



Correlation of electrodiagnostic and clinical findings in unilateral S1 radiculopathy

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ABSTRACT – *Objectives:* Lumbosacral radiculopathy is a challenging diagnosis and electrodiagnostic study (EDX) is a good complementary test to magnetic resonance imaging (MRI). Physical examination, MRI and electrodiagnosis have different diagnostic value in this regard. MRI can provide anatomical evidence and is useful in choosing the treatment procedure, but it may also yield false-positive results. In this study, we assessed the correlation of clinical and EDX findings in patients with L5-S1 disc herniation on MRI. *Methods:* EDX was performed in 87 patients referred for clinical and MRI diagnosis of S1 radiculopathy. The consistency of EDX results with MRI and clinical findings was evaluated by Pearson χ^2 -test and odds ratio. *Results:* Disc protrusion was present in 58% and disc extrusion in 42% of patients. Physical examination revealed absent Achilles reflex in 83% and decreased S1 dermatome sensation in 65% of patients. In this study, EDX sensitivity was about 92%. The highest consistency between EDX parameters and physical examination findings was recorded between absent H-reflex and decreased Achilles reflex (OR=6.20; p=0.014), but there was no significant consistency between H-reflex and either muscular weakness or straight leg raising test result (p>0.05). There was no relationship between the type of disc herniation on MRI and H-reflex either. There was correlation between H-reflex abnormalities and absent ankle reflex in patients with unilateral L5-S1 disc herniation on MRI. *Conclusion:* Results of this study showed that in patients with L5-S1 disc herniation and S1 nerve root compression, it is still beneficial to perform EDX for selected patients.

Key words: electromyography-nerve conduction studies, magnetic resonance imaging, H-reflex, lumbosacral, S1 radiculopathy

INTRODUCTION

Lumbosacral discopathy is one of the most common causes of low back pain. Estimated lifetime prevalence of lumbosacral radiculopathy is 3%-5% of the general population (1). The intervertebral disc between fifth lumbar and first sacral vertebrae (L5-S1) is the most susceptible point to herniation accounting for 42% of all lumbar disc herniation (2). Lumbosacral radiculopathy is a challenging diagnosis. Electrodiagnostic study (EDX) is a useful modality to help in diagnosis because the test is very specific and is therefore a good complement to lumbosacral magnetic resonance imaging (MRI), which is a highly sensitive but nonspecific test. In addition, it is the unique test to evaluate physiologic function of the spinal nerves to see if they are damaged or not. A comprehensive study can also help rule out differential diagnoses that cause pain or neurologic changes in lower extremity. In the hands of a skilled examiner, EDX is very specific and can help us rule out some differential diagnoses that are very common (3). In some studies, two limb muscles plus associated lumbar paraspinal muscle abnormality, two limb muscle abnormality, or one limb muscle plus associated lumbar paraspinal muscle abnormality on electromyography (EMG) showed 97%, 96%, and 92% specificity, respectively, for radiculopathy (4). The specificity of 85% has been reported for EDX in another study (5). There are other studies claiming that EDX could not be replaced by MRI (6). However, there is no systematic review regarding this comparison. Therefore, as there is no gold standard test for lumbosacral radiculopathy, a combination of history, physical examination, imaging, and EDX is used to confirm the diagnosis in research, as well as in clinical setting (3).

There are multiple clinical, imaging and electrodiagnostic tests to detect S1 radiculopathy (2,7). Lumbar radiculopathy is known to have various presentations. Some patients are vague historians, and physical exam is neither highly sensitive nor specific in these patients. Because of this, and because there is no gold standard test for diagnosis, it is common for patients to undergo additional work up. From the evidence based medicine perspective, it may be difficult to assess the value of these tests (3).

Imaging (especially MRI) can well depict disc degeneration and herniation. However, there is very poor consistency between imaging findings of disc herniation and clinical presentation or course. In other words, MRI is more sensitive than clinical findings and consequentially has a large amount of

false-positive results (8). For example, lumbar disc protrusions can be seen in as many as 67% of asymptomatic patients older than 60 and more than 20% have lumbar central stenosis (3).

