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CONDUCTION VELOCITY MEASUREMENT IN HUMAN SPINAL CORD AND TIBIAL NERVE USING SKIN ELECTRODES RECORDING OF THE SPINAL EVOKED POTENTIAL

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Abstract

Conduction velocity of the spinal cord and tibial nerve was measured in 21 normal young adults using somatosensory spinal evoked potential recorded simultaneously from surface electrodes placed over the lumbar, thoracic and cervical spine. Conduction velocity of the spinal cord was 70.1m/sec (±1SD 8.4) and that of the tibial nerve was 57.5m/sec (±1SD 2.5). The speed may represent a maximal conduction velocity of the spinal cord, however, the precise localization of conducting pathway was unknown. Our non-invasive recording technique reported here should provide a valuable aid to evaluate functional disturbances of the spinal cord and peripheral nerves.

INTRODUCTION

In human study Liberson and co-workers[1] recorded summated response to peripheral nerve stimulation from surface electrodes attached over the cervical and lumbar spine. The somatosensory spinal evoked potential (SSEP) has received much attention clinically since Cracco's report[2] in 1973. However, the surface recording of SSEP was done with a great difficulty and now there are dissenting opinions among workers concerning recording technique and evaluation of the wave form.

In the present study the surface SSEP to tibial nerve stimulation was recorded systematically from 11 recording electrode locations over the spine using MULTI-PURPOSE BIOPHYSICAL DATA PROCESSOR. The multichannel SSEP recording may enable examiners to observe a temporal relationship among the waves ascending the spinal cord and to measure conduction velocities of spinal cord and tibial nerve more accurately.

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MATERIALS AND METHODS

Observations were made on 31 normal young male adults, ranging in age from 19 to 25 years. In this study our routine technique[3] to record somatosensory cerebral evoked potential (SCEP) was used. Subjects were relaxed in a supine position with eyes closed in a semi-dark, quiet and electrically shielded room. Bilateral simultaneous electric shocks were given percutaneously over the posterior tibial nerve at ankles. The duration of stimuli was 0.2 to 0.6 msec and the strength was adjusted 10 V above the motor threshold of the stimulated muscles as to provide equal contraction bilaterally. They were given randomly at intervals ranging from 200 to 900 msec.

Eleven recording electrodes were attached to the skin over the spine from the suboccipital depression to the spinous process of the fourth lumbar vertebra as to divide into 10 equal distances of about 5 cm. Ten bipolar derivations from these electrodes and two monopolar ones from parietal scalp electrodes

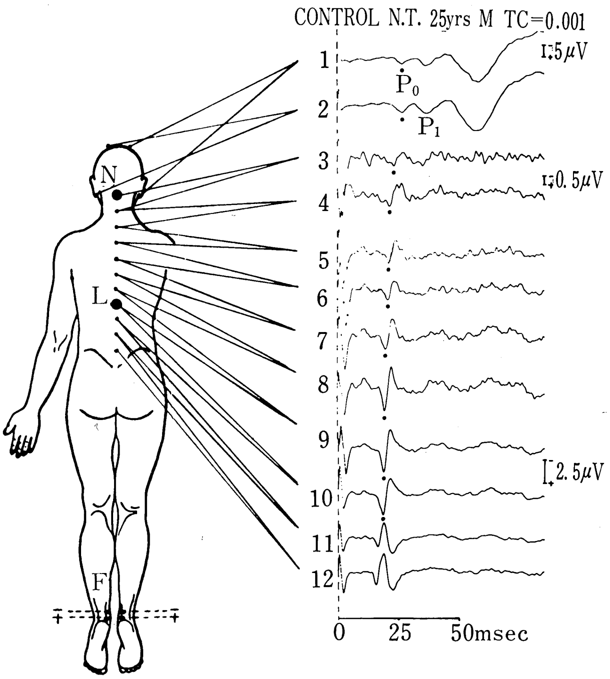

Fig. 1 Recording of SSEP and SCEP. N: Location of rostral electrode of lead 3 on the suboccipital depression. L: Location of rostral electrode of lead 10. F: Location of proxymal stimulating electrode of the tibial nerve at the ankle. A phase reversal of SSEP is noted between lead 10 and 11.

over the both hemispheres were done simultaneously (Fig. 1).

The input from 12 derivations were led to a 13-channel electroencephalograph with time constant of 0.1 sec in SCEP and of 0.001 sec in SSEP. The output was summated by a 16-channel MULTI-PURPOSE BIOPHYSICAL DATA PROCESSOR (SAN-EI INSTRUMENT Co. LTD.) and then displayed on the section paper through an X-Y plotter serially. Routinely 1,000 responses were summated and the first 100 msec following the stimulus was analyzed. SSEP summated from electroencephalograph with time constant of 0.01 sec was recordable, though the potential peaks were relatively blunt in some cases (Fig. 2).

