Technical Considerations for Measurement of Median Nerve Conduction Velocity at Wrist

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Abstract: Nerve conduction velocity (NCV) testing for the median nerve is the gold standard for diagnosing carpal tunnel syndrome (CTS), which affects about 6% of the general population. However, NCV equipment is relatively expensive and not always available at outpatient clinics. This study investigated the effects of different sampling rates and electrode placements on the NCV values of the median nerve to establish the practical significance of those specifications. The NCV of the median nerve at the wrist was measured in 30 healthy subjects with sampling rates of 2 kHz or 10 kHz and wide or narrow spacing of the electrode; Paired t-tests were used to compare the NCV values acquired by the different testing protocols. We found that the sampling rate had a statistically significant effect on the NCV values (P < 0.01), while the electrode placements did not significantly affect the NCV values (P > 0.05). The findings of this study have implications for improving the cost-effectiveness and technical applicability of NCV instruments.

Key words: electrode placement, nerve conduction velocity, sampling rate.

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Introduction

Carpal tunnel syndrome (CTS) describes a cluster of signs and symptoms, including atrophy of the small hand muscles, numbness, paresthesia and pain in the median nerve distribution over the lateral portion of the hand. It is the most common entrapment neuropathy, with a reported prevalence of 6% [1, 2]. The etiology is due to compression of the median nerve under the transverse carpal ligament at the wrist [3]. Untreated CTS can lead to irreversible palmar numbness, hand muscle atrophy and loss of hand function [4, 5]. Accurate diagnosis of CTS is essential for implementing early intervention. Suspected cases of CTS are often referred for electrodiagnostic evaluation of median nerve conduction velocity (NCV), as a compressed median nerve with damage to the myelin sheath will demonstrate slower electrical conductivity [6, 7].

NCV testing for median nerve has been accepted as the gold standard for diagnosing CTS [8], but the modern electrodiagnostic equipment is relatively expensive and not always available at outpatient clinics, where most patients suffering from CTS are treated. Due to cost considerations, surgeons may opt to perform decompression surgeries of the carpal tunnel without even referring the patients for the NCV evaluation [9]. Without the NCV data, it is difficult to assess the effects of rehabilitation, surgical outcomes, or progress of the syndrome.

Traditionally, the testing on the median nerve requires signal acquisition at a sampling rate of 10 kHz with three surface electrodes located on the abductor pollicis brevis (APB) muscle, the interphalangeal joint of the thumb, and the dorsum of the hand, respectively [6, 10]. However, little information is available to support the above specifications or to establish the optimal standards for testing. Also, no literature is available as to whether it is possible to reduce the sampling rate and simplify the electrode placement without sacrificing the accuracy of the NCV evaluation.

The present study aimed to investigate the effects of 1) sampling rate and 2) electrode placement on median nerve conduction velocity evaluation at the wrist. Based on the rationale that decreasing the hardware requirements can reduce the production cost of the NCV instruments and that more convenient electrode placement can facilitate the ease of the NCV testing procedures, the findings of this study could help improve the cost-effectiveness of NCV instruments.

The null hypotheses for the present study are as follows: 1) 2 kHz and 10 kHz sampling rates would lead to comparable NCV values of the median nerve. 2) Wide- and narrow-spacing electrode placements (Fig. 1) would not make a significant difference in the NCV values of the median nerve.

Materials and Methods

Study Design

Controlled laboratory study with cross-sectional design, within-subject comparisons.

Participants

Thirty able-bodied subjects (16 females and 14 males) aged between 18 and 46 years were recruited by convenient sampling. Their average age, weight and height were 31 ± 6.9 years, 61.4 ± 14.3
kg, and 169.7 ± 6 cm, respectively. Subjects were excluded if they had neuropathy or radiculopathy in the upper limbs, a cardiac pacemaker implanted, previous upper limb surgery, a tremor or involuntary muscle control, systemic rheumatic or inflammatory diseases, upper limb injury or pain in the previous three months, or cognitive impairment that precludes protocol compliance. The study protocol was approved by the human subjects ethics committee of the administering institution.

**Procedures and instruments**

The participants were positioned in supine and the wrist and hand on the dominant side were cleaned with methylated spirit, and three disposable surface electromyography (EMG) electrodes (Neurotron, Denver, CO, USA) were applied according to the wide- and narrow-spacing placements in random order (Fig. 1). The electrodes were connected to an EMG differential amplifier (DAM 50, World Precision Instruments, Sarasota, FL, USA) that conditions the EMG signal with a gain of 100 and bandwidth of 10-1000 Hz.

A nerve stimulator (Model 54120, Dupaco, Oceanside, CA, USA) delivered a 200-ms DC square pulse at the point where the median nerve is most superficial at the wrist. This point is located 8 cm superior to the APB (Fig. 2). The intensity of the nerve stimulus was set at 30 to 40 mA to elicit the APB contraction. The waveforms of the stimulation and corresponding evoked response of the APB were collected using a computerized data logger (USB-1208HS, Measurement Computing, Norton, MA, USA) with related software (TracerDAQ Pro, Measurement Computing, Norton, MA, USA). In order to standardize the nerve stimulator placement during the NCV testing, a modified lab jack (Fisher Scientific, Pittsburg, PA, USA) was used to hold the bipolar probe of the stimulator firmly onto the wrist (Fig. 2).
The NCV testing of the median nerve was repeated five times with a 10-second rest between trials for each of the following testing conditions: wide-spacing of electrodes with a sampling rate of 10 kHz; wide-spacing of electrodes with a sampling rate of 2 kHz; narrow-spacing of electrodes with a sampling rate of 10 kHz; narrow-spacing of electrodes with a sampling rate of 2 kHz.

