Affected Segments of the Median Nerve Detected by Fractionated Nerve Conduction Measurement in Vibration-Induced Neuropathy

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Abstract: Peripheral neuropathy in the hand has often been reported in workers using hand-held vibrating tools. But the affected location in the hand is not clearly demonstrated. To elucidate the impaired segment of the median nerve within the hand, fractionated median sensory nerve conduction velocity (SCV) was measured in the digital, finger-to-palm, palm-to-wrist and wrist-to-elbow segments. Subjects were 56 patients with hand-arm vibration syndrome and 43 healthy controls of similar age. SCV in the digital and the wrist-to-palm segments was significantly slower in the patients than the controls. Slowed SCV in the digital segment was encountered in 36% of the patients, while the slowing in SCV in the wrist-to-palm segment (across the carpal tunnel) was found in 20% of them. The slowing in the digital segment was more frequently encountered in the advanced stage of the Stockholm sensorineural (SN) stage for hand-arm vibration syndrome: 10% in OSN (no neurological symptoms) while 56% in 3SN (severe stage). The present study has demonstrated that vibration-induced nerve impairments dominantly exist both in the digits and across the carpal tunnel. Careful neurophysiological assessment is important to confirm the impaired location within the hand.

Key words: Carpal tunnel syndrome, Digital nerve, Hand-arm vibration syndrome, Peripheral neuropathy

Introduction

Peripheral neuropathy, as well as vibration-induced white finger, has often been reported in workers using hand-held vibrating tools. Previous electroneurographic studies have shown that significantly reduced sensory nerve conduction velocities (SCVs) occur within the hands of patients with hand-arm vibration syndrome1,2. However, previous studies could not clearly demonstrated the precise location of the nerve impairments within the hands, because they usually measured SCVs between the finger and the wrist; some studies3-6 indicate that the nerve fibers are markedly damaged in the wrist like carpal tunnel syndrome, while others5,6 suggest that the most peripheral nerve fibers in the digits are prominently affected like polyneuropathy. Thus, whether the affected location in vibration-induced neuropathy is in the digits or in the wrist is a matter of controversy.

The authors have measured SCVs in the digital nerve by recording electrically evoked potentials from two pairs of ring electrodes in the finger, and have shown that the
measurements can detect digital nerve impairments in patients with vibration syndrome. Such fractionated SCV measurements are expected to show the impaired nerve segments within the hands more clearly.

The aim of the present study was to further investigate the affected location of the median nerve within the hand in vibration-induced neuropathy by fractionated SCV measurements in the digital, finger-to-palm, palm-to-wrist, and wrist-to-elbow segments. Additionally, relationships were studied between SCV in the fractionated segments and the Stockholm vascular and sensorineural stages for vibration syndrome.

**Materials and Methods**

**Subjects**

The present subjects were 56 male patients with vibration syndrome and 43 healthy male controls of similar age. The patient subjects were collected from cases under treatment for vibration syndrome at three hospitals (Kyushu Research Institute for Social Medicine, Ohmuta; Tokushima Kensei Hospital, Tokushima; and Kochi Seikyo Hospital, Kochi, Japan). They all had been officially diagnosed as hand-arm vibration syndrome, based on clinical examinations such as finger skin temperature, nail compression test, vibration perception threshold, and pain threshold before and after a cold provocation test, and gripping power. The control subjects were healthy volunteers from residents near the hospitals who had never been occupationally exposed to hand-arm vibration. They were mainly desk workers or light manual workers such as clerks, teachers and guards.

All subjects were selected after excluding those who had any diseases associated with peripheral neuropathy, such as diabetic, chemical and drug-induced neuropathies, cerebral vascular diseases, other neurological diseases and severe injuries in the hand. If drinkers, they were limited to those who took alcohol equal to ethanol of less than 80 ml a day.

The patients had used hand-held vibrating tools of rock drills or chain saws for 21.3 (standard deviation; 8.5) years, and had been under treatment for 4.6 (3.4) years (Table 1). VWF was found in 64% (n=36) of them, and numbness or tingling of the hand in 82% (n=46). The healthy controls had no such symptoms, because of excluding the subjects with neurological symptoms. The mean age was similar in both groups: 59.4 (5.6) years in the patients (range 41–70 years) and 58.7 (5.5) years in the controls (range 45–69 years).

All subjects were informed about the present study and consented to the measurements.

