Research Article

DOI: 10.5152/NSN.2019.11499

# Cauda equina sensory conduction time in normal adult humans

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### Abstract

**Objective:** The clinical usefulness of the cauda equina motor conduction time (CE-MCT) is well established either by magnetic or electrical stimulation of the lumbar roots at the lumbar spine levels. However, the cauda equina sensory conduction time (CE-SCT) is not studied systematically in human adults.

**Methods:** Lumbar laminar electrical stimulation from the level of theL1 and L5 vertebrae was applied using needle electrodes. The smallest M-responses obtained from both soleus muscles were considered as the motor threshold for the L1and L5 motor root levels. Afterwards, with the needles in the same place, the connection cables were removed from the stimulation channel and replaced to the recording channel, then the sensory program of the electromyograph was selected. The posterior tibial nevre was excited with superficia lbipolar electrodes from the popliteal fossa, and after a very slight muscle twitch was observed the intensity was reduced slightly. Therefore, the pure sensory fibers were stimulated. Cauda equina sensory action potentials were recorded and averaged at the laminar levels of L1 and L5 in the spine. Twenty adult normal controls were studied.

**Results:** The monopolar recordings of cauda equina sensory responses at the L1 and L5 laminar levels were measured from their first positive peaks and the CE-SCT was found as 1.9±0.4 msec (mean ± SD) and ranged from 1.0 to 2.8 msec.

**Conclusion:** The method of CE-SCT recording and calculation is very easy to use and applicable in all normal adult subjects. Themean CE-SCT value is similar to those found for CE-MTC.

**Keywords:** Cauda equina, laminar stimulation, lumbosacral roots, sensory and motor conduction

## INTRODUCTION

Cauda equina motor conduction time (CE-MCT) has been investigated using percutaneous magnetic coil stimulation at the dorsolumbar spine levels (1, 2). CE-MCT from L1 to L5 levelshas provided an alternative method in the evaluation of the lumbar motor root in lumbosacral root and motor nerve fiber disorders (2-7). However, there are some disavantages of using magnetic stimulation even stronger than Magnetic Augmented Translumbosacral Stimulation-coil stimulation (7). One of the disadvantages of magnetic stimulation in measuring the CE-MCT is that it is impossible to obtain supramaximal compound muscle action potential at the most proximal cauda equina, which prevents us from judging whether there is a conduction block within the cauda equina (7). Another disadvantage of magnetic stimulation at the lumbar level is the large size coil and high cost (6).

In such circumstances, using a needle electrode could be a choice for stimulation of the cauda equina (8-10). However, previous reports have stimulated only one level of the lumbar spine and were not help fulin obtaining information about L1-L5 CE-MCT. When laminar electrical stimulation is performed at the posterior lamina of the spine from two different levels, such as L1 and L5, muscle recordings are obtained from the anterior tibial and/or soleus unilaterally or bilaterally; such methods could give us the values of motor conduction time along with the cauda equina. It has been found that this kind of method was more reliable to measure the CE-MCT

This study has been orally presented in the 31st National Clinical Neurophysiology EEG-EMG Congress, 9 April 2015, Antalya, Turkey.

**You may cite this article as:** Süzen Ekinci A, Tabakoğlu AY, Oto A, Bademkıran F, Ertekin C. Cauda equina sensory conduction time in normal adult humans. Neurol Sci Neurophysiol 2019; 36(3): 136-40.

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in patients with lumbar spinal stenosis (11). In normal adult subjects, the CE-MCT was found to be about 1.4 msec and ranged from 0.5 to 2.5 msec.These values were obtained by subtracting the proximal latency (L1) from the distal latency (L5) of cauda equina stimulation.

Although conduction block could be easily demonstrated through the stimulation of the L2-L3 spine level with electrical stimulation of the lumbar root in a single site in the earliest period of Guillain-Barre syndrome, two-site stimulation may provide an advantage in observing chronic compressive lesions of the cauda equina such as lumbar stenosis or any kind multiple radiculopathies (3, 10, 11).

Although CE-MCTs are under investigation, by using electrical and magnetic stimulation techniques, the cauda equina sensory nerve fibers in the roots have never been investigated in terms of cauda equina sensory conduction time (CE-SCT), neither in normal subjects nor in patients with cauda equina involvement. It is anticipated that CE-SCT would be more sensitive because with lumbar root involvements the sensory signs and symptoms occur prominently, except acute in L5 herniated nucleus pulposus or in acute traumatic cauda equina dissections.