Electrodiagnostic studies including electromyography-nerve conduction studies (EMG-NCS), when performed by an expert physician, are a very valuable method to diagnose root involvement. It is especially valuable in patients whose physical examination is not reliable (7), as well as in highly suspicious patients who have negative MRI, thus a non-compressive radiculopathy such as infective or immune mediated one being suspected. EDX is very helpful in the work up of patients who have multiple level involvements, and also in patients who are at the risk of neuropathy (3). One study found the needle EMG to be highly specific in the diagnosis of lumbar radiculopathy when using appropriate EDX criteria (92% specificity). EDX for radiculopathy has a low rate of false-positive results (6).

Among EDX findings, H waves are very helpful in the diagnosis of S1 radiculopathy. In some studies, it has been characterized as a definitive sign of S1 radiculopathy, even without the need to perform needle EMG (9-12). This wave has several strengths, including the ability to detect injury to sensory fibers and, unlike needle examination, they are not dependent on a window of opportunity to discover abnormalities because they become abnormal as soon as compression occurs and the deficit can last indefinitely (12).

The aim of the present study was to describe the utility of electrodiagnostic studies in confirming clinically suspected diagnosis and investigate the consistency between clinical and paraclinical findings (EDX) in patients highly suspected of S1 radiculopathy with disc herniation on MRI.

PATIENTS AND METHODS

This prospective study was conducted at the Shohada-e-Tajrish Hospital, Shahid Beheshti University in Tehran, Iran, in 2014. Our patients were referred from neurosurgery department with a high clinical suspicion of S1 radiculopathy and disc herniation findings on MRI in the preceding 3 weeks. All 87 patients referred between 2013 June and 2014 December with a suspicious diagnosis or requiring additional evaluation for better treatment decision were consecutively included in the study. None of the patients had local soft tissue infection or other contraindication for EDX. All study pa-

tients signed their informed consent. The inclusion criteria were as follows: low-back pain radiating to one lower limb and onset of symptoms between 3 weeks to 3 months before.

Individuals with bilateral radicular symptoms, previous spine surgeries, polyneuropathies, focal neuropathies in lower limb, myopathies and known motor neuron diseases were excluded from the study.

On physical examination, the ankle reflex, straight leg raising (SLR) test, plantar flexion strength and sensory loss in S1 territory were examined. Manual muscle testing was recorded in grading system of the Medical Research Council Scale: full available range of motion (ROM) is achieved against gravity and is able to demonstrate maximal resistance (5/5); full available ROM is achieved against gravity and is able to demonstrate moderate resistance (4/5); full available ROM is achieved against gravity but is not able to demonstrate resistance (3/5); full available ROM is achieved only with gravity eliminated (2/5); a visible or palpable contraction is noted, with no joint movement (1/5); and no contraction is identified (0/5) (14). Achilles reflex was determined by taping Achilles tendon with a reflex hammer in prone position and assessed as 0 (no response), 1+ (diminished but present and might require facilitation), 2+ (usual response), 3+ (more brisk than usual), and 4+ (hyperactive with clonus).

We performed EDX studies to confirm diagnosis and to determine the severity of progressive axonal loss.

PARACLINICAL EVALUATION

Electrodiagnostic (EDX) test was performed by a two-channel synergy electrodiagnostic instrument (Medelec™ Synergy T-EP). Needle EMG with a concentric needle electrode was performed by an experienced physiatrist, professor of physical and rehabilitation medicine.

Multiple muscles within the appropriate myotome and adjacent myotomes (above and below) were examined (13,14).

NERVE CONDUCTION STUDIES (NCS)

Standard EDX techniques (13) were used for sural, saphenous and superficial peroneal nerve sensory conduction studies. Sensory action potentials (SNAPs) and nerve conduction velocities (NCVs)

of the above nerves were calculated. Surface electrodes were used for NCS.

Motor conduction studies were also performed for tibial and deep peroneal nerves and compound motor nerve action potentials (CMAPs) were recorded from the abductor muscle of great toe and short extensor muscles of toes. NCVs of both tibial and deep peroneal nerves were also measured.

