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The Value of Mixed Somatosensory Evoked Potential in the Diagnosis of Lumbosacral Spinal Canal Stenosis

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Abstract

Background Lumbosacral spinal canal stenosis is a common cause for chronic low back pain. The diagnosis is mostly radiological, yet, the extent of neural impairment cannot be expressed by radiological means. It is hypothesized that somatosensory evoked potential indicate a nerve root involvement complementary to the neurological examination.

Objectives To evaluate the usefulness of different parameters of mixed somatosensory evoked potential in the diagnosis of lumbosacral stenosis.

Methods Thirty five patients with Lumbosacral stenosis, clinically and radiologically confirmed by MRI examination and 20 normal individuals were enrolled in the study. Mixed-somatosensory evoked potentials of tibial nerve was done using subdermal monopolar needle electrodes at 4 channels; cortical, lower thoracic, lumbar and popliteal. From these channels negative waves (N45, N25, N20 and N10) were studied for both latency and amplitude, besides the central sensory conduction time which represents inter-peak latency between N25 and N45.

Results The cutoff values of N25, N45 and N20 wave latencies presented highly significant differences between affected sides and controls; with the highest difference given by N25 wave ($P< 0.0001$). There was no significant difference regarding N10 and N25-N45 latencies. The mixed somatosensory wave amplitude cutoff values showed equivocal results about the sensitivity and specificity percentages.

Conclusions Mixed somatosensory evoked potential study can be used as a supplementary test in the diagnosis of Lumbosacral stenosis. N25 wave has the highest diagnostic yield due to having the highest sensitivity and specificity. Equivocal results of the evoked potential amplitudes and their lower sensitivities and specificities compared to evoked potential latencies, lower their validity in the diagnosis of Lumbosacral spinal stenosis.

Keyword Cutoff, sensitivity, specificity, referred.

List of abbreviation: L3S = Third lumber spinous process, LSS = Lumbosacral spinal canal stenosis, MRI = Magnetic resonance image, TN = tibial nerve, ROC = receiver operating characteristic, SEP = Somatosensory evoked potential, $T_{12}S$ = Twelfth thoracic spinous process.

Introduction

Lumbosacral spinal canal stenosis (LSS) is defined as narrowing of the lumbosacral spinal canal, its lateral recesses, and neural foramina which can cause compression of the lumbosacral nerve roots. The stenosis can be symptomatic or asymptomatic. It can be the result of congenital or acquired causes. Frequently, they are combined [(1)]. The extent of narrowing of the spinal canal correlates poorly with symptom severity and radiologically significant lumbar stenosis can be found in asymptomatic individuals [(2,3)].

The electrophysiological techniques may help in the definitive diagnosis of LSS particularly when the patient's clinical and MRI findings are

incompatible; there are root compressions at more than one level; the patient's history and clinical findings suggest radiculopathy but the MRI examination is normal, or the patient's history and clinical findings do not allow a distinction among plexopathy, mononeuritis, and radiculopathy [4]. It is hypothesized that electrophysiological recordings, especially somatosensory evoked potentials (SEPs), indicate a nerve root involvement complementary to the neurological examination. They provide confirmatory information in less obvious clinical conditions and help in the exclusion of other abnormalities [5].

The existing literature on the use of dermatomal somatosensory evoked potentials in lumbosacral spinal stenosis is limited. The aim of this study is to evaluate the value of different parameters ofmixed somatosensory evoked potential of the tibial nerve in the diagnosis of LSS.

Methods

Thirty five patients with clinically suspected and radiologically confirmed LSS were randomly collected among those attending the neurosurgery clinic in Al-Imamain Al-Kadhimain Medical City- Baghdad/ Iraq.

Electrophysiological assessment was done and patient were excluded if clinical, radiological and/or electrophysiological evaluations revealed signs of lumbosacral plexopathy, neuromuscular disorder, peripheral neuropathy associated with any systemic disease, spinal tumors, post traumatic or surgical stenosis or any previous disk-related operation.

A control group of 20 healthy subjects free from any musculoskeletal or neurological deficits confirmed clinically and radiologically were also included for the determination of the normal electrophysiological values.

