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Case report

Electrodiagnosis-based management of patients with radiculopathy: The concept and application involving a patient with a large lumbosacral disc herniation

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ABSTRACT

Objectives: The evaluation of patients with lower back pain (LBP) is based mainly on clinical examinations and imaging procedures that are subjective or anatomic in nature. The treatments, either physical therapy or osteopathy, lack evidence-based protocol and may be disruptive to the spine. Therefore, a neurophysiologic-based approach to managing such patients is necessary.
Methods: A 40-year-old female complained of LBP and radiculopathy for more than 12 years, a condition that was accompanied by numbness, tingling and weakness in the left leg. This study examined the effectiveness of using an innovative concept and method on a patient with a 19-mm disc herniation. An electro diagnosis-based evaluation and treatment approach testing tool, Soleus H-reflexes, was applied during unloading (with the patient lying down), loading (with the patient standing or sitting), and various trunk position protocols. A structured treatment was based on the results of H-reflex, including direction-sensitive exercises and manipulation, progressing from unloading to full loading. A custom-based home program was developed for sleeping and sitting positions, with all being directed at non-invasively decompressing the compromised nerve root. Data was analyzed using descriptive statistics.
Intervention and results: Stepwise application of the developed procedures resulted in complete resolution of the radicular and spinal symptoms, with a reduction in the size of the herniated disc from 19 mm to 4 mm and recovery of the H-amplitude by the end of the treatment. Functional recovery was also complete by the end of the program. A follow-up after 12 months showed maintained results.
Conclusions: The discussed concept and method exhibited their effectiveness in this case study, and the results obtained are due to the consistency and maintenance of the neural decompression using a direction sensitive therapy protocol.
Significance: Direction sensitive exercise therapy based on H-reflex testing is effective in treating large herniated lumbar discs.

1. Introduction

Lower back pain (LBP) management is based on clinical, imaging and electromyographic (EMG) studies. EMG and magnetic resonance imaging (MRI) are generally performed on a patient who is in a resting position. An objective electrophysiological method that is sensitive to nerve root pathologies can be tested on patients while they are lying down or standing up. These tests relate information that can lead to effective treatment strategies (Abdulwahab and Sabbahi, 2000; Ali Ashraf and Sabbahi, 2001; Ali and Sabbahi, 2000; Bronfort et al., 2008). This procedure has been under development in our laboratory for several years, with many successful studies that were reported in abstract forms. The procedure is based on testing the amplitudes of H-reflex of patients in static positions (lying and free standing) and during eight different trunk postures (Abdulwahab and Sabbahi, 2000; Ali Ashraf and Sabbahi, 2001; Ali and Sabbahi, 2000). The H-reflex latency has been used to detect the delayed signal due to neural/root's degeneration while ignoring the amplitude that detects axonal dysfunction (Ali and Sabbahi, 2000; Alrowayeh et al., 2011). This report presents a single case of a patient with a large (19 mm) herniated disc, with the purpose of discussing the techniques (testing and treatment)

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and their effect on saving the patient from spinal surgery. A cross-sectional study is currently being prepared for future publication.

H-reflexes have long been used to test nerve root pathologies (Abdulwahab and Sabbahi, 2000; Ali Ashraf and Sabbahi, 2001). The α-moto neurons are activated by electrical stimulation of the afferent nerve fibers with the signal passing centrally to the spinal cord; this results in reflex muscle contraction (Fisher, 2002). Testing soleus H-reflexes while the patient is standing has resulted in increasing the possibility of detecting minimal neural impingement (Ali Ashraf and Sabbahi, 2001). Nerve root impingement might be contained while the patient is lying down, causing an increased H-amplitude. An increased trunk load while a patient is standing may provoke an increased disc protrusion with pressure on the nerve root, resulting in small H-reflex amplitude. Although some studies have tested H-reflexes before and after manipulation therapy, a test on the dynamical changes of H-reflex and its effect on neural pressure are lacking (Sabbahi, 1997; Suter et al., 2005).