These kinds of clinical senses motivate us to investigate the CE-SCT in normal healthy adults.

## METHODS

Twenty healthy participants were enrolled from our elctromyography (EMG) laboratory. The participants had no known systematic disease (such as diabetes mellitus), any kind of polyneuropathy, spinal cord disease, or any lumbar vertebral pathology. Needle EMG, motor and sensory conduction, and H-F wave studies were performed and all electrophysiologic findings were found as normal.

The subjects had either normal magnetic resonance imaging and/or computed tomography or their radiologic appearance of the lumbar spines showedno significant pathology. Their clinical examinationswere unremarkable.

The mean age of the participants (10 males, 10 females) was 32.5 (range, 23-59) years.

All subjects were laid down on an examination table in the prone position. One Ag-Ag Cl surface electrode was fixed to the belly of soleus muscles, a reference Ag-Ag Cl surface electrode was placed just above the Achilles tendon. Soleus muscles were recorded bilaterally. The posterior tibial nerves were stimulated at the popliteal fossa usinglarge bipolar surface electrodes (Medelec, LBS, Oxford medical instruments). Four-channel EMG (Viking IV D, Nicolet Biomedical, Madison, USA) was used for all examinations.

Lumbar laminar stimulation was performed in the healthy subjectswhile they were lying in the prone position as described previously (8). Sterile Teflon-coated monopolar needle electrodes were used (26 G with a diameter of 50 mm, 26 GAMBU with a diameter of 25 mm) for laminar stimulation. The active electrode (a long needle, 50 mm) was placed between the L1 and L2 inter disc space after finding T12 spine by palpating the 12th rib in the course of the chest wall. When the examiner felt the needle touch bony tissue, the insertion was stopped. The tip of the needle electrode was placed at the dorsal part of the lamina of the lumbar spine (Figure 1). The reference electrode (short needle, 25 mm) was inserted in the midline subcutaneously 2 or 3 levels above the active electrode. The surface Ag-AgCl disc electrodes used for recording were attached; the active electrode to the body of the soleus muscle and the reference electrode to the tendon of the muscle. Afterwards, rectangular electrical pulses with a duration of 1.0 msecwith increasing intensity were delivered at the laminar level. The smallest M-responses obtained from both soleus muscles were considered as the motor threshold for the L1 motor root levels.

Without moving the needle, the connection cables were removed from the stimulation channel and replaced to the recording channel, then the sensory program of EMG was selected. The posterior tibial nerve was excited using superficial bipolar electrodes from the popliteal fossa, and after a very slight muscle twitch was observed the intensity was reduced slightly (Figure 2). Thus, the pure sensory fibers were stimulated. An average of 200 stimuli were given using the average

**Figure 1.** Schematic representation of the lumbar-laminar stimulation technique, lateral view

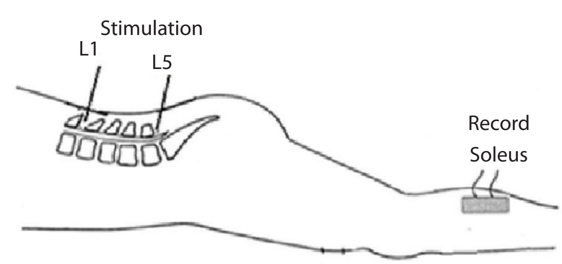



**Figure 2.** Stimulation of sensorial fibres by stimulating the posterior tibial nerve at the popliteal fossa and recording from the lumbar roots at L1 and L5 levels

technique. At least two average responses were recorded and superimposed.

After recording from the L1 spine level, the monopolar needle electrodes were removed from their insertion points. The second recording point was at the laminar level of L5 spine (between L5 and S1). The same procedure was performed for L5 spine position; the needle was placed between the L5-S1 spaces by palpating the upper edge of the sacrum at the midline. Again, the posterior tibial nerve was stimulated at the same side and same points at the popliteal fossa (Figure 2). Averaged sensory responses were also obtained from the L5 level. The differences in responses from L1 to L5 sensory action potentials were calculated from the first peak of positive deflection and the CE-SCT was calculated. The amplitude of each average sensory response was measured from peak to peak. The institutional review board approved the Atatürk Training and Research Hospital (date: 2018) and informed consent was obtained from all participants.