Patients with impaired nerve conduction studies including patients with peripheral nerve injury, lumbosacral plexopathy or polyneuropathy were excluded from the study. Patients with a history of radiation, immune or infectious disease, which could induce postirradiation radiculitis, plexopathy, infective or immune mediated radiculopathy were also excluded.

Standard EMG techniques were followed for six muscles in S1 myotome (*gastrocnemius*, *soleus*, *abductor hallucis*, *gluteus maximus*, *peroneus longus*, *flexor hallucis longus*) and paraspinal muscles. Also, muscles innervated by L4 and L5 were examined for diagnosing S1 radiculopathy and ruling out differential diagnoses. The criteria for neurogenic EMG included membrane instability, defined as fibrillation potentials and/or positive sharp waves, polyphasic (>4 phases) and/or long-duration motor unit action potentials (MUAPs) (≥ 13 ms), reduced recruitment, and/or reduction in interference pattern (14).

H-reflex was recorded from gastro-soleus muscle using Braddom's technique by submaximal stimulation over the tibial nerve (14). We also adjusted these values for patient leg length and age. All these electrodiagnostic tests were done in both limbs.

STATISTICS

Statistical analysis was conducted using the SPSS version 20. Association between EDX parameters and clinical findings was calculated by odds ratios with the level of significance determined by Pearson χ^2 -test. Paired T-test was used to assess changes in continuous variables. The level of statistical significance was set at $p < 0.05$.

RESULTS

During this 18-month study, 102 patients with high suspicion of clinical and imaging findings indicating unilateral S1 radiculopathy were referred to our EDX lab. Of these patients, 15 patients were excluded as they had other diagnoses leading to

their symptoms: nine patients had sensorimotor polyneuropathy, and three patients had sciatic nerve injury and lumbosacral plexopathy each. Finally, 87 patients with S1 lumbosacral radiculopathy remained in the study. Demographic and clinical characteristics of these patients are shown in Table 1.

According to patient MRI results, 51 (59%) patients had protruded and 36 (41%) patients extruded

Table 1. *Demographic characteristics and physical examination findings in patients with S1 radiculopathy*

Sex	Male	Female
Male/female	48 (55%)	39(45%)
Age (years)		
Mean	41.2	
Range	19-65	
Duration of patient symptoms, range (months)	6-24	
Physical exam findings:		
Straight leg raising test	Positive 41 (47%)	Negative 46 (53%)
Ankle reflexes	Absent or decreased 73 (84%)	Normal 14 (16%)
Sensation in S1 dermatome	Decreased 47 (65.5%)	Normal 30 (34.5%)
Plantar flexor muscle strength	Weak 2 (2%)	Normal 85 (98%)

ed disc herniation. Physical examination revealed absent Achilles reflex in 83%, decreased S1 dermatome sensation in 65%, positive SLR test in 47%, and prominent muscular weakness in only 2.3% of patients. In this study, EDX sensitivity was high (92%, positive result in 80 patients). There was no association between the type of disc herniation and Achilles tendon reflex ($p=0.47$, $OR=0.65$, 95%CI 0.2-2.0); there was no association between the type of disc herniation and either H-reflex ($p=0.769$, $OR=0.82$, 95%CI 0.23-2.94) or EMG result ($p=0.13$).

Calculated sensitivity of H-reflex to diagnose S1 radiculopathy was 87.4% (76 patients had decreased or absent H-reflex) and only 11 (12.6%) subjects had normal H-reflex. There was no association between H-reflex and SLR test results ($p=0.58$, $OR=1.08$, 95%CI 0.3-3.8), between H-reflex and plantar flexor muscle weakness ($p=0.23$, $OR=0.133$, 95%CI 0.008-2.30), or between H-reflex and decreased sensation in S1 dermatome ($p=0.12$, $OR=2.6$, 95%CI 0.7-9.3) but H-reflex and ankle jerk were strongly associated ($p=0.014$, $OR=6.2$, 95%CI 1.5-24.5) and were seen together in 77% of all patients and 91% of patients with decreased Achilles reflex (Table 2).