In this study, H-reflex amplitude was measured to evaluate the degree of on-line axonal compression/decompression during trunk static and dynamic procedures (Abdulwahab and Sabbahi, 2000; Ali Ashraf and Sabbahi, 2001, Ali and Sabbahi, 2000). Test-retest reliability of H-reflexes on a patient in different positions has been previously reported (Ali and Sabbahi, 2000). Furthermore, soleus H-reflex amplitude was reported to be 100% specific for lumbosacral radiculopathy (Sabbahi et al., 1990).

1.1. The concept

Radiculopathy is a neuro-mechanical disorder caused by compression of the nerve root associated with foraminal narrowing

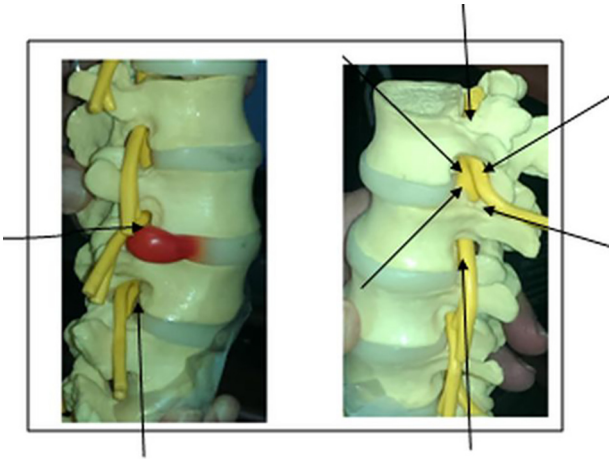

Fig. 1. A spinal segment with disc herniation bulge (left) and a spinal segment with an illustration of possible direction of nerve root impingement in advanced arthritis.

(Fig. 1). This compression is mainly direction-sensitive. Decompressing the nerve root can be achieved by direction-sensitive exercise (DSE) therapy (Table 1). Identifying the direction of neural compression/decompression can be accomplished by testing the H-reflexes in "static" and "dynamic" protocol. The decompression posture is called the optimum spinal posture (OSP) and the compression posture is called the unwanted spinal posture (USP), (Fig. 2), (Sabbahi et al., 2015b). Fig. 2 shows the reflex amplitude

Table 1
Exercise types with loading level. Mobilization (Mob), manipulation (Manip) and strengthening (Strength) protocol during an 8-week period of treatment.

PERIODS	INITIAL			MIDDLE		FINAL		MAINTENANCE
WEEKS	1	2	3	4	5	6	7	8
Unloading exercise (prone)	3 x/ week ⟷							
Partial loading (sitting)		3x/week ⟷						
Full loading (standing)				2x/week ⟷		1x/week ⟷	⟷	
Exercise types	Mob. Manip.	Mob. Manip.	Mob. Manip. Streng	Mob. Manip. Streng	Mob. Strengt	Strengt Mob.	Streng Mob.	Endurance in neutral posture

