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The role of the somatosensory evoked potential in the evaluation of patients with cervical radiculopathy:

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Summary:
Background: *SSEP studies theoretically should be of help in evaluating patients with suspected root lesions because they are the only simple means (excluding F and H wave studies) of studying sensory function in proximal portions of the PNS .The interest in using SSEP for the evaluation of radiculopathies is based on the fact that symptoms and signs in radiculopathies can usually be related to injury to afferent fibers, and SSEP can monitor injury to these fibers.*
Objective:*test the sensitivity of the spinalN13 potential in uncovering lesions of cervical nerve root.*
Subjects and methods: *Ninety five (95) patients with cervical radiculopathy with a mean age of (48.4±11) years and twenty six (26) healthy control subjects with a mean age of (45.2±10.1) years involved in the study. Rt and Lt sides median and Rt side ulnar sensory and motor nerve conduction study andRt and Lt sides median SSEP study were performed.*
Results:*there is a significant difference between the patients and the control groups regarding the Rt and Lt sides N13 peak latency, Rt and Lt sides N9-N13 and N13-N20 inter-peak latency.*
The positive predictive value was high for the cervical and cortical components and the N13 was the most sensitive one.
Conclusion: *N13 is a sensitivetechnique that is correlated with the MRI findings and N13, N20, P14 SSEP components are positive predictors for cervical radiculopathy.*
Keywords: *SSEP somatosensory evoked potential, Rt right, Lt left, EMG electromyography.*

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I. Introduction:

Cervical radiculopathy can be defined as pain in a radicular pattern in one or both upper extremities related to compression and/or irritation of one or more cervical nerve roots. Frequent signs and symptoms include varying degrees of sensory, motor and reflex changes as well as dysesthesias and paresthesias related to nerve root (s) without evidence of spinal cord dysfunction (myelopathy) (1,2). Patient presentations can range from complaints of pain, numbness, and/or tingling in the upper extremity to electrical type pain or even weakness. Cervical radiculopathy can be a debilitating disease that can cause patients significant impairment. The toll on this population can be significant both economically, from lost work and wages, and psychologically, from prolonged pain and impaired social functioning. The goal for clinicians should be the rapid diagnosis and treatment of this condition in order to facilitate the return of the patients to their normal state of health (3).The most common cause of cervical radiculopathy (in 70 to 75 % of cases) is foraminal encroachment of the spinal nerve due to a combination of factors, including decreased disc height and degenerative changes of the uncovertebral joints anteriorly and zygapophyseal joints posteriorly (i.e., cervical spondylosis). In contrast to disorders of the lumbar spine, herniation of the nucleus pulposus is responsible for only20 to 25 percent of cases. Cervical radiculopathy may also result from spinal root avulsion, diabetes mellitus, bacterial abscess, herpes zoster infection, Lyme disease, neurosyphilis, tumor invasion of the leptomeninges, and various inflammatory polyradiculoneuropathies (4).Several electrophysiological methods have been used to evaluate nerve root functions in cervical radiculopathy. Among these tests are needle electromyography (EMG) and F-wave studies which are useful, but they only give information concerning efferent fibers and do not allow evaluation of sensory fiber function. Therefore, if motor fibers are not damaged, needle EMG and F wave studies will be normal (5).
Compression of the ventral (motor) root may cause demyelination or axon loss, or both. These yield different electrodiagnostic findings:
●When the compression causing axon loss, Wallerian degeneration will occur. One of the electrical manifestations of this process when it involves the extrafusal motor fibers is SA in an appropriate myotomal distribution. With some chronic root lesions in which SA are lacking, MUAP changes indicate that both motor

axon degeneration and subsequent regeneration have occurred. However, if the axon loss severe enough, low-amplitude CMAPs with decreases conduction velocity of the peripheral nerve that derived from the affected root.

● Pure demyelination: with many radiculopathies, even acute ones studied within a few weeks of onset, no evidence of motor axon loss is detectable. This suggests that another pathophysiologic process, focal demyelination, is operative. At times, such demyelination is severe enough to produce conduction block. Lesser degrees of focal demyelination may result in conduction slowing at the injury site.