Electromyography showed neurogenic pattern (neurogenic MUAPs or active denervation) in 92% of subjects. Only seven patients were normal on EMG exam and 80 patients had positive findings,

Table 2. *Physical examination and H-reflex findings in patients with S1 radiculopathy*

	Ankle reflex		Straight leg raising test		Sensory examination	
	Normal	Decreased	Negative	Positive	Normal	Decreased
Normal H-reflex	5 (45.5%)	6 (54.5%)	6 (54.5%)	5 (45.5%)	5 (45.5%)	6 (54.5%)
Prolonged/absent H-reflex	9 (11.8%)	67 (88.2%)	40 (52.6%)	36 (47.4%)	9 (11.8%)	67 (88.2%)
Significance	$p=0.014$; $OR=6.20$ Pearson $\chi^2=8.04$		$p=0.582$; $OR=1.08$ Pearson $\chi^2=0.014$		$p=0.124$; $OR=2.60$ Pearson $\chi^2=2.24$	

Table 3. *Needle electromyography (EMG) findings in patients with S1 radiculopathy*

Electromyographic finding	n (%)
Normal	7 (8%)
Denervation potentials	33 (38%)
Chronic neurogenic process	24 (26%)
Decreased interference	17 (18%)
Denervation potentials & neurogenic pattern MUAPs	6 (7%)
Total abnormal EMG	80 (92%)

MUAP = motor unit action potential

as shown in Figure 2 (92% total sensitivity). The highest sensitivity was recorded for active denervation (37.9%), followed by chronic neurogenic pattern (27.6%) (Table 3). There was no correlation between the type of disc herniation on MRI and type of EMG abnormalities in electrodiagnostic study ($p=0.13$).

DISCUSSION

Low-back pain with radiating pain to the lower limb is the most common reason for referral to

EDX lab. EDX has been used to assess for lumbosacral radiculopathy diagnosis, determine the involved roots, physiologic function of nerve, and severity of lesion. It can also serve as an adjunct to clinical history and physical examination, and to confirm neuroimaging result (15). In our study, the sensitivity of EMG and H-reflex in diagnosing lumbosacral radiculopathy was 92% and 87%, respectively, and the two most common physical exams were decreased Achilles reflex and S1 dermatome abnormality. In another investigation, sensory loss in the painful dermatome was the most frequent finding on physical examination (56% of cases) and EMG was abnormal in at least one myotome in 42% of cases (16).

Recently, some evidence has been reported for the role of EDX before surgery to know which patients have better prognosis, but it is beyond the scope of this article. H-reflex is routinely used to evaluate S1 radiculopathy diagnosis. The H-reflex diagnostic criteria are latency difference between two sides, prolonged latency, and absence of H-reflex (12,13). Diagnostic sensitivity and specificity vary widely among studies. The sensitivity and specificity of 50% and 91% are reported for H-reflex, respectively (8). In the present study, ankle jerk reflex abnormalities were followed by H-reflex latency abnormality in 91% of patients. In similar investigations, H-reflex study was abnormal in 88% of subjects (17). Bobinac-Georgijevski *et al.* report that EMG abnormalities indicating S1 radiculopathy were followed by H or F wave latency abnormality in 63% of patients. The rest of patients (37%) showed mild EMG abnormalities, followed by normal H or F wave (11). Our study revealed similar results; there was significant association between EMG findings and H-reflex ($p=0.066$). Normal EMG finding was followed by normal H or F wave in 64% of patients. In a study performed by Katirji and Weissman, the maximal H-reflex amplitude and maximal H/maximal M amplitudes were associated in a positive slope with ankle jerk (18). In most of the previous studies, H-reflex abnormalities including H-reflex latency or its absence were strongly associated with ankle reflex.

