	46.35 ± 4.27	46.33 ± 2.88	47.87 ± 1.41	46.05 ± 14.14	0.044
Fmean	44.40 ± 3.95	44.66 ± 2.46	46.45 ± 1.39	44.22 ± 13.64	0.048
Fd	3.28 ± 0.96	2.35 ± 0.98	2.65 ± 0.95	3.13 ± 1.35	0.139
Fp	100	100	100	91.60 ± 19.80	0.373

The maximal latency (Fmax) and mean latency (Fmean) indices varied significantly with the severity of the condition ($p < 0.05$).

3.3.3. Relationship between Tibial H-reflex Indices and MRI Root Compression

Table 3.6. Relationship between tibial H-reflex and degree of root compression on MRI

Mean ± SD	Grade 0	Grade 1	Grade 2	Grade 3	p-value
Latency	28.00 ± 2.65	34.51 ± 4.80	28.48 ± 9.78	34.45 ± 8.39	< 0.05
Amplitude	3.36 ± 2.10	4.71 ± 2.38	4.33 ± 1.92	1.66 ± 1.16	< 0.05

H-wave latency and amplitude demonstrated statistically significant differences across the varying degrees of root compression on MRI.

4. Discussion

4.1. General Characteristics

Age: Our study aligns with findings from other authors. According to Phan Viet Nga, the mean age of onset is 46.55 ± 9.64, with the highest prevalence in the 40-59 age group (63.4%) [4].

Gender: In our study, the female-to-male ratio was 2.73, which differs from some other studies. For instance, Tran Cong Chinh reported an equal gender distribution. Thus, gender may not be a specific distinctive feature of lumbosacral radiculopathy [5].

Occupation: 70.3% of the participants were manual laborers. Their occupations often subject the spine to physical stress beyond physiological limits, including continuous heavy lifting, which predisposes them to disc herniation. This is consistent with Nguyen Tuan Luong's research on lumbosacral radiculopathy caused by disc herniation [6].

4.2. MRI Characteristics and Lower Limb Nerve Conduction

4.2.1. MRI Characteristics

Our findings indicate that degenerative disc disease was the leading cause of nerve root compression (88.46%), aligning with epidemiological studies on lumbosacral radiculopathy. This was followed by foraminal stenosis (84.61%), which may result from disc bulging, anterior osteophytes, or posterior hypertrophy of the facet joints and ligamentum flavum [7], [8]. Regarding vertebral body degeneration, the most common MRI presentation was osteophyte formation, matching studies that reported an incidence of 48.5% in lumbar spondylosis [6], [9].

The L5 root experienced the highest rate of compression at 40.38% (mostly grade 3), followed by L4 at 28.85% (mostly grade 2). Compression rates were lower for L3 (13.46%) and S1 (17.31%). This is consistent with previous research demonstrating that L4 and L5 are the most frequently compressed lumbosacral roots [6], largely because the L4-L5 and L5-S1 segments bear the most biomechanical stress leading to herniation [3], along with anatomical variations contributing to nerve compression.

4.2.2. Lower Limb Nerve Conduction Characteristics

Our study's results on lower limb peripheral nerve conduction closely parallel those reported by Phan Viet Nga, Tran Cong Chinh, and Nguyen Dinh Khanh [4], [5], [7]. The conduction indices on the affected side showed no statistically significant differences compared to the healthy side. This suggests that during routine peripheral nerve conduction studies of the lower limbs, the recorded parameters may remain within normal limits. Such normal findings might not correlate with the patient's clinical presentation or the structural abnormalities causing compression in the lumbosacral spine. Therefore, relying solely on standard lower limb nerve conduction studies may result in missed diagnoses of compressive radiculopathy [10].

4.3. Characteristics of Late Responses

4.3.1. F-wave and H-reflex Characteristics

The prolongation of the minimal, maximal, and mean F-wave latencies on the affected side in our study is consistent with the findings of Sachin and Xiao [11], [12]. Furthermore, we observed that the minimal, maximal, and mean F-wave latencies were shorter on the healthy side than on the affected side.

Regarding the H-reflex, the latency on the affected side was significantly prolonged compared to the healthy side: 30.36 ± 4.10 ms (healthy) vs. 32.10 ± 7.32 ms (affected) ($p < 0.05$). H-reflex evaluation is a highly useful method for detecting S1 radiculopathy [11]. Moreover, it provides valuable insights into the most proximal segments of the plexus and nerve roots, which are difficult to assess directly with standard nerve conduction studies [12], [13]. However, the H-reflex amplitude did not show a statistically significant difference between the healthy and affected sides, a finding corroborated by Sandip's study [13].

4.3.2. Relationship between Tibial F-wave Indices and MRI Root Compression

Although our results indicated that a more severe degree of compression resulted in a prolonged F-wave latency and decreased F-wave persistence in patients with grade 3 compression [12], there was no overall statistically significant difference across the various compression grades regarding persistence, and most patients exhibited normal F-wave responses. This could be attributed to the small sample size or an insufficient degree of compression to induce substantial F-wave alterations. Thus, among the five F-wave parameters, only Fmax and Fmean exhibited significant changes corresponding to the severity of nerve root compression.

