

# Morphologic Classification of Nailfold Capillary Microscopy in Workers Exposed to Hand-arm Vibration

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**Abstract:** The aim of this study was to investigate the association between the morphologic classification of nailfold capillary microscopy and the clinical and demographic findings in workers exposed to hand-arm vibration. The subjects were 44 male forestry workers (average age;  $51.9 \pm 14.8$  yr). The nailfold capillaries (NC) and the mean blood flow velocity were measured on the middle finger of the dominant side by a peripheral capillary observer. The analyses were made using 39 subjects after excluding five subjects who received medication for hypertension. The observed NC were classified into 5 types according to Kusumoto's classification: Type I, n=5; Type II, n=15; Type III, n=8; Type IV, n=5; and Type V, n=6. After excluding the subjects in the Type V, we divided the subjects into two groups: Type I/II group, n=20; and Type III/IV group, n=13. In the Type III/IV group, the operating year of handheld vibrating tools was relatively longer, the mean blood flow velocity was significantly slower, and the body mass index was relatively higher as compared to the Type I/II group. These results suggested that the nailfold capillary microscopy may reflect the effect of the vibration exposure.

**Key words:** Hand-arm vibration syndrome (HAVS), Nailfold capillary microscopy, Peripheral circulatory dysfunction, Blood flow, Autonomic nervous system

## Introduction

A patient is certified as suffering from hand-arm vibration syndrome (HAVS) as an occupational disease in Japan if: 1. the patient is required to be employed for a reasonable period of time in an occupation that entails exposure to vibration in upper limbs, 2. Raynaud's phenomenon must be observed, and 3. either peripheral

circulatory disturbance, peripheral neuropathy, or motor dysfunction must all be observed or one of these must be present to a marked degree<sup>1</sup>.

When diagnosing HAVS, an overall evaluation is made based on the results of a vibration medical examination in accordance with criteria based on Circular 609 of the Ministry of Labor (now the Ministry of Labor, Health and Welfare)<sup>2</sup>. In many cases, however, attacks of Raynaud's phenomenon as vibration-induced white finger (VWF) last for less than 15 min, and even if workers are able to confirm this for themselves while

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working, opportunities for visual confirmation during HAVS examination are extremely rare. Accordingly, the function tests for peripheral circulatory disturbance, such as FST during cold water provocation tests, are regarded as important for the diagnosis of HAVS<sup>3, 4)</sup>. This is due to exaggeration of the vasoconstriction reflex (vasospasticity), which suggests that the increase in sympathetic response can be objectively assessed.

Localized damage (histopathological changes) to peripheral blood vessels has also been identified as contributing to the onset of VWF. At present, both the vasospasticity and the histopathological changes are believed to be involved<sup>5)</sup>.

Currently, finger angiography is performed as an investigative technique for assessing morphological changes to peripheral blood vessels. This method, however, is indicated electively for the determination of HAVS severity or a differential diagnosis from other arterial disorders, in light of the invasiveness of the examination and safety considerations<sup>6)</sup>.

Nailfold capillary microscopy, on the other hand, offers a noninvasive testing method that is simple and quick, and it can provide a valuable addition to the present functional testing of peripheral blood vessels.

The present study used capillaroscopy during HAVS tests and examined its utility as a testing method to supplement the more objective and accurate assessment of peripheral circulatory disturbance in workers exposed to hand-arm vibration by investigating correlations between morphologic classification and the findings.

## Subjects and Methods

Subjects were 44 men who underwent health examinations for HAVS in December 2008. They were mainly chainsaw operators in a private forest in Wakayama Prefecture. After the subject taking a 20-min of acclimation period in a room at an ambient temperature of  $24.2 \pm 0.6^\circ\text{C}$ , they underwent the several kinds of physiological tests with the standard procedure proposed by the Ministry of Health, Labor and Welfare notification<sup>2)</sup>.