In a study conducted by Lauder *et al.* to determine the extent to which the history and physical examination predicted the outcome of EDX evaluation in patients with suspected lumbosacral radiculopathy, the history and physical examination could not reliably predict electrodiagnostic outcome (2). However, there was strong association between the presence of an abnormality in the respective reflex and radiculopathy at that level. For example, sub-

jects with an abnormal Achilles reflex were more than eight times more likely to have S1 radiculopathy than those with normal Achilles reflex (19). These findings are almost consistent with the results of our study.

Finally, we should say that imaging can be considered complementary to electrodiagnostic medicine. It depicts disc degeneration and disc herniation, and can also suggest the presence of discogenic abnormality, but the lack of the gold standard obviates any definitive conclusions. As we know, there is very poor correlation between imaging findings of disc herniation and the clinical presentation or course (9). In our study, EDX findings were used to confirm the diagnosis of disc herniation but there was no significant correlation between the pattern of disc herniation (extrusion *vs.* protrusion) and electrodiagnostic results including EMG findings, H-reflex latency, etc.

In conclusion, in the population of patients with suspected lumbosacral radiculopathy referred for an EDX study, generally physical examination may not be reliable in predicting EDX outcome. However, ankle reflex can be assessed and considered as a H-reflex study in electrodiagnostic testing. This study also showed that in a patient with L5-S1 disc herniation on MRI, in the presence of an EMG expert, it is still beneficial to perform EDX study, in particular in patients that are candidates for surgery intervention or those with negative MRI results. However, MRI and EDX are complementary to each other. MRI investigates the anatomic change of discvertebral complex and electrodiagnostic studies provide physiologic information. EDX could reveal nerve root compression, its progress and its stage, i.e. acute or chronic lesion, but imaging and other investigations may be necessary to determine the exact cause of spinal nerve damage other than disc herniation.

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Korelacija elektrodijagnostičkih i kliničkih nalaza kod jednostrane S1 radikulopatije

SAŽETAK – Ciljevi: Lumbosakralna radikulopatija je zahtjevna dijagnoza, a elektrodijagnostičko ispitivanje (EDX) je valjana dopunska pretraga magnetskoj rezonanci (MRI). Fizikalni pregled, MRI i elektrodijagnostika imaju različitu dijagnostičku vrijednost u ovom području. MRI pruža anatomske dokaze i korisna je za odabir terapijskog postupka, ali isto tako može dati lažno-pozitivne rezultate. U ovom istraživanju procjenjivali smo korelaciju kliničkih i EDX nalaza u bolesnika s hernijom diska L5-S1 na MRI. **Metode:** EDX je provedeno u 87 bolesnika upućenih na kliničku i MRI dijagnostiku radikulopatije S1. Sukladnost rezultata EDX s MRI i kliničkim nalazima procijenjena je Pearsonovim χ^2 -testom i omjerom izgleda (*odds ratio*, OR). **Rezultati:** Protruzija diska bila je prisutna u 58 %, a ekstruzija diska u 42 % bolesnika. Fizikalni pregled je otkrio odsutnost Ahilova refleksa u 83 % i smanjeni osjet dermatoma S1 u 65 % bolesnika. Osjetljivost EDX u ovom istraživanju bila je oko 92 %. Najviša razina sukladnosti između parametara EDX i nalaza fizikalnog pregleda zabilježena je između odsutnog H-refleksa i sniženog Ahilova refleksa (OR=6,20, p=0,014), ali nije bilo značajnije sukladnosti između H-refleksa i mišićne slabosti ili rezultata testa podizanja ispružene noge (p>0,05). Nije bilo niti povezanosti između tipa hernije diska na MRI i H-refleksa. Utvrđena je korelacija između nenormalnosti H-refleksa i odsutnosti refleksa skočnog zgloba u bolesnika s jednostranom hernijom diska L5-S1 na MRI. **Zaključak:** Rezultati ovoga istraživanja su pokazali kako je u bolesnika s hernijom diska L5-S1 i kompresijom korijena živca S1 ipak korisno provesti EDX u odabranih bolesnika.

Ključne riječi: elektromiografija - ispitivanje živčane provodljivosti, magnetska rezonanca, H-refleks, lumbosakralni, radikulopatija S1