The slowing may affect all axons to the same degree (synchronized slowing) or alter the speed of conduction along different axons to different degrees (desynchronized or differential slowing). Both focal slowing and conduction block; cannot be evaluated well because roots are not accessible to conduction studies. Thus, apart from reduced MUAP recruitment, the needle EMG studies might be otherwise normal (6,7).

Patients and methods: This study has been conducted at the department of neurophysiology at al Kafeelsuperspeciality hospital during the period from April 2016 to October 2017.Ninety five (95) patients with cervical radiculopathy with a mean age of (48.4±11) years and twenty six (26) healthy control subjects with a mean age of (45.2±10.1) years involved in the study.All the patients were diagnosed and referred by neurosurgeons and neurologists. MRI of the cervical spine was performed for all patients to detect cervical nerve root compression if present.

Procedures: The following electrophysiological studies were doneusing Nicolete Viking Quest , EMG, NCS, EP measuring system:a. Rt and Lt sides median and Rt side ulnar sensory and motor nerve conduction study (any subject with abnormal median or ulnar SNCS were excluded from the study).b. Rt and Lt sides median SSEP study. The SSEPrecording procedures was carried out in a semi-darkened, quiet room which is away from other electrical machines. The room temperature was monitored and kept between 26-28C during the test. The subject asked to lie supine on the coach with his limbs kept extended and relaxed and was advised not to move and not to blink continuously and sometimes to close his eyes during the test to decrease muscle artifacts from the eyes and all skeletal muscles which may increase the noise and affect the evoked potential waves. Before applying the electrodes, good cleaning and sterilizing the skin with rectified spirit should be done and low impedance (below 5k ohm) should be kept.The 4 channels montage below is recommended as a minimal montage required for recording the obligate waveforms listed in the most recent guidelines 9D of the ACNS, 2008 (8).

Channel 1: EPi-EPc
Channel 2: C5S-EPc
Channel 3: CPi-EPc
Channel 4: CPc-CPi.

The channels record Erbs point peripheral potential (N9), cervical spinal potential (N13), subcortical response (P14) and cortical response (N20). The used sweep speed was 10 ms/division, sensitivityof 1–5 V/division and a filter band setting between 10 Hzand 3 kHz. The stimulation was done with pulse duration of0.5 ms and a frequency of 2 Hz. The recorded findingsincluded the latency of the N20 for mixed and dermatomal

SSEP and the N13 latency.The intensity of the stimulus was adjusted according to the minimal contraction in intrinsic muscles supplied by the median nerve. Analysis time was 100 mes. To insure reproducibility of the waves, an averageof500 to 1000 have been used.

Statistical analysis: Two software programs were used to summarize, present and to analyze the data; SPSS (Statistical Package for Social Sciences, version 17) and Microsoft Office Excel 2007. Numeric variables were presented as mean +SD (standard deviation). Nominal variables were presented as frequency and percent. Data of the patients and control group were compared using independent sample (t) test. The number and percentage of abnormalities were calculated with Chi-square test. The level of statistical significance was defined as (P) value < 0.05.

While one way ANOVA was used to compare the means of more than two groups. Post hoc LSD test was used to find an individual p -value between any two groups. Chi-square test was used to compare frequencies. Pearson's correlation coefficient was used to determine correlation between two numeric variables in an individual group (conduction velocity and distal amplitude of motor nerve conduction study). The level of $P<0.05$ was considered to be significant. Descriptive statistics for all data of each set were expressed as mean + SD and the percentage of abnormal values in any test were calculated as exceeding the mean + 3SD of the normal values of the matched control group.

II. Results:

In assessing the SSEP responses, the latencies of the individual components and the intervals between different components (i.e., the interpeak latencies) are examined. Because the hight of our subjects was not recorded and the age was not taken into account for evoked potential measurments, obtained data were considered abnormal if exceeded thecut off points (mean± 2 SD).In addition, absence of individual components was also considered as abnormal. Changes in morphology and in the degree of dispersion of the response may also reflect a lesion of the somatosensory pathways, but defining the boundaries of normality is difficult.