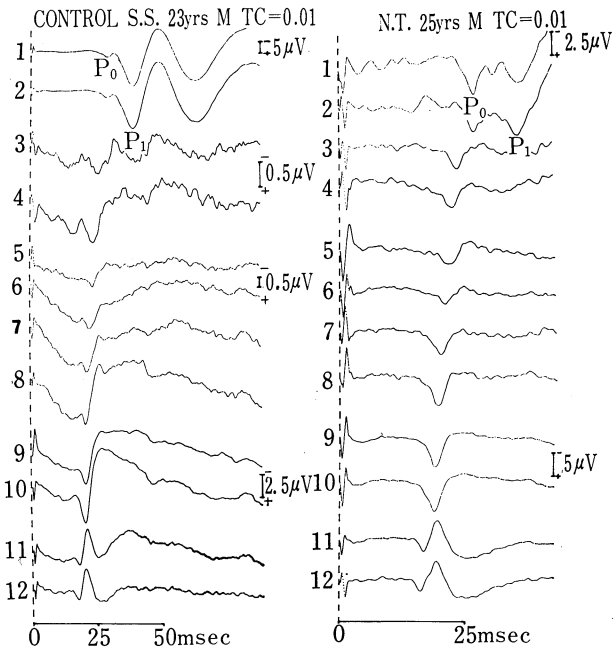

Fig. 2 SSEP summated from EEG with time constant of 0.01 sec. Analysis time is 100 msec (Left) and 50 msec (Right).

RESULTS

The response consisted of triphasic potentials over the lumbar spine and of diphasic ones over the thoracic and cervical spine. In all subjects a phase reversal of SSEP was noted between lead 10 and 11 (or 12). The rostral electrode of lead 10 was usually located just on the spinous process of the first lumbar vertebra or on the same vertebra, in other words, on the level of the sacral segment. The location was shown as L, and it may be reasonably assumed that peripheral stimuli arrive in the spinal cord at L point.

From lead 10 to lead 3, the initial positive peaks of SSEP progressively increased in latency at more rostral recording locations. This suggested that the responses arose in spinal cord afferent pathways ascending from sacral to cervical spinal cord. The rostral electrode of lead 3 was shown as N, which was located on the suboccipital depression just above the spinous process of the second cervical vertebra in the midline.

The peak latency of the initial positive potential at each recording location was measured and the spinal conduction velocity of the response from L to N was estimated. Tibial nerve conduction velocity was calculated dividing the distance from F (location of proxymal stimulating electrode of tibial nerve) to L by the initial positive peak latency of lead 10.

In 31 subjects SSEP was recorded also to unilateral tibial nerve stimulation and the appearance rate of responded peaks to the stimulation diminished

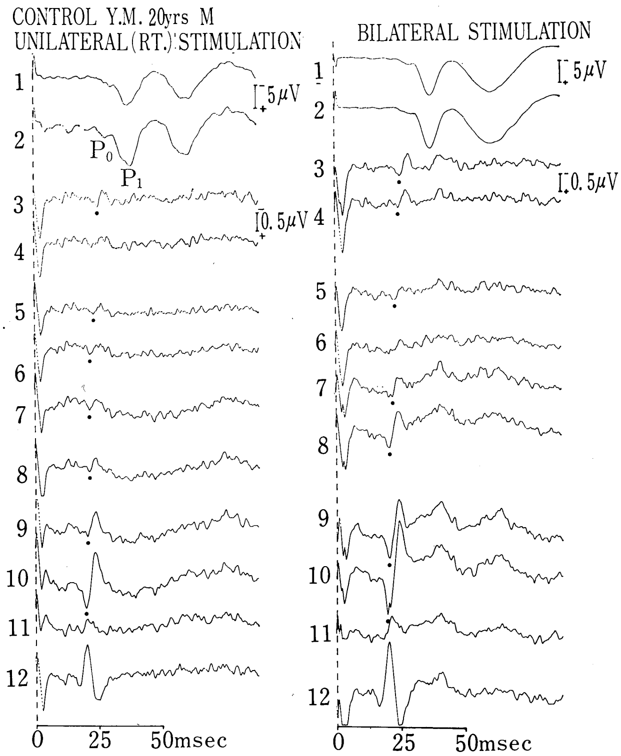

Fig. 3 SSEP recorded to unilateral (Left) and bilateral (Right) tibial nerve stimulation.

moderately. In the same subject SSEP was recorded more clearly and with higher amplitude by bilateral simultaneous stimulation comparing with unilateral one (Fig. 3). Of 31 subjects using bilateral tibial nerve stimulation a definite positive peak in lead 3 was observed in 21 cases in which the appearance rate of peaks from lead 3 to 12 was compared with unilateral tibial nerve stimulation (Table 1). In general, the appearance rate of peaks was reduced

TABLE 1.
Appearance rate of SSEP peaks
to bilateral and unilateral tibial nerve stimulation

Bilateral stimulation (21 subjects)			Unilateral stimulation (20 subjects)		
Lead No.	Peaks appeared	Appearance rate(%)	Lead No.	Peaks appeared	Appearance rate(%)
3	21	100	3	7	35.0
4	21	100	4	8	40.0
5	18	85.7	5	8	40.0
6	18	85.7	6	9	45.0
7	20	95.2	7	15	75.0
8	21	100	8	16	80.0
9	21	100	9	20	100
10	21	100	10	20	100
11	21	100	11	20	100
12	21	100	12	20	100

over the upper thoracic and cervical spine, however, those over the lumbar spine were recorded constantly in all cases.