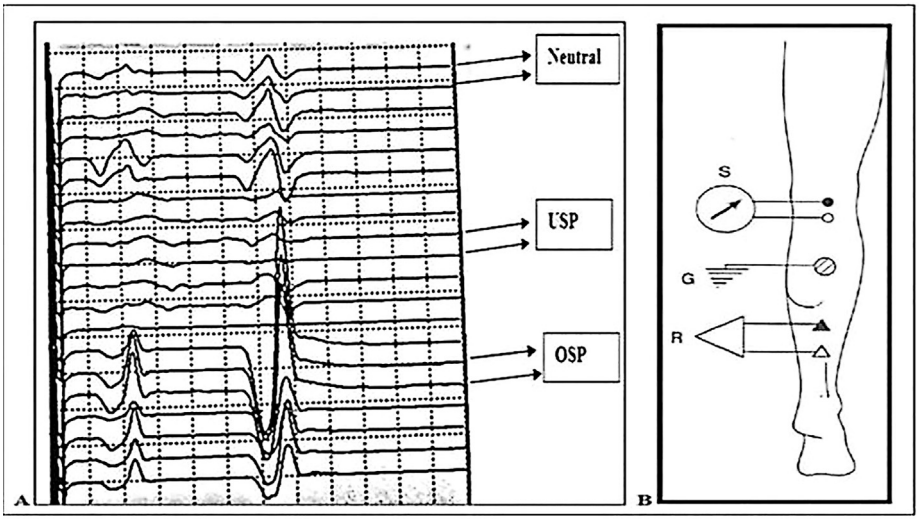

Fig. 2. A: Dynamic testing of soleus H-reflex in a patient with radiculopathy showing the reflex amplitude in the neutral stand and in different movement directions with the USP (decreased signal) and OSP (recovered) signal amplitudes. **B**; Location of the stimulus electrodes, **S**: stimulus electrode, **R**: recording electrode, **G**: ground electrode.

modulations in different trunk positions in an optimal patient presenting both the OSP and the USP.

2. Case presentation

A 40-year old female complained of LBP for 12 years. Although spine surgery was recommended, the patient rejected it.

2.1. Clinical examination

The patient reported severe pain in the lumbosacral region radiating to the left lower limb, accompanied by a burning sensation on the bottom of the foot and numbness/tingling and weakness in the leg. A Straight Leg Raise (SLR: a nerve tension test) was limited to 30°, Achilles tendon reflex was absent in the left foot, and sensory loss in L4-L5 dermatome in the left leg was present.

2.2. Functional evaluation

The Oswestry LBP disability questionnaire (OD), Visual Analogue Scale (VAS) for pain, gait evaluation (symmetry), tiptoes/heels walking and self-reported functions were evaluated before and at the end of the program (Table 2).

2.3. MRI reports

"L4-5: large extruded central to left paracentral disc herniation measuring 19 mm in craniocaudal dimension by 11 mm in AP, with marked compression of bilateral L5 nerve root" (Fig. 3).

2.4. The electro diagnostic testing/procedures

The patient signed a consent form prior to an EMG/NCV testing routine using Cadwell Sierra unit (Kennewick, WA). This was followed by a static and dynamic H-reflex test. Although routine EMG/NCV studies were completed, this report discusses the H-reflex data to represent nerve root function/dysfunction. The tibial nerve was electrically stimulated in the popliteal fossa using 1 msec pulses at 0.2 Hz, and the signal was recorded using a 1000–5000 gain and 10 Hz–10 K Hz filter. All tests were performed while the patient was prone (Sabbahi et al., 1990) as well as while she was standing. The peak to peak amplitudes of the soleus muscle's H-reflex was measured to identify the degree of reflex asymmetry or lack thereof between both legs (Ali Ashraf and Sabbahi, 2001). Five representative traces were recorded in each limb at different phases (lying and standing) of the test. The results identified the left leg with the smaller H-amplitude in both lying and standing positions, indicating the severity of the neural pressure (Sabbahi et al. 2015a, 2015b). Soleus H-reflex of the symptomatic leg was recorded at the end of each trunk direction in order to structure the treatment protocol. Five representative traces were recorded in the following trunk positions; right-side bend (RSB), left-side bend (LSB), backward bend (BB), forward bend (FB), right rotation (RR), left rotation (LR), right-side bend and left rotation (RSB + LR), and left-side bend and right rotation (LSB + RR). The H-reflexes were measured at the same level of motor-neuron excitability in different movement direction. This was carried out by adjusting the stimulus amplitude to keep the M-response constant during these dynamic tests. These descriptive movement directions were

Table 2
Soleus H-reflex amp, MRI, pain intensity, and functional data; before and at the end of the treatment program.

Limb	Evaluation	Soleus H-reflex amp; mv		SLR	VAS	ODS	MRI disc herniation size
		Prone	Standing				
Right	Before	4	4.5	90°	0		
	After	1.5	2	90°	0		
Left	Before	0.01	0.01	30°	7/10	96%	19 mm
	After	3.25	2.75	90°	1/10	10%	4 mm

*__SLR:__ Straight Leg Raise, **VAS**: Visual analogue scale, **ODS:** Oswestry Disability Scale, **mv**: millivolts.