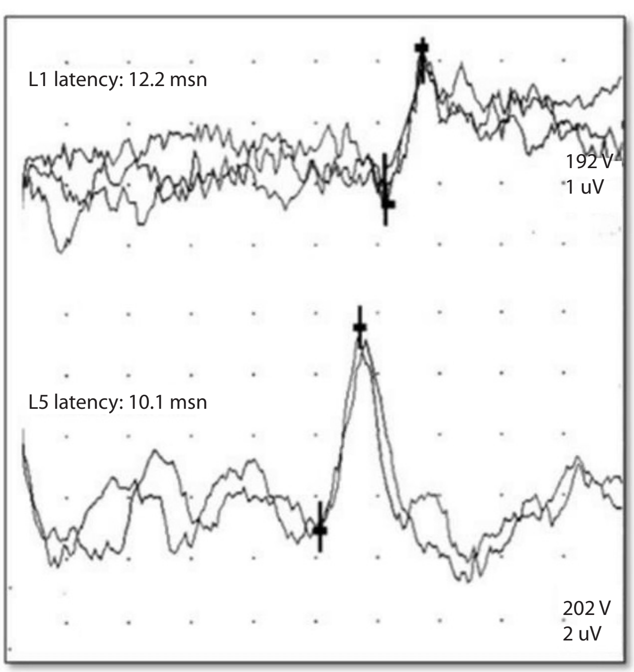
### Statistical Analysis

All statistical analyseswere performed usingthe Statistical Package for the Social Sciences 22 for (SPSS IBM Corp.; Armonk, NY, USA) Windows software package. Descriptive analyses were performed for all parameters. Wilcoxon tests were used for evaluating differences between the groups. A probability value of $p<0.05$ was considered to be statistically significant.

## RESULTS

From both L1 and L5 spine laminae, the cauda equina sensory responses were consistently obtained in all 20 participants.

**Figure 3.** L1-L5 latency difference; 2.1 msec (CE-SCT)




Sensory responses from L1 and L5 were triphasic potentials with negative prominence. Their first positive and negative peaks were stable, but if the subjects were not sufficiently relaxed, the same background activity appeared and there could be some difficultiesin measuring the peaks clearly. A slightly different lumbar prone position may solve this problem on most occasions. Furthermore, the two averaged responses were superimposed (Figure 3). The measurements of the individual latencies are illustrated in (Figure 4).

**Figure 4.** Latency measures of patients at L1 (A) and L5 (B) levels

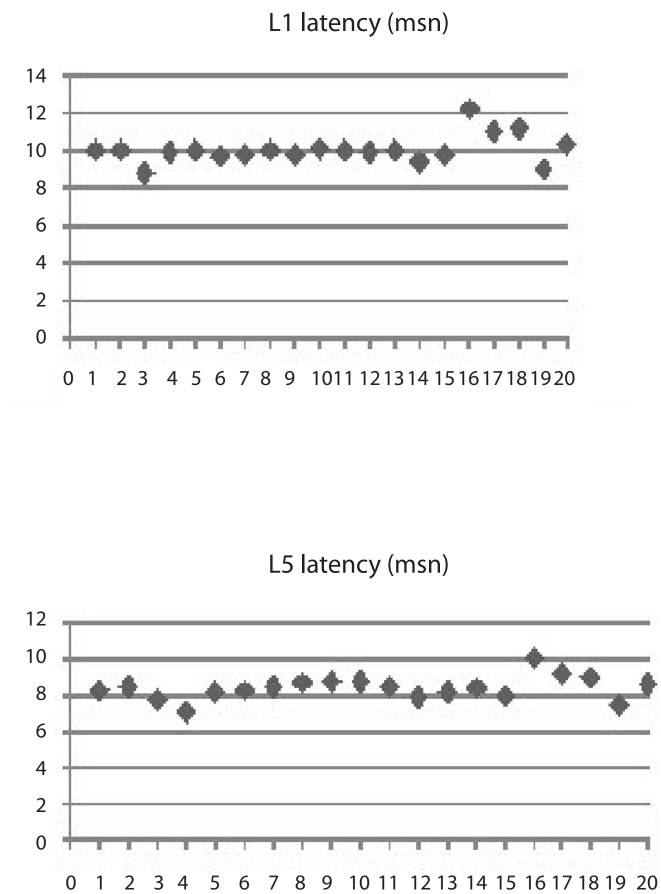
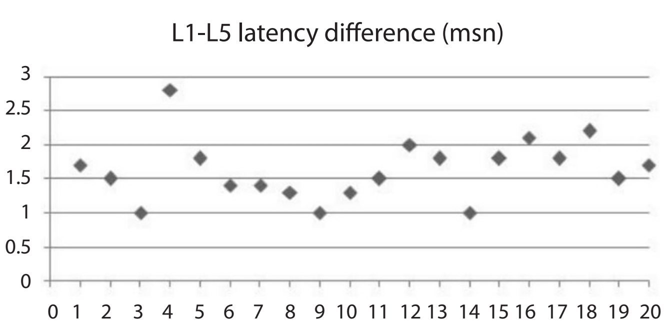



**Figure 5.** L1-L5 Latency difference or CE-SCT



The L1 latency to the first positive peak was 10±0.7 (mean ± SD), ranging from 8.8 to 12.0 ms. However, latency values did not change greatly from case to case (Figure 4).