Nail-pressure test evaluated the recovery time of normal color after pressing the nail strongly for ten seconds. Blood pressure was measured on the left arm when subjects in the sitting position.

Cold provocation test was carried out by immersing the subject's hand of the dominant side into cold water bath at the temperature of  $12^\circ\text{C}$  for 5 min<sup>7)</sup>. The skin temperature was measured continually through the test with a thermometer put on the distal phalanx of the middle finger<sup>2)</sup>. The recovery rate (%) at the point of 10 min after cold provocation test was calculated by the following formula:



**Fig. 1. Measurement of nailfold capillary microscopy.**

The movie clip is recorded from the peripheral capillary observer (M320) by capture with the personal computer. The start of software (MEDICS) inserts special dongle of the attachment in the personal computer. The penetration liquid is spread on the skin of the nailfold, the capillary is confirmed under the microscope, and the movie clip is recorded for ten seconds.






{[At the point of 10 min finger skin temperature (FST) after finishing the test – FST immediately after finishing the test] ÷ [FST just before starting the test – FST immediately after finishing the test]} × 100

After the cold provocation test, the nailfold capillary was evaluated on the middle finger of the immersed hand using a peripheral capillary observation unit (M320; JMC Co., Ltd, Japan) (Fig. 1). The capillary types were read from video images and categorized according to a Kusumoto's classification system (as shown in Table 1)<sup>8)</sup>. The criteria in details were as follows: Type I, no twists in loops; Type II, one twist; Type III,  $\geq 2$  twists; Type IV, Y-shaped; Type V, arteriolar and venular limbs unclear. Subjects were categorized as Types I through IV if the respective morphological changes could be seen in at least one finger among video images of multiple capillaries.

Mean blood flow velocity was estimated using blood flow measurement software (MEDICS) (JMC Corporation, Japan) supplied with the M320. After choosing a peripheral vein with a sufficient diameter manually with the measurement software, we recorded a 10-s movie clip of the blood flow of the vein at 30 frames per second. The mean blood flow velocity was calculated from the movie clip by analyzing the flow of red cells. The measurement was conducted by one experienced engineer.

According to Kusumoto, healthy individuals are mainly categorized in Type I or II, whereas HAVS sufferers are clustered in Types II, III and IV. We therefore catego-

**Table 1. The breakdown of the nailfold capillary types**

Capillary types	Frequency, n (%) <sup>*</sup>
Type I 	5 (7.8)
Type II 	15 (38.5)
Type III 	8 (20.5)
Type IV 	5 (12.8)
Type V 	6 (15.4)

The criteria: Type I, no twists in loops; Type II, one twist; Type III,  $\geq 2$  twists; Type IV, Y-shaped; Type V, arteriolar and venular limbs unclear.

<sup>\*</sup>Number and percentage of capillary types.

rized subjects into the Type I/II Group or the Type III/IV Group, and compared these groups with HAVS examination data using the Mann-Whitney U test. StatView-J5.0 (SAS Institute, USA) was used for statistical analysis, with values of  $p < 0.05$  regarded as significant.

## Results

The analyses were performed in 39 subjects after excluding five subjects who were received medica-

tion for hypertension. The mean ( $\pm$  standard deviation) age of the subjects was  $51.5 \pm 15.5$  yr. The mean operating years of using handheld vibrating tools was  $18.7 \pm 14.3$  yr.

A total of five subjects suffered from VWF symptoms. The severity was confirmed with both an interview by a physician and the results of medical examination. According to the Stockholm workshop scale<sup>9</sup>, three subjects classified in the stage II and two were in the stage III for vascular staging.

In the peripheral capillary observation, the capillary types were determined for each subject. The details were as follows: Type I, 5 subjects (7.8%); Type II, 15 subjects (38.5%); Type III, 8 subjects (20.5%); Type IV, 5 subjects (12.8%); and Type V, 6 subjects (15.4%) (as shown in Table 1). Among five subjects with VWF, three were determined as the Type II and two were in the Type III.