Spinal conduction velocity between sacral and upper cervical segment was 70.1 $\pm$ 8.4 m/sec in the normal 21 subjects.

Sensory nerve conduction velocity (SCV) of the tibial nerve was 57.5 $\pm$ 2.5 m/sec in the same group (Table 2).

DISCUSSION

Recently, Cracco et al.[2,4] described a precise method to record SSEP by using surface electrode. In the present study we adopted multi-channel surface SSEP recording to bilateral simultaneous tibial nerve stimulation. The study showed more favourable results to measure the conduction velocity of the spinal cord, because the distribution of SSEP which progressively increased in peak latency at more rostral recording locations could be identified more easily.

The triphasic waves recorded in lead 11 and 12 may correspond with lumbar nerve root potentials (LNRP) named by Liberson et al.[5], and the ascending responses rostral to the triphasic waves may represent the evoked pote-

TABLE 2.
Conduction velocity of the response to tibial nerve stimulation

No.	Name	Age	Spinal cord (m/sec)	Tibial nerve (m/sec)
1	O. H.	19	59.0	52.5
2	N. M.	21	69.4	56.9
3	Y. M.	20	74.7	56.9
4	N. H.	20	58.9	59.9
5	N. T.	24	76.6	57.2
6	K. U.	22	60.3	54.1
7	Y. K.	22	73.5	55.0
8	T. K.	23	66.2	58.7
9	Y. S.	23	78.7	55.2
10	Y. S.	22	62.4	60.6
11	M. S.	23	84.7	55.1
12	T. S.	23	62.4	57.9
13	T. S.	23	62.5	56.4
14	Y. T.	24	70.0	60.1
15	N. T.	25	75.2	58.3
16	M. T.	22	80.5	59.7
17	K. T.	24	82.4	60.6
18	M. T.	25	64.7	61.7
19	K. T.	23	59.2	59.5
20	M. T.	22	79.6	57.1
21	S. T.	24	72.0	54.4
Mean			70.1 ± 8.4	57.5 ± 2.5

ntials of the spinal cord itself. Phase reversal of evoked potentials at the upper lumbar or lower thoracic spine region had been recorded in studies of Cracco et al.[2,4], but they did not separate SSEP from LNRP. So, they noted that the speed of conduction up the spine was non-linear and it was slower over the caudal cord segments than over the cauda equina or rostral spinal cord. The conduction velocity of the response to peroneal nerve stimulation measured by them was about 65 m/sec. The speed was slightly slower than our results.

In human spinal cord the descending conductive velocity of 73.0 ± 9.4 m/sec was measured by Yabuki et al.[6] They used extradural electrode recording and suggested that the velocity represented the conduction velocity of posterior superficial large diameter fibers of the lateral column. Ertekin[7,8] measured the propagation velocity of the volleys along the dorsal funiculus of the human spinal cord using intrathecal recording technique. If two intrathecal electrodes were situated behind the cord dorsum at the lower cervical and lower thoracic levels respectively, on both rostral and caudal stimulations, almost the same type of potentials were evoked. The conduction velocity of this potential, on both rostral and caudal direction, was on average about 45 to 47 m/sec. Ertekin noted that the conduction velocity was often above 60 m/sec, if the lateral recording and stimulating position was used. Then, he suggested that the speed was related to the neural structures adjacent to the cord dorsum. The findings may correspond with the notion of Yabuki et al.[6)]

The speed of the spinal conduction velocity in our study may represent a maximal one of the spinal cord, though the precise localization of conducting pathway was unknown. Clinical application of our method may be useful as an indicator of functional disturbances of the spinal cord in various neurological disorders.

The measurement of tibial nerve SCV might produce some errors, because the nerve length was determined on the skin along the nerve. To find out laterality of SCV, it is necessary to record summated responses to each tibial nerve stimulation. Previously reported SCV measurements have been performed mostly on the distal segment of peripheral nerves. In our study[9)] posterior tibial nerve SCV from ankle to knee was 55.7 $\pm$ 6.3 m/sec. Using needle recording electrodes Buchthal and Rosenfalck[10)] reported that sciatic nerve SCV between popliteal fossa and buttoch was 56.8 $\pm$ 1.1 m/sec which accords well with our result on tibial nerve SCV of 57.5 $\pm$ 2.5 m/sec. The SCV along the whole length of the peripheral nerve may be much useful to estimate the nerve root lesions as in the case of Gullain-Barré syndrome or radicular neuropathies due to spondylosis.

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