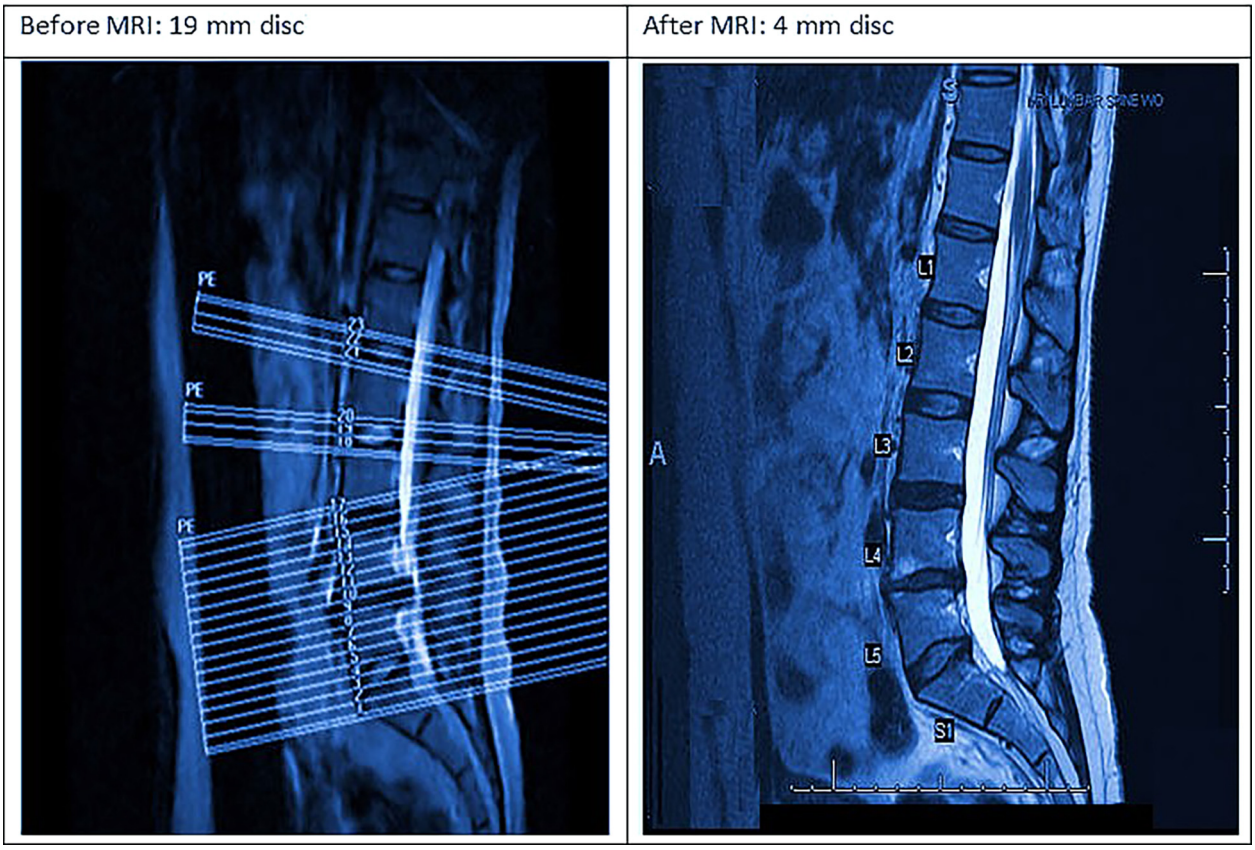

Fig. 3. MRI scan before and at the end of the treatment program.

selected to direct the patient to her OSP and a home exercise regime (Fig. 4). This dynamic test was carried out at the beginning of the program to structure the treatment protocol, i.e., identify the optimum spinal posture (OSP) and the unwanted spinal posture (USP). Repeatability and H-amplitude stability were maintained by recording the five traces in the static phase at the final range of movements in OSP and USP. This study aims to discuss not only the electrodiagnostic technique and its application to a patient with a 19 mm herniated disc but also the process of physical therapy protocol and its outcome.