After excluding the Type V group, 20 subjects in the Type I and Type II were grouped and treated as Type I/II group. Similarly, 13 subjects in the Type III and Type IV were as Type III/IV group. The comparisons between the two groups were made for the clinical and demographic parameters: mean blood flow velocity in nail capillary vessels, age, history of using handheld vibrating tools, body mass index; brachial systolic and diastolic blood pressure; FST; nail pressure recovery time, FST recovery rate, and room temperature. The results are shown in Table 2. The Type III/IV group subjects had significantly slower mean blood flow velocity compared with the Type I/II group subjects ( $p = 0.03$ ).

**Table 2. Comparison of the examination data between Type I/II group and Type III/IV group**

	Type I/II group (n=20)	Type III/IV group (n=13)
Age, yr	54.5 (28.0)	59.0 (35.8)
BMI, kg/m <sup>2a</sup>	22.0 (3.8)	23.5 (2.2) <sup>†</sup>
Chainsaw usage, d/yr	8.0 (24.0)	30.0 (33.8) <sup>†</sup>
Systolic blood pressure, mmHg	126.5 (21.0)	131.0 (13.3)
Diastolic blood pressure, mmHg	73.0 (18.5)	76.0 (15.5)
Room temperature, °C	24.4 (0.7)	24.1 (1.3)
Finger skin temperature, °C	31.7 (5.0)	32.2 (6.6)
Finger skin temperature recovery rate, % <sup>b</sup>	54.3 (62.6)	51.6 (53.1)
Nail fold pressure test, sec <sup>c</sup>	1.6 (0.4)	1.5 (0.7)
Blood flow velocity, $\mu\text{m}/\text{sec}^d$	154.0 (67.0)	79.0 (83.5) <sup>*</sup>

Values are expressed as median (inter quartile range).

<sup>a</sup>Number of subjects were 19 and 12 for Type I/II group and Type III/IV group, respectively.

<sup>b</sup>Recovery rate of the skin temperature based on the data measured 10 min after cold water provocation test.

<sup>c</sup>Recovery time of normal color after pressing the nail strongly for ten seconds.

<sup>d</sup>Number of subjects in Type I/II group was 13. 7 subjects were excluded because of the narrow vein.

<sup>\*</sup> $p < 0.05$ , <sup>†</sup> $p < 0.1$  as compared with Type III/IV group by Mann-Whitney U test.

The operating years of handheld vibrating tools was relatively longer ( $p=0.05$ ) and body mass index was higher ( $p=0.08$ ) among the subjects in the Type III/IV than those in the Type I/II. There were no significant differences between the groups for the other tested variables.

## Discussion

The gold standard for diagnosing HAVS is the objective confirmation of the appearance of VWF, but as the existence of this condition is extremely difficult to determine other than during an attack, other effective methods of objectively assessing this condition have been investigated.

In Japan, FST during a cold water provocation test and the nailhold pressure test are used as tests of peripheral circulatory function in HAVS examination. The tests have been regarded as valuable screening methods because of their features. As conditions that involve peripheral circulatory disturbance exhibit multifactorial aspects, both functionally and organically, the onset of a phenomenon such as VWF is problematic to explain with a single factor.

The present study therefore examined the utility of capillaroscopy, a simple, noninvasive method capable of observing capillary types, as a testing method to supplement the current functional testing of peripheral blood vessels by providing a more objective and accurate assessment of peripheral circulatory disturbance in HAVS, a disorder with a complex clinical presentation.

When the Type I/II Group and the Type III/IV Group were compared with various HAVS examination data, in the subjects in the III/IV type group, the operating years of handheld vibrating tools was relatively longer, and the mean blood flow velocity was significantly slow. However, no significant differences were evident in age, peripheral circulatory function (FST, nailhold pressure test, FST recovery rate) and blood pressure.

These results suggest that morphological changes in capillary types are more profoundly associated with capillary wall damage caused by long-term vibratory stimulation than alteration of the blood flow via the autonomic nervous system caused by aging and cold stimulation.