Data analysis

After collecting the data, offline evaluation was done using signal analyzing software (EMG-works 4.0, Delsys, Boston, MA, USA). To identify the nerve stimulation and the APB evoked potential onsets, the raw signal was full-wave rectified and the mean and standard deviation of the 1000-ms resting signal were calculated. The onset time was identified as the time at which the signal exceeded one standard deviation above the mean [11] (Fig. 3). The NCV was expressed as the absolute time difference, in milliseconds, between the two onsets, which is also referred to as the distal median motor nerve latency [12]. Each testing condition was repeated five times, producing five NVC values which were averaged to minimize potential random errors.
Statistical analysis

Using SPSS Statistics 17.0 software (SPSS, Chicago, IL, USA), the computed NCV values were compared by paired \( t \)-tests with \( \alpha \) set at 0.05. Four separate statistical comparisons were done as follows: wide-spacing of electrodes, 2 k sampling versus 10 k sampling; narrow-spacing of electrodes, 2 k sampling versus 10 k sampling; at a 2 k sampling rate, wide-spacing of electrodes versus narrow-spacing of electrodes; at a 10 k sampling rate, wide-spacing of electrodes versus narrow-spacing of electrodes.

Results

There was a significant difference in the NCV values for both wide- and narrow-spacing of electrodes with different sampling rates \((P<0.01)\). The data showed that higher sampling rates resulted in shorter NCV values (Table 1).

Electrode spacing did not affect the NCV values significantly at 2 k sampling \((P=0.054)\) or 10 k sampling \((P=0.674)\), respectively.

All the NCV values were less than 4.4 ms and, therefore, within the normal range [13] (Table 1).

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<th>Table 1. NCV values with various EMG settings</th>
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Discussion

This study was designed to help establish simplified EMG specifications for median nerve conduction measurement without compromising its accuracy. For traditional surface EMG and NCV recordings, the ground electrode would usually be placed on bony tissues that are electrically silent and inactive so as to minimize common mode noise and stimulus artifacts. However, the bones are covered by epidermis that is electrically conductive. Therefore, an absolutely electrically silent placement for the ground electrode does not exist because the electrocardiographic wave can spread throughout the whole body surface [14]. Our data showed that the traditional wide-spacing electrode placements are comparable to the narrow-spacing placements in the NCV values. This implies that the exact location of the ground electrode is less important than the arrangement of the recording electrodes as long as the active electrode is over the APB muscle and the reference electrode is placed nearby.
An important consideration in EMG recording is the rate at which the signal is captured. Since the dominant power spectrum of the surface EMG signal is between 30 and 150 Hz, it has been recommended that a signal bandwidth of 20-500 Hz would be sufficient for surface EMG recording. According to the Nyquist theorem, the ideal sampling rate for analog signals should be at least two times the highest bandwidth; otherwise, under-sampling can occur. This may lead to a loss of data points during the analog to digital conversion; thus the sampled data may not truly represent the signal of interest [15]. Therefore, the appropriate sampling rate for the APB muscle should be at least 1 kHz or higher. Our analyses revealed that the 2 kHz and 10 kHz sampling rates resulted in statistically different NCV values, but the difference was very small (less than 0.2 ms, which is practically negligible). Since the sampling rate is controlled by the microprocessor in the data logger and this component is directly related to the cost of the equipment [16], using a 2 kHz sampling frequency is advantageous in terms of simplicity, potentially decreasing the cost of production of the NCV equipment. Furthermore, using a lower sampling frequency of 2 kHz can minimize the required computer storage capacity for saving EMG data.

Regarding limitations in the present study, it is uncertain if the narrow spacing of integrated recording electrodes is applicable to a CTS patient with severe atrophy of APB since the study only tested healthy subjects; also, as only the NCV of the median nerve was tested, it is not known if the electrode placement and the sampling rate would affect the precision of other peripheral nerve testing. This warrants further study in future.

**Conclusion**

For NCV testing of the distal median motor nerve, precise NCV values can be achieved with narrow spacing of the integrated recording electrodes.

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手関節における正中神経伝導速度計測の技術的検討

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要 旨: 一般集団の6%が罹患しているといわれる手根管症候群(CTS)の診断において、もっとも使用される手技の一つが正中神経の神経伝導速度(NCV)検査である。しかしながらNCVの計測機器は比較的高価であり、必ずしも外来診察時に使用できるとは限らない。そこで本研究ではサンプリング周波数および電極間距離の違いが正中神経におけるNCV計測値に与える影響について調べ、NCV計測機器開発への視座を得ることを目的とした。30名の健常成人を対象に、手関節正中神経のNCVを2種類のサンプリング周波数(2KHzと10kHz)および電極間距離(1cm以下と短母指外転筋-母指指節間関節間)で計測した。各条件間におけるNCV計測値の比較には対応のあるt検定を用いた。その結果、サンプリング周波数によるNCV計測値に有意差が検出されたものの、電極間距離の違いはNCV計測値に影響を与えないことが明らかとなった。本研究の結果はNCV計測機器の性能価格比および技術的適用性を改善するうえで極めて示唆に富むものである。

キーワード：電極間距離、神経伝導速度、サンプリング周波数。

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