All subjects were subjected to thorough history taking and full neurological examination of both lower limbs by the neurosurgeon, MRI examination and conventional electrophysiological studies by a neurophysiologist to exclude lumbosacral plexopathy, neuromuscular disorders or peripheral neuropathy. Bilateral mixed-SEP of the tibial nerve (TN) study was done for all subjects.

Mixed tibial SEP study was done with individuals lying in prone position in a quiet environment and was instructed to lie comfortable on the coach and the limbs were kept extended and relaxed and advised not to move or blink in order to decrease muscle contraction artifacts which obscure the waves of SEPs.

TN was stimulated just behind the medial malleolus at both sides, with an intensity enough to create a slight twitch in the toes, with the cathode placed at mid-point between medial malleolus and Achilles tendon and the anode about 3 cm distal to the cathode [6].

The study was performed using Micromed computerized EMG/EP device and the responses were recorded at 2µV/Division gain, 100 ms time base, and 14 Hz–2.5 kHz filtration range. The average of 150-200 cortical responses was taken and each measurement was carried out at least twice to confirm the reproducibility of the SEP.

Recordings were made by using subdermal monopolar needle electrodes that were put in the following positions:-

a) Active electrode was placed at Cz´ (2 cm posterior to Cz) and referred to Fz according to the international 10–20 system (for channel 1).

b) Active electrode was placed at twelfth thoracic spinous process ($T_{12}S$) and referred 4 cm rostrally (for channel 2). $T_{12}S$ is the first blade-like spinous process, felt by tracing upwards and inwards on the floating 12th rib to find it.

c) Active electrode was placed at third lumber spinous process (L_3S) and referred 4 cm rostrally (for channel 3). L_3S felt midway in line between right and left iliac crest with the spinous process above.

d) Active electrode was placed at the popliteal fossa (4-6 cm above popliteal crease) and

referred to medial knee (for channel 4). This site is between the tendons of the semitendinosus and semimembranosus muscles.

From these channels negative waves (i.e. pointing upward from isoelectric line) were recorded. From channel-1, N45 was recorded. N25 was recorded from channel-2. N20 and N10 were recorded from channel-3 and channel-4; respectively. For each waveform, both latency and amplitude were recorded as well as central sensory conduction time (CSCT) which represents the inter-peak latency between N45 and N25.

The results of the demographic characteristics of the studied groups were presented as mean ± SD for the age and as numbers and percentages for the gender. Unpaired Student's t-test was used to compare ages between patients and controls. Chi-square test, on the other hand, was used to express differences in gender ratio between patients and controls. Cutoff value, sensitivity and specificity percentages of latencies and amplitudes of SEP waves were estimated using receiver operating characteristic (ROC) test. Chi-square and Fisher Exact tests were used to evaluate the differences of the studied parameters between two groups (affected and control groups); where the number and percentage of abnormal values in any of the studied parameters were calculated from the determined cutoff values.

Results

Thirty five patients (42.86% males and 57.14% females) were enrolled in this study. Their mean age was 46.43 years (ranged from 25 to 63 years). The control group consisted of 20 individuals, ten males (50%) and 10 females (50%). Their mean age was 38.95 years (ranged from 23 to 56 years). There was a significant difference regarding the mean ages between patients and control groups (*P*= 0.0092); whereas there was no significant difference in sex between the two studied groups (*P*=0.779) (Table 1).

Table 1. Demographic Characteristics of the Studied Patients and Control Groups

Parameters		Patients No (%)	Control No (%)	*P* value
Male Female		15 (42.86) 20 (57.14)	10 (50) 10 (50)	0.779 *
Age (years)	Mean±SD Range	46.43±10.11 (25-63)	38.95±9.5 (23-56)	0.0092 **

* = using chi-square test, ** = using unpaired t- test.

Mixed SEP-TN study included 4 main negative evoked potential waves; which were N10, N20, N25 and N45 with two studied parameters for each wave (peak latency and amplitude) as seen in (Fig. 1).

Since the pathophysiological abnormalities in LSS affect different nerve roots independently with no commitment to the sides affected; therefore, results of the mixed-SEPs were presented as affected sides compared to control sides, i.e. results of the right and left sides were added together as one group. Therefore, the study included 70 affected sides (35 patients on each side) and 40 control sides (20 controls on each side).