As noted in table (2), there is a significant difference between the patients and the control groups regarding the Rt and Lt sides N13 peak latency.

While,there are no-significant differences between thepatients and the control groups regarding the peak latency of the Rt and Lt sides N9, N20 and P14 somatosensory components.

Consequently, there is a significant difference between the patients and the control groups regarding the Rt and Lt sides N9-N13 and N13-N20 inter-peak latency.

However, there are no-significant differences between the patients and the control groups regarding theRt and Lt sides N9-N20.

By using the MRI as a gold standard and comparing the SSEP components to it (table 3) to test the validity of these components in the diagnosis of cervical radiculopathy, the positive predictive value was high for the cervical and cortical components and the N13 was the most sensitive one (table 4).

N9, N20, P14 peak latency:

Table (1): Comparison of the peak latency of the N9, N20, P14 SSEP components between the patients and the control groups.

N9, N20, P14 peak latency	Patients		Control		P value
	Number	Mean ±SD	Number	Mean ±SD	
Rt N9 (msec)	95	0.83±0.62	26	9.75±0.69	0.56
Lt N9 (msec)	95	9.74±0.64	26	9.69±0.67	0.75
Rt N20 (msec)	88	19.75±0.98	26	19.85±0.76	0.62
Lt N20 (msec)	87	19.97±0.95	26	19.76±0.70	0.29
Rt P14 (msec)	86	14.43±1.07	26	14.24±0.67	0.4
Lt P14 (msec)	84	14.5±1.08	26	14.2±0.81	0.2

*Significant using Students-t-test for difference between two independent means at 0.05 level.

Spinal N13 peak latency:

Table (2): Comparison of the peak latency of N13 components of the somatosensory evoked potential between the patients and the control groups :

N13 peak latency	Patients		Control		P value
	Number	Mean ±SD	Number	Mean ±SD	
Rt N13 (msec)	65	13.43±1.01	26	12.86±0.71	0.01*
Lt N13 (msec)	65	13.34±0.99	26	12.88±0.82	0.04*

*Significant using Students-t-test for difference between two independent means at 0.05 level.

Table (3): Distribution of the results of the peak latencies and interpeak latencies of the SSEP components as true positive, false positive, false negative and true negative values using the MRI as agold standard.

SSEP components		MRI	
		Positive No. (%)	**Negative** No. (%)
N9 peak latency (msec)	Positive	-	-
	Negative	92 (100)	3 (100)
		MRI	
N13 peak latency (msec)	Positive	49 (53.3)	1 (33.3)
	Negative	43 (46.7)	2 (66.7)
		MRI	
N20 peak latency (msec)	Positive	12 (13.3)	2 (40)
	Negative	78 (87)	3 (60)
		MRI	
N9-N20 inter-peak latency (msec)	Positive	16 (17.8)	2 (40)
	Negative	74 (82.2)	3 (60)
		MRI	
N13-N20 interpeak latency(msec)	Positive	37 (40.2)	1 (33.3)
	Negative	55 (59.8)	2 (66.7)
		MRI	
N9-N13 inter-peak latency (msec)	Positive	37 (40.2)	1 (33.3)
	Negative	55 (59.8)	2 (66.7)

		MRI	
P14 peak latency (msec)	Positive	10 (10.9)	1 (33.3)
	Negative	82 (89.1)	2 (66.7)

Table (4): Validity of SSEP components in the diagnosis of cervical radiculopathy using the MRI as gold standard.

	Sensitivity	**Specificity**	**PPV**	**NPV**
N9	-	-	-	-
N 13	53.3	66.7	95.6	4.4
N 20	13.3	60	85.7	3.7
P14	10.9	66.7	90.9	2.4

III. Discussion:

Somatosensory evoked potentials(SSEP) study is an objective assessment of the functional integrity of the neural pathway. There is probably no area that has generated as much controversy as the use of (SSEP) in the evaluation of radiculopathies. SSEP studies theoretically should be of help in evaluating patients with suspected root lesions because they are the only simple means (excluding H wave studies) of studying sensory function in proximal portions of the PNS (6).