3. Clinical impressions

3.1. Electrodiagnostic tests

The dynamic tests (completed only before the intervention) showed the maximum H-amplitude in the (RSB + LR), which was the OSP. Forward bending (FB) showed further reflex depression (USP). These two postures were applied to develop a treatment protocol, and the patient was presented as a candidate for the treatment program.

3.2. Intervention program development

A direction-sensitive treatment protocol which included modalities in the OSP while avoiding the USP was developed. Patient education was instrumental in adopting the OSP during sleeping and sitting postures.

3.3. The sleeping and sitting postures

The patient lay down on her left side, bending the left leg and stretching the right leg backward while turning the torso into a semi-prone position to induce left rotation (Fig. 4a) for at least 2 h of sleep time. The sitting posture was implemented using a 3-inch book placed under the right hip throughout the sitting period (Fig. 4b).

3.4. Intervention protocol

A DSE protocol was implemented, progressing from lying to sitting to standing positions (2 weeks each for 45–60 min. sessions) (Table 1, Fig. 4). A maintenance period of 2 weeks carried out mostly in sitting and standing positions ended the program (Fig. 4). The patient was treated 3x/wk for the first 4 weeks (initial period), 2x/wk in loading (Fig. 4c), for one week (middle period/partial loading) (Fig. 4d, f) and then 1x/wk until discharge, using full loading (Fig. 4e) (final period). Treatment included the application of modalities, the exercise program in RSB + LR and avoiding FB. Radicular symptoms were monitored during treatment. Centralization (pain moving toward the posterior side of the thigh) was interpreted as progress while peripheralization (pain moving toward calf and foot) was interpreted as regression (Donelson et al., 1990).

Mobilization exercises (ME) and manipulation (quick thrust) were carried out in each session in the OSP (Fig. 4h, i) and were followed by strengthening exercises (SE) (Fig. 4j). They progressed

Fig. 4. Sample program of exercise, manipulation, and exercise of a different level. RSB: Right side bending, LR: Left rotation.

from lying to standing postures, while leg and back pain were being monitored at the same time. A home care program (in the sitting and sleeping postures) as well as specific pictured exercises (Fig. 4) was recommended for 3x/day, for 10 min each. The patient abstained from taking medications during the treatment protocol.

4. Results

The pain decreased from the distal (foot) to the proximal limb (glutei, and vertebral level) segment following the **centralization concept** (Mulligan, 1993). The intensity of leg pain was reduced in the first session, from 7 to 3 on the VAS scale, and was completely centralized to the lumbar spine by the 12th session. The patient was pain-free by the end of the treatment protocol. This was followed by improvement of the sensory symptoms and muscle weakness beginning at the 6th session.

With increasing straight leg raising (SLR) to 90°, OD showed a test score which improved from 96% to 10% disability by the end of the program (Table 2). Functional activities were substantially improved compared to the initial assessment (Table 3).

By the 5th session, the patient's gait was more symmetrical during swing and stance phases, and she was able to walk on her tiptoes and on the heels of both feet by the end of the program. She reported that she was able to practice her gardening and daily activities by the end of the 12th session (Table 3).

Table 3
Subjective functional condition before and after treatment.

Functions	Before	After
Gardening	X	1–2 h daily
Cooking	X	√
Toileting	X	√
Walking	10–12 steps	Able to walk for 2 hrs. continuously
Lifting	X	15 lbs.
Shopping	X	√
Driving	X	1 h/day
Sport activities	X	Once a week
Sleeping efficiency	X	Sleep with no pain
Travelling	X	Could travel to NY

5. Imaging results

After the treatment program, an MRI showed a reduction of the L5 disc herniation from 19 mm to 4.0 mm (Fig. 3). The MRI results reported: "Asymmetric to the left, disc herniation bulge with a