According to table 2, the best cutoff value with the highest sensitivity and specificity % was that of N25 latency (24.02ms, 70% and 72.5%; respectively), followed by N45 and then N20 that have lower sensitivity and specificity percentages; respectively, while N10 latency cutoff value (9.61ms) shows the lowest sensitivity and specificity%. Likewise, the cutoff value of the central sensory conduction time

(N25-N45) showed a very low sensitivity and specificity (Table 2).

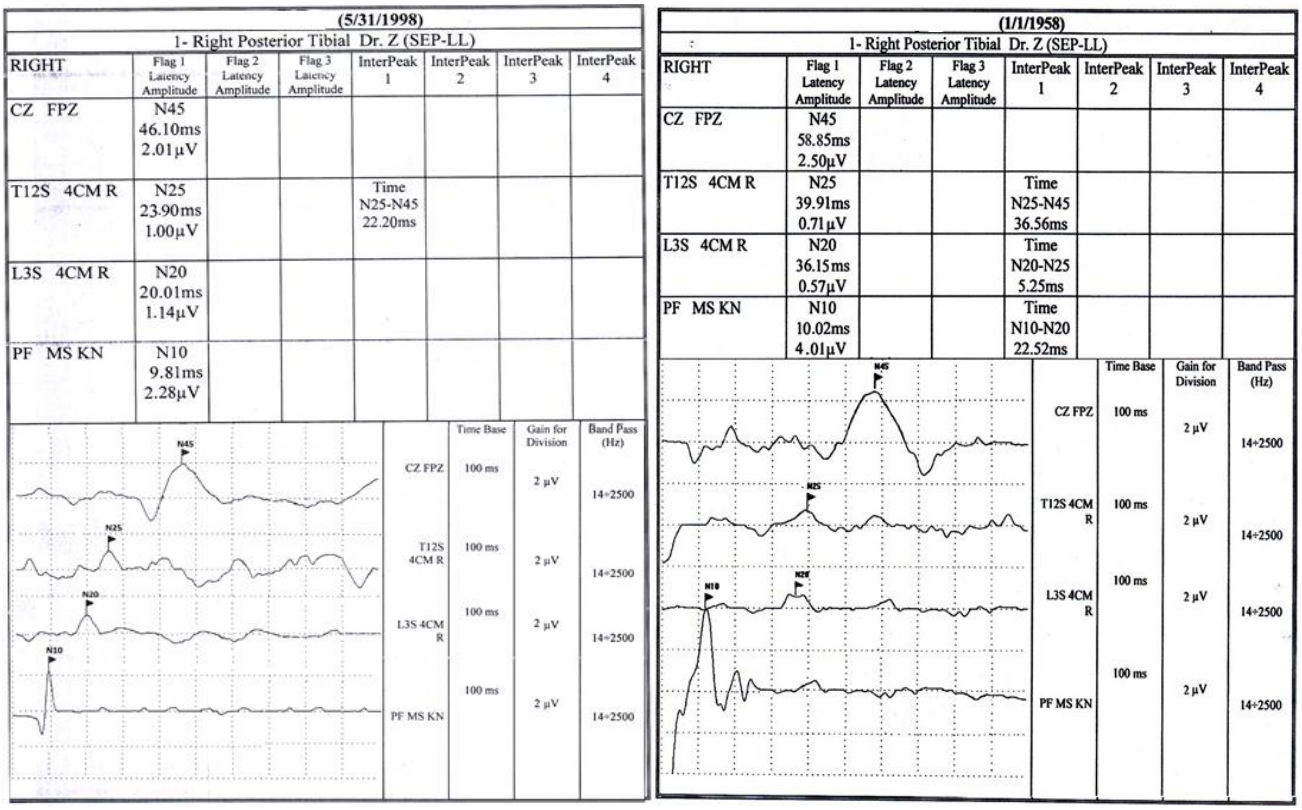

Fig. 1. Mixed SEP-TN (Left) of normal values, (Right) of abnormal values.