The interest in using SSEPs for the evaluation of radiculopathies is based on the fact that symptoms and signs in radiculopathies can usually be related to injury to afferent fibers, and SSEP can monitor injury to these fibers (9).

The SSEP pathway follows the classical posterior column pathway.

The stimulus must excite the largest myelinated afferent fibers in the peripheral nerve then the dorsal column sensory fibers, the cell bodies of which lie in the dorsal root ganglion. The response then travels in the ipsilateral posterior column to synapse in the dorsal column nuclei. They cross in the medial lemiscus to the ventral posterior lateral nucleus of the thalamus. After synapse in the thalamus the third relay goes to the cortex. The stimulation techniques may be through mixed nerve stimulation, cutaneous nerve stimulation, dermatomal nerve stimulation, motor point stimulation or paraspinalnerve stimulation. Because electrical stimulation of a mixed nerve initiates a relatively synchronous volley that elicits a sizeable SSEP, it becomes the standard clinical use (10).

Most studies on SEPs in cases of cervical radiculopathy routinely analyze scalp (cortical) responses, depending mainly on evaluation of N20 whose origin is the primary somatosensorycortex (11). It was suggested that selective study of the N13 potential, might be a useful technique to improve both accuracy and sensitivity of the diagnosis of cervical radiculopathy (8).The spinal potential, termed N13 potential reflects the activity of dorsal horn neurons receiving their inputs from large myelinated fibers (12).N13 spinal potential reflects the response of dorsal horn neurons to stimulation of collateral branches of somatosensory ascending pathways (13).N13 refers to the potential recorded at the lower level of the neck most often at sixth cervical spinal process.N13 is considered to originate from postsynaptic dorsal neuron activity in the spinal cord (14).

Sensitivity and specificity of the SSEPwere determined using MRI as a gold standard (Table 3& 4).

However, the spinal N13 potential is the most sensitive with comparision to the other SSEP components 53.3% (table 4); these results goes in parallel with the study of Marwa and Mohammed, 2013 who get a senitivity of 64.5 for the spinal N13 and conclude thatN13 is a sensitive technique that is correlated with the MRI findings.

In another part of the current study; a significant difference results from the comparision of the spinal N13 between the patients and the control group table (2). In addition to, a significant difference results from the comparision of the N9-N13 and N13-N20 between the patients and the control group table (3) while non-significant differences results from the comparision of the median SEP components (N9, N20,P14, N9-N20, N9-N20) between the patients and the control group As shown in tables (3)

Hence, although SSEPs offer the theoretic advantage of assessing proximal portions of sensory nerves, their routine use is limited by a variety of factors including:

- As with the H-reflex and F wave, SSEP record responses only from the fastest conducting nerve fibers, so that focal or partial conduction block or slowing is not apparent, masked by normally conducting afferent fibers and diluted by the long nerve segment over which the SSEP travels(15, 6)
- Focal conduction block in some fibers may not lead to any obvious abnormality in the SSEP because conduction is unaffected in the remaining fibers within the root or nerve that is stimulated (6).
- Mixed SSEP assess conduction along primarily large fiber sensory pathways that subserve proprioceptive and vibratory perception functions, not the pain and cutaneous sensation pathways that are more likely to be affected in radiculopathy (16).

- There is normally some interside and intersubject variation in amplitude of SSEP so that only an extreme change or loss of the response reliably indicates the presence of an underlying lesion (15, 6).
- AlthoughSSEP abnormality may indicate a lesion in the somatosensory pathways proximal to the limb plexus, any further localizing information is very limited (15, 6).
- SSEP abnormalities provide no clue to the nature or age of a lesion in the sensory pathways (6).

IV. Conclusion

From this study we can conclude that N13 is a sensitive technique that is correlated with the MRI findings and it is suitable for detecting early and minor cervical nerve root lesion with sensory complaints.

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