**Fractionated SCV measurements**

Fractionated SCV in the median nerve was antidromically measured by attaching two pairs of ring electrodes to the middle finger: one pair to the distal and middle phalanges [finger (distal; d)] and another to its proximal phalange [finger (proximal; p)] of the finger, and one pair of disk electrodes above the median nerve on the palm at the second metacarpophalangeal interspace, and applying electrical stimulation of 0.1 ms duration at 1 Hz to the median nerve proximal to the wrist and distal to the elbow. Each response was amplified, passed through a bandpass filter of 20 Hz-2 kHz, and 5 or 10 responses were averaged and stored in an electromyograph (Medelec, Sapphire 4ME). After all measurements, the records were displayed and SCV was calculated from the finger (p) to the finger (d), from the palm to the finger (p), from the wrist to the palm, and from the elbow to the wrist. This measuring method was similar to that of the previous study.

During the measurements subjects were supine on a bed, and their right hands were measured except for four cases with any injuries of the right middle finger or hand. All subjects were examined by the same physician. The measurements were conducted in summer to keep the hand and arm warm; air temperature in the room was around 26°C.

Mean (standard deviation) skin temperature of the finger, palm and forearm, measured with an infra-red ray thermistor (Horiba, IP340), was respectively 31.6 (2.0) °C, 32.0 (1.6) °C and 32.5 (0.7) °C in the patients; and 32.3 (2.1) °C, 32.7 (1.6) °C and 32.5 (0.7) °C in the controls. Then, measured SCVs were adjusted for standard skin temperature at 33°C according to a formula by de Jesus et al.

**Statistical analysis**

Mean SCV was statistically compared between the patients
and the controls using Student’s t-test. Number of subjects with slowed SCV below a tentative lower limit of the lower 5%ile value of the controls under study was compared using Fisher’s exact probability test.

**Results**

**SCV in fractionated segments**

Table 2 shows mean SCV in each fractionated segment of the median nerve. SCV was significantly slower both in the digital [from the finger (p) to the finger (d)] and the wrist-to-palm segments (between the wrist and the palm) in the patients than in the controls (p<0.01 or p<0.05). The velocities from the palm to the finger (p) and from the elbow to the wrist did not significantly differ between the two groups.

**Slowed SCV in fractionated segments**

Slowed SCV below a tentative lower limit of the 5%ile value of the controls under study was also significantly more encountered in the digital and the wrist-to-palm segments among the patients than the controls (p<0.01 or p<0.05, Table 3). The slowing in SCV was most frequently found in the digital segment of the patients: 36% of the patients and 5% of the controls. Reduced SCV in the wrist-to-palm segment was found in 20% of the patients (5% of the controls). Among twenty patients with slowed SCV in the digital segment, thirteen cases did not have the slowing in the wrist-to-palm segment, while seven cases had the reduced SCV in the wrist-to-palm segment as well (Table 4).

**SCV in fractionated segments and the Stockholm stage**

Table 5 shows mean SCV and the number of subjects with the slowing in the patient groups classified by the Stockholm sensorineural (SN) and vascular (V) stages for hand-arm vibration syndrome. The staging was made on the hand where SCV was measured. There was no case in the 4V (very severe vascular) stage. Age did not differ significantly among the groups. Slowed SCV in the digital segment was encountered in 10% of the patients in the 0SN stage (no sensorineural symptoms like numbness), whereas the slowing was found in 56% of them in the 3SN (severe) stage. The percentage of the slowing in SCV was significantly higher in the latter stage than the former (p<0.05). Such relation was not found in the wrist-to-palm segment according to the Stockholm sensorineural stage and in both of the digital and the wrist-to-palm segments according to the Stockholm vascular stage.

**Discussion**

Previous nerve conduction studies, which usually measured SCVs between the finger and the wrist, have shown that vibration-induced nerve impairments exist within the hands, but they could not objectively indicate the more detailed location of the nerve impairments within the hands. In order to elucidate the impaired nerve segments within the hands, the present study measured SCV in fractionated segments of the median nerve: the digital, the digital-to-
palm, the palm-to-wrist, and the wrist-to-elbow. As a result, the present fractionated SCV measurements have revealed that both the digital and the wrist-to-palm (across the carpal tunnel) segments are predominantly damaged in vibration-induced neuropathy. These findings are consistent with those of our previous study. Recently, a study, in which the measurements were made between the finger and the palm and between the palm and the wrist, showed that SCVs were significantly reduced in the finger-to-palm segment as well as in the palm-to-wrist segment. This is in accordance with the present results. Thus, the present study has confirmed that vibration-induced nerve impairments dominantly exist both in the finger and in the wrist across the carpal tunnel.