Table 2. Cutoff Value, Sensitivity and Specificity Percentages of Peak Latencies of Mixed SEP-TN Using ROC Test

Mixed SEP-TN Latencies	Cutoff value (ms)	Sensitivity (%)	Specificity (%)
N10	9.61	48.6	52.5
N20	20.705	67.1	67.5
N25	24.02	70.0	72.5
N45	46.22	67.1	70.0
N25 - N45	22.28	48.6	50.0

After dividing the studied patients and controls into 2 groups: prolonged and normal latency groups according to the chosen best cutoff values; results showed that cutoff values of the three N25, N45 and N20 SEP wave latencies presented highly significant differences between affected sides and controls; with the highest difference given by N25 (P< 0.0001, P=0.0003 and P=0.0007; respectively). However, there was no significant difference between affected sides and controls regarding N10 latency cutoff value (P= 1.0). As well, the N25-N45 cutoff value showed no significant difference between affected sides and controls (P = 1.0) (Table 3).

Regarding the amplitude of the measured SEP-TN waves, cutoff values showed equivocal results about the sensitivity and specificity %. The cutoff value of N25 amplitude (0.94µv) presented the best harmonized sensitivity and specificity %. Although N20 and N45 amplitudes have higher specificity % than N25 amplitude, their sensitivities were lower. On the other hand, the cutoff value of N10

amplitude has lower sensitivity and specificity (55% and 57%, respectively) compared to N25.

Table 3. Comparison of Mixed SEP Latencies between Affected Sides and Control Group by Chi Square and Fisher Exact Test

Parameters	Status	Affected sides N=70		Control Group N=40		*P* value
		No.	%	No.	%	
N10	Prolonged	34	48.57	19	47.50	1.000
	Normal	36	51.43	21	52.50	
N20	Prolonged	47	67.14	13	32.50	0.0007
	Normal	23	32.86	27	67.50	
N25	Prolonged	49	70.00	11	27.50	< 0.0001
	Normal	21	30.00	29	72.50	
N45	Prolonged	47	67.14	12	30.00	0.0003
	Normal	23	32.86	28	70.00	
N25 - N45	Prolonged	34	48.57	20	50.00	1.000
	Normal	36	51.43	20	50.00	

Table 4. Cutoff Value, Sensitivity and Specificity Percentages of Amplitudes of Mixed SEP-TN Using ROC Test

Mixed SEP-TN Amplitudes	Cutoff value (µV)	Sensitivity (%)	Specificity (%)
N10	2.77	55.0	57.1
N20	0.94	55.0	75.7
N25	0.94	60.0	64.3
N45	2.08	57.5	68.6

Amplitude cutoff values of the studied TN-SEP waves differentiate the studied patients and controls into 2 groups: low and normal amplitudes. N20, N25 as well as N45 amplitude cutoff values presented significant differences between affected sides and controls (*P*= 0.0018, 0.0171 and 0.0092; respectively); despite that the differences are more significant in cases of N20 and N45. On the other hand, no significant difference was obtained between affected sides and controls using the N10 amplitude cutoff value (*P*= 0.2395) (Table 5).

Discussion

Neurophysiological testing such as SEPs are helpful in determining the function of the nerve roots in LSS patients. They can be very helpful by providing objective information about the existence of, extent and severity of, and prognosis of neurologic deficits [1].

In this study, the presence of significant difference regarding the mean ages between patients and controls can be explained by the fact that LSS increases in occurrence with advancing age [1] explaining that most of included patients were of older ages; as compared to the younger ages of most of the control group.

In the current study, the lesser effect played by N20 latency cutoff value can be explained by the fact that the difference in conduction velocity between fast and slow fibers within a family of nerve axons would be intensified by increased distance of recording, which can be further exaggerated by the presence of compression neuropathy [7]. On the other hand, N45 measures a different entity of

somatosensory pathway of neurons (third order neurons) which may explain the lower sensitivity and specificity of its peak latency cutoff value compared to that of N25.

Table 5. Comparison of Mixed SEP Amplitudes between Affected Sides and Control Group by Chi Square and Fisher Exact Test

Mixed SEP-TN Amplitudes	Status	Affected sides N=70		Control N=40		*P* value
		No.	%	No.	%	
N10	Low	40	57.14	18	45.00	0.2395
	Normal	30	42.86	22	55.00	
N20	Low	53	75.71	18	45.00	0.0018
	Normal	17	24.29	22	55.00	
N25	Low	45	64.29	16	40.00	0.0171
	Normal	25	35.71	24	60.00	
N45	Low	48	68.57	17	42.50	0.0092
	Normal	22	31.43	23	57.50	

The least sensitivity and specificity percentages obtained by N10 latency cutoff value were expected because it measures the latency of peripheral part of the pathway (before the site of the pathology of the studied disease).