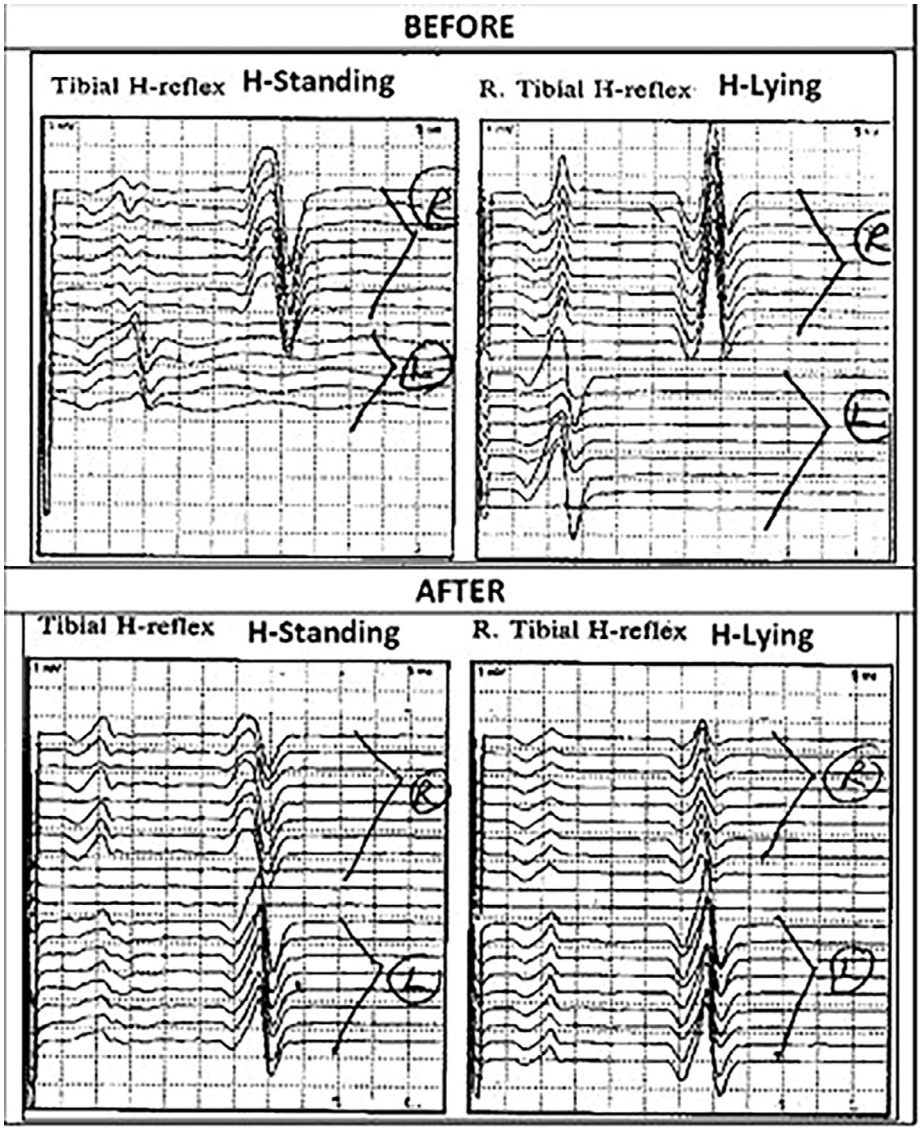

Fig. 5. The soleus H-reflexes during lying and standing postures, before and after completion of the treatment program. In each panel (lying and standing), the traces from the right side is on the top and the left side is on the bottom (labeled right/left). Stimulus intensities were comparable as seen in M-amplitudes.

small 4 mm AP diameter, central and paracentral disc herniation protrusion that mildly narrows the left lateral recess and minimally displaces the left L5 nerve root" (Fig. 3).