The sensory response obtained from the L5 spine level was also stable and the mean of the latency values were 8.5±0.6 (mean ± SD) msec and ranged from 10.1 to 7.1 msec. The L1 and L5 latency values depended upon the longevity of stimulation and recording sites on the whole. Certainly L1 latency was longer than the L5 latency due to itsproximity to the L5 recording site.

The amplitudes of the cauda equina sensory responses at L5 were not significantly higher than those at L1. The mean amplitude of L5 was 3.0±2.1 (range, 0.8-10) μV, and the amplitudes were similar at L1 with a meanamplitude of 2.9±2.2 (range, 8.8-10) μV.

Cauda equina sensory conduction time was calculated between the first positive peak latencies of the L1 and L5 sensory responses. The latency difference or CE-SCT was found as 1.9±0.4 msec and ranged from 1.0 to 2.8 msec (Figure 5). However, there was no significant difference in the L1-L5 CE-SCT andheight distribution of the participants.

## DISCUSSION

Lumbar root action potentials or, in other words, cauda equina potentials can be clearly recorded by using intrathecal electrodes, which werefirst reported in 1951 by Magladery et al. (12). The root and cord potentials were stimulated by the electrical stimulation of the posterior tibial nerve at the popliteal fossa. Magladery et al. and other investigators have used the intrathecal recording level or the epidural level (12-15). Similar dorsal root potentials were also recorded from the lumbar region by using surface recording techniques with the aid of the computer averaging (16).

If the posterior tibial nerve is stimulated in the popliteal fossa by a submaximal electric shock, we may primarily stimulate group II afferent nerve fibers with large diameter, which have lower thresholds. This condition may lead to the appearance of ventral root potentials with late latency in the ventral roots. Thus, the risk of incorrect measurement of sensory latency may occur (15). This monosynaptic ventral root reflex response is recorded in the lower lumbar spaces 4-5 m sec later than the dorsal root potentials (15). This biologic error may be seen more often during lumbar superficial recordings. As a result, the posterior tibial nerve must be stimulated supramaximal in the popliteal fossa. In this case, the amplitude of the dorsal root potential increases and the ventral root reflex response becomes suppressed. Caution is advised against taking wrong measurements caused by this possibility.

The importance of the CE-MCT was demonstrated and satisfactory results were obtained for patients with lumbar disease using magnetic or electric stimulations (2, 5, 11, 16-20). In chronic multiple radiculopathies such as lumbar stenosis, the clinical objective motor finding may not be found, but the sensory root fibers may be lesioned without clear-cut sensory clinical signs (3, 11). On the other hand, only CE-SCT was previously calculated by Ertekin et al. who found the mean value of 1.9 msec from L1 to L5, which is the almost same mean value for the CE-SCT in the present study (15).



One question remains to be solved, however. Antidromically activated motor fibers can be mixed at the L1 and/or L5 root levels (8, 14). The method of lumbar laminar recording of the cauda equina seems to be a sensitive method to measure CE-SCT accurately. This method of laminar recording is inexpensive, easy to use, andvery fast, and its invasiveness has been exaggerated because the introduction of the needle electrodes does not give as much pain as in needle EMG or superficial brachial plexus stimulation (7). Certainly, the clinical application of CT-SCT still remains to be explored in different cauda equina involvements.

**Ethics Committee Approval:** Ethics committee approval was received for this study from the ethics committee of Atatürk Training and Research Hospital (date: 2008).

**Informed Consent:** Written informed consent was obtained from patients who participated in this study.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept – C.E.; Design – C.E., F.B.; Supervision – C.E.;Data Collection and/or Processing – A.S.E.; Analysis and/or Interpretation – A.S.E., A.Y.T., A.O.; Literature Search – A.S.E.; Writing Manuscript – C.E., A.S.E.; Critical Review – C.E.

**Conflict of Interest:** The authors have no conflicts of interest to declare.

**Financial Disclosure:** The authors declared that this study has received no financial support.

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