4.3.3. Relationship between Tibial H-reflex Indices and MRI Root Compression

Our findings demonstrated that both H-wave latency prolongation and amplitude reduction were significantly correlated with the increasing severity of root compression ($p < 0.05$). Since our study was conducted on a relatively small cohort of 41 patients, it may not perfectly represent the broader population of patients with MRI-confirmed radiculopathy. While Xiao found a direct linear correlation, our results merely established an association with the degree of severity, similar to Sandip's findings [12], [13]. In this study, routine NCS showed no significant difference whereas all the H-reflex parameters including H-amplitude , H-latency and H/M ratio were significantly different (p< 0.0001) , when compared with controls. They concluded that patients had not only partial conduction block but also secondary axonal loss due to nerve root compression. They further suggested that soleus H-reflex study should be included in evaluation of radiculopathy. Based on these outcomes, we recommend that when evaluating patients for suspected lumbosacral radiculopathy, clinicians should perform F-wave and H-reflex testing alongside standard lower limb nerve conduction velocity studies to accurately detect nerve root compression. However, the study population was small and further studies with large sample size and multicentric design are required for confirmation.

5. Conclusion

- The F-wave indices of the tibial nerve in patients with lumbosacral radiculopathy did not show a statistically significant difference compared to the healthy group (p > 0.05).

- The Fmax and Fmean indices exhibited a statistically significant difference across the various degrees of nerve root compression on MRI (p < 0.05).

- The latency and amplitude of the H-wave demonstrated statistically significant differences across the degrees of nerve root compression on MRI (p < 0.05).

Acknowledgement

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of Generative AI and AI-Assisted Technologies

The authors declare that no artificial intelligence (AI) was used during the research process or in the writing of this manuscript.

Author Contributions

The authors who participated in the research in the following roles: Conceptualization and study design, performing experiments, data analysis, interpretation of results, preparing figures, drafting the manuscript, editing and critical review of the manuscript, and final approval of the manuscript.

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NGHIÊN CỨU CHỈ SỐ CỦA CÁC ĐÁP ỨNG MUỘN Ở BỆNH NHÂN CÓ BỆNH LÝ RỄ CỘT SỐNG THẮT LƯNG-CÙNG

Nguyễn Thị Hiếu Dung[1*], Phan Thị Tuyết Nhung[1], Trương Hữu Hùng[2], Nguyễn Thanh Minh[3], Nguyễn Đình Toàn[4]

[1] Bộ môn Sinh lý, Trường Đại học Y-Dược, Đại học Huế

[2] Đơn vị Thăm dò chức năng, Bệnh viện Trường Đại học Y-Dược Huế

[3] Bộ môn Ngoại, Trường Đại học Y-Dược, Đại học Huế

[4] Bộ môn Nội, Trường Đại học Y-Dược, Đại học Huế

TÓM TẮT

Tổng quan: Bệnh lý rễ thần kinh thắt lưng-cùng là hội chứng đau do chèn ép hoặc kích thích rễ thần kinh từ L1 đến S5. Chẩn đoán bệnh lý rễ cột sống thắt lưng-cùng thường dựa trên lâm sàng, hình ảnh học và chẩn đoán điện sinh lý. Các đáp ứng muộn như sóng F, phản xạ H là kỹ thuật giúp đánh giá chức năng rễ của các dây thần kinh, có ý nghĩa trong bệnh rễ thắt lưng-cùng. Vì vậy, mục tiêu đề tài là đánh giá mối liên quan của các chỉ số đáp ứng muộn với hình ảnh cột sống thắt lưng-cùng trên cộng hưởng từ. **Đối tượng và phương pháp:** Nghiên cứu mô tả, cắt ngang 41 bệnh nhân được chẩn đoán bệnh lý rễ cột sống thắt lưng – cùng, có hình ảnh chèn ép rễ cột sống thắt lưng cùng trên cộng hưởng từ, được khảo sát điện cơ dẫn truyền, sóng F, phản xạ H tại phòng Điện cơ đồ, Đơn vị Thăm dò chức năng, Bệnh viện Trường Đại học Y Dược Huế từ tháng 04/2023 đến 12/2023. **Kết quả:** Bệnh nhân ở trong nhóm tuổi 40-59 tuổi, với tỉ lệ 65,9%. Nguyên nhân hàng đầu gây chèn ép rễ trong nhóm nghiên cứu này là Thoái hóa đĩa đệm với 88,46%; rễ L5 chiếm tỷ lệ cao nhất 40,38% với mức độ chèn ép tỷ lệ cao nhất là độ 3. Các chỉ số sóng Fmax và Fmean có sự khác biệt theo mức độ chèn ép rễ thần kinh trên cộng hưởng từ ($p < 0,05$). Thời gian tiềm và biên độ sóng H kéo dài và giảm theo mức độ chèn ép trên hình ảnh cộng hưởng từ cột sống thắt lưng-cùng ($p < 0,05$). **Kết luận:** Các chỉ số đáp ứng muộn là các chỉ số có giá trị trong chẩn đoán bệnh lý chèn ép rễ cột sống thắt lưng-cùng.

Từ khóa: Bệnh lý rễ cột sống thắt lưng-cùng, sóng F, phản xạ H.