Slowed SCV was most frequently encountered in the digital segment (36% of the patients), whilst the slowing in the wrist-to-palm segment was found in 20% of them. The slowed SCV in the digital segment was encountered in twenty patients. Among them, thirteen patients did not show reduced SCV in the wrist-to-palm segment, while seven experienced the slowing in the wrist-to-palm segment as well. It is known that in carpal tunnel syndrome SCV is markedly decreased between the palm and the wrist, and in severe cases reduction in SCV can occur in the finger as well. The impaired tactile sensation of the finger has been also reported in vibration-exposed workers. Slowed SCV in the digital segment in the present study is supposed to be associated with these nerve impairments in the finger. Animal experiments have shown that exposure of the limbs or tails of rats and rabbits to vibration induces morphological changes in the distal nerves, such as intraneural edema, disruption of the myelin sheath, and constriction of the axon. An experiment has suggested that distal nerves are more markedly affected than the proximal nerves. Hand-arm vibration may primarily damage the distal nerves in the hands.

On the other hand, a recent biopsy study has also shown demyelination and fibrosis in peripheral nerves proximal to the wrist among workers using hand-held vibrating tools. Such nerve injury may constitute a structural component in carpal tunnel syndrome among them. Intraneural edema induced by vibration exposure as well as repetitive motions and strenuous manual work is presumed to contribute to carpal tunnel syndrome in vibration syndrome.

In the present study, slowing in SCV in the digital segment was more frequently encountered in the advanced Stockholm sensorineural stage: 10% in the OSN stage and 56% in the 3SN stage. SCV in the wrist-to-palm segment did not show this tendency. SCV in the digital segment seems to be more likely to reflect the Stockholm stage than SCV in the wrist-to-palm segment. One of the reasons may be that SCV in the digital segment can detect nerve impairments in the finger including damaged vibrotactile perception, because the Stockholm sensorineural staging is based on reduced sensory

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Table 5. Mean and standard deviation of SCV and number (percentage) of subjects with slowed SCV in digital and wrist-to-palm segments according to the Stockholm sensorineural (SN) and vascular (V) stages

<table>
<thead>
<tr>
<th>Stage</th>
<th>n</th>
<th>Age (yrs)</th>
<th>Finger (p)-finger (d)</th>
<th>Wrist-Palm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean SCV (m/s)</td>
<td>N (%) of slowed SCV</td>
</tr>
<tr>
<td>0SN</td>
<td>10</td>
<td>58.5±4.1</td>
<td>49.6±4.8</td>
<td>1 (10.0)</td>
</tr>
<tr>
<td>1SN</td>
<td>6</td>
<td>58.8±3.9</td>
<td>48.4±8.1</td>
<td>2 (33.3)</td>
</tr>
<tr>
<td>2SN</td>
<td>24</td>
<td>60.1±5.9</td>
<td>46.6±9.4</td>
<td>8 (33.3)</td>
</tr>
<tr>
<td>3SN</td>
<td>16</td>
<td>59.3±6.9</td>
<td>45.4±11.7</td>
<td>9 (56.3)*</td>
</tr>
<tr>
<td>0V</td>
<td>20</td>
<td>59.6±5.0</td>
<td>46.3±7.4</td>
<td>6 (30.0)</td>
</tr>
<tr>
<td>1V</td>
<td>8</td>
<td>57.8±4.8</td>
<td>47.8±12.8</td>
<td>4 (50.0)</td>
</tr>
<tr>
<td>2V</td>
<td>16</td>
<td>59.1±5.1</td>
<td>49.8±10.0</td>
<td>4 (25.0)</td>
</tr>
<tr>
<td>3V</td>
<td>12</td>
<td>60.8±7.9</td>
<td>45.1±8.6</td>
<td>6 (50.0)</td>
</tr>
</tbody>
</table>

*p<0.05, significant difference between 0SN and 3SN by Fisher’s exact probability test. *Slowed SCV: see Table 4.
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perception as well as neurological symptoms in the hand[10]. The present fractionated SCV measurements have demonstrated that vibration-induced nerve impairments are located both in the digital and the wrist-to-palm segments. The former suggests finger neuropathy, while the latter does carpal tunnel syndrome. Hence, these two types of peripheral neuropathies can co-exist in hand-arm vibration syndrome, though the digital segment may be more dominantly affected than the palm-to-wrist segment, as shown by the present study. Careful neurophysiological assessment is important to confirm the damaged location in vibration-induced neuropathy.

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