As an underlying mechanism, because the vibratory stimulation and noise generated by handheld vibrating tools increased the cold stimulation, the capillary contraction became severe, and ischemia or nutritional deficiency brought about damage to vascular wall tissues by peripheral circulatory disturbance.

Kaji *et al.*<sup>10</sup> observed capillary types in workers who used handheld vibrating tools, and classified three

types, Types A, B, and C, according to the diagnostic criteria<sup>11</sup> of Fagrell and Lundberg. They further investigated diagnostic accuracy by examining the frequency of classification by type in the presence or absence of HAVS and found that the sensitivity for HAVS was 59.2% and the specificity for non-HAVS was 50.0%, indicating that capillary types could be assessed in HAVS, but was not of great use.

Kaji *et al.* also reported that as the diagnostic criteria of Fagrell and Lundberg were based on subjects with severe lower-limb arterial occlusive disease, no correlation was found between the existence (frequency) of HAVS and classification types (frequency), making this classification system difficult to apply to HAVS.

Kusumoto analyzed observations of capillary types in 102 subjects with HAVS and 28 healthy controls<sup>8</sup>. He found that capillary types in HAVS sufferers frequently exhibited morphological changes such as twists, flexion, and tortuosity, with these changes tending to worsen with increasing duration of tool use. He did not, however, find any correlation with digital plethysmography pulse height or FST.

Other morphological classifications of capillary types in HAVS, in addition to that of Kusumoto *et al.* described above, include those of Bollinger and Fagrell<sup>12</sup>, Bossnev *et al.*<sup>13</sup> and Nomizu<sup>14</sup>. The present study used the classification of Kusumoto *et al.*, as this has few categories, enabling easy classification and reducing the likelihood of bias due to differences in tester proficiency. Type V, however, was excluded from the analysis. This was because in preliminary experiments, Type V was found to appear frequently in healthy individuals as well as HAVS sufferers, and the association with peripheral circulatory dysfunction was unclear. It remains uncertain whether Type V was seen as a result of insufficient light transmission caused by thickening of the nail bed, or because nail bed capillaries are deflected so that only part of the hoof shape can be seen. However, some reports have noted that dropout capillary types like those of Type V are characteristic of VWF sufferers<sup>15</sup>, and in future we intend to perform an additional investigation to clarify whether Type V nailfold capillaries are characteristic of HAVS by gathering data from subjects at a more severe stage as well as from healthy subjects.

In addition, blood flow velocity could not be measured from the Type V hoof shape due to the short length of visible loops. Blood flow velocity also could not be measured in 7 subjects in the Type I/II Group (Type I,  $n=2$ ; Type II,  $n=5$ ) due to narrow blood vessel diameter. In this regard, further improvements in blood flow measurement software are desirable.

Subjective symptoms of VWF were present in 7 sub-



jects in this study, of whom only one was assessed as management classification C<sup>16</sup>), and a detailed investigation was not performed. We intend to perform a further investigation of this issue in the future.

From these results, it is suggested that morphologic classification of nailfold capillary microscopy is useful as one of the screening tests in health examinations for HAVS because the influence of the hand-arm vibration exposure made capillary flexure, meandering remarkableness.

This study has some limitations. First, there were few subjects, especially subjects with VWF. Therefore, the association between the pathologic of VWF and the morphologic classification of nailfold capillaries is not clear. Second, it is controversial whether Type V nailfold capillaries are a manifestation of HAVS. A detailed examination that adds the other elements of nailfold capillaries may be necessary. Third, the association between the morphologic findings and the blood flow velocity remains unclear. Only one study<sup>14</sup>) reported that the blood flow velocity is variable by time and location. Further investigation should be needed.

## Conclusion

In conclusion, the results of this study suggested that the performance of nailfold capillary microscopy during HAVS examination may be useful for determining the effect of exposure to vibration, when evaluated in addition to the results of examination items.

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