5.1. Electrodiagnostic tests

Post-treatment, H-reflexes amplitudes showed a significant increase from 0.01 mv to 3.25 mv while the patient was prone position (Fig. 5) and from 0.01 mv to 2.75 mv while she was standing. The H-amplitude of the right non-symptomatic side was a little smaller at the end of the treatment program, resulting in more reflex symmetry between both lower limbs (Table 2). No changes were recorded in H-latency.

For consistency purposes, all pre- and post-tests were carried out by the same physical therapist.

6. Discussion

A new method of pain management for patients with radiculopathy based on EMG/H-reflex studies has been discussed. The concept and application of this technique was used on a patient with a 19 mm L4-5 disc herniation. The soleus H-reflex is commonly used for S_1 nerve root pathology. However, the somatic organization of the sciatic nerve originates from L4, L5, S1-S3 rootlets (Giuffre and Jeanmonod, 2018). Tibial nerve stimulation would activate L4-L5, L5-S1 spinal segments that might result in the recorded soleus H-reflex.

The present approach is based on the neuromechanical dysfunction concept. Pain, numbness and burning sensations originate from sensory neural dysfunction. Muscle weakness may result from compromised motor axons. These neural compromises may be a consequence of the mechanical dysfunction caused by the herniated disc pathology. Testing and treatment in this study addressed both components with numeric procedures that were sensitive to postural modification (Licciardone et al., 2005). The current manual therapy for severe cases of radiculopathy without electrodiagnostic testing might have missed the double axes posture (OSP) reported in this study, which could result in an insufficient treatment outcome (Licciardone et al., 2005).

The H-reflex amplitude was tested in a modified protocol to evaluate nerve root compression/decompression. The on-line depression and recovery of its amplitude as seen in this patient

makes it useful for initial and serial monitoring of LBP patients. The increased H-reflex amplitude post treatment is electrophysiological evidence of neural decompression associated with axonal recovery (Burke, 2016; Alrowayeh et al., 2011; Mazzocchio, 2001).

The treatment approach included sleeping and sitting postures, as well as a direction-sensitive exercise protocol. The sleeping position produced the needed OSP during sleep and resulted in a reduction in radicular pain in the morning. This posture appears to result in diminished neural compression during sleep, causing reported substantial lessening of morning radicular and spinal pain. The sitting posture with a 3-inch book under the right hip reduced the radicular pain by tilting the pelvis to right side, which caused a partial opening of the spinal foramina in a single axis and partially decompressed the nerve root. This further reduced the radicular and spinal pain during daily sitting times.

The mobilization exercises (ME) in RSB + LR caused alleviated radicular symptoms due to the elimination of stiffness at the facet joints, "freeing" the nerve root from impingement and further reducing the pain. The strengthening exercises (SE) appeared to stabilize the compromised spinal segment after mobilization.

Previous treatment approaches ignored the harmful positioning and exercises and put more emphasis on the decompression exercises. Our treatment approach emphasized the total avoidance of the compression postures as tested by the H-reflex in addition to OSP exercises. Avoiding USP reduced the continuing neural damage while keeping the neural foramina open, promoting neural regeneration.

The reduction of the compromised disc herniation from 19 to 4 mm is probably due to the maintained OSP, which appears to reduce neural impingement and diminish neural irritation, inflammation and edema. These processes increased the recorded SLR to 90° and caused gait symmetry and improved functions of daily activities.

The stepwise reduction of symptoms was probably related to the neural decompression (Abdulwahab and Sabbahi, 2000; Mazzocchio, 2001) of sensory and motor nerve axons. The reported concept and technique are shown to be effective for treating radiculopathy. A cross-sectional study is under preparation for future report. Limitations of this study include a single patient (n = 1), subjective gait analysis, and the lack of a control group comparison. Therefore, a causal relationship of the treatment cannot be extrapolated.

7. Conclusions

H-reflex-based evaluation and treatment were effective in a patient with a 19- mm disc herniation who was saved from spine surgery. The electrophysiological imaging and functional evaluation shifted to more normal standards by the end of the treatment program. DSE, manipulation and daily protocol maintained the recovery of disc herniation.

Conflict of interest

No conflict of interest or financial support for this paper.

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