N25-N45 latency cutoff value showed a very low sensitivity and specificity and this proves that conduction time in the segment proximal to the lumbosacral spine has poor effect in the diagnosis of LSS.

Applying the selected cutoff values demonstrates that there were no significant differences between affected sides and controls concerning N10 peak latency (representing the conduction time in the peripheral segment of the somatosensory pathway) and N25-N45 latency (representing the central sensory conduction time) and these results are expected from the lowest sensitivities and specificities of these cutoff values and the fact that they represent the conduction time in the proximal and distal segments to the presumed site of compression, and hence logically they should not be affected by the pathology of the disease.

Significant differences were witnessed between affected sides and controls when applying the N20, N25 and N45 latency cutoff values, mostly by N25 latency. These rational results are expected, even more for N25 latency, due to their high sensitivity and specificity percentages and as these SEP parameters represent conduction times of different distances across the supposed site of compression. Therefore, these parameters are useful in the diagnosis of compression in the somatosensory pathway at the level of lumbosacral spine.

Results of the current study are in agreement with Eltantawi and his group [5], who found that there was a significant difference in SEP latency between patients and controls with a *P*=0.001 compared to (0.0003) *P* value in this study.

The results in this study disagree with that of Bingöl and co-workers [4] who stated that cortical SEP latency and the spinal SEP latency showed no significant differences between patients and control groups. This can be explained by using different statistical procedure, having low number of patients or studying patients with one level root compression. As peripheral mixed nerves such as TN contains fibers from multiple roots, results of SEP-TN can be normal despite the existence of a single root compression due to the diluting effect from the remaining unaffected roots.

Again, N25 amplitude cutoff value showed the highest harmonized sensitivity and specificity percentages, in the same way as the results of peak latency. However, other EP amplitudes showed higher specificities but lower sensitivities in some or lower both specificities and sensitivities in others than N25 amplitude. These equivocal results can be explained by the complex relationship between neuronal pathways in the central nervous system, with the presence of different order neurons and lots of convergence and divergence, which probably lower the validity of the amplitude measurements of the different evoked potentials in the somatosensory pathway.

Results of the chosen amplitude cutoff values showed significant differences between affected sides and control in all the SEP wave amplitudes, apart from N10 being a measure of peripheral conduction. These results demonstrate a diagnostic value of mixed SEP-TN amplitude in LSS; despite having lower sensitivities and specificities compared to latency. These results are in accordance with Eltantawi *et al* 2012 [5] who found that the cortical SEP amplitude had high significant difference between patient and control ($p < 0.05$) but disagree with Bingöl and his group 2010 [4] who found no significant difference ($p = 0.09$) between symptomatic and asymptomatic sides which may be explained by the same reasons mentioned earlier.

In this study abnormal mixed SEP-TN found in 70% of patients according to results of N25 wave; similar findings were detected by Egli *et al* 2007 [8] who found mixed SEP-TN abnormalities in 78% of the studied 54 patients.

In conclusion, mixed SEP study can be used as an add-on test in the diagnosis of LSS. N25 of the mixed SEP has the highest diagnostic yield in LSS because of having the highest sensitivity and specificity. Equivocal results of the SEP wave amplitudes and their lower sensitivities and specificities compared to SEP latencies, lower their validity in the diagnosis of LSS.

We recommended a combination of clinical, radiological and electrodiagnostic test like SEP to be included in the evaluation of patients with suspected LSS. Data on MRI findings of the lumbar spine of asymptomatic subjects should be supported by SEP studies as radiologic findings may not represent physiologically important LSS. Further studies correlating imaging and electrophysiological procedures with operative findings need to be done to further document the role of mixed SEP study in accurate evaluation of LSS patients.

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Author Contribution

Dr. Essa performed the SEP study while Dr. Al-Hashimi did the conventional NCS and EMG for exclusion criteria and both share the writing of the paper. Dr. Nema was responsible for collection of patients who participate in the work and their clinical examination.

Conflict of Interest

The authors declare no conflict of interest concerning this work.

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