Clinical Features and Laboratory Findings of Vibration Disease: A Review of 300 Cases

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MATOBA, T., KUSUMOTO, H., MIZUKI, Y., KUWAHARA H., INANGA, K. and
TAKAMATSU, M. Clinical Features and Laboratory Findings of Vibration Disease:
features and laboratory findings of 300 inpatients with vibration disease before and
after treatments were reviewed. Having been using chain saws or pneumatic
hammers for a long period, the patients were afflicted with Raynaud’s
phenomenon, numbness, pain or stiffness of fingers, pain of elbows and neck,
stiffness of shoulders and lumbago. They had high incidences of complaints
due to the disorder of the central nervous system, especially of the higher center
of the autonomic nervous system; i.e. headache (52.0%), palmar hyperhidrosis
(70.6%), forgetfulness (78.2%), fatiguability (61.3%), tinnitus (41.8%), impotence
(55.1%), etc. Laboratory findings of the autonomic nerve activity tests,
electroencephalograms and audiograms also suggested the disorder of the central
nervous system. Treatments during three months had improved significantly
the subjective symptoms and the objective findings (p<0.05 to 0.001). Thus,
vibration disease should be considered as a systemic disease, including disorders
of the central nervous system, especially of the higher center of the autonomic
nervous system, and disturbances of the peripheral functions. — vibration
disease; clinical features; laboratory findings; disorder of autonomic nerve
activity

Since the report of Loriga in 1911, it has been known that Raynaud’s
phenomenon may occur in the fingers of operators who use vibrating tools for a
long period, which has been named “white fingers” or “Raynaud’s phenomenon
of occupational origins”. Recently, this disease has been recognized not only
in the iron-steel and engineering industry but also in forestry. In Japan, it was
in 1965 that the eruption of a large number of patients with vibration disease
among chain saw operators became a nation-wide social problem.

The principal symptoms of this disease have been manifested in disturbances
of peripheral circulation and nerve, and in the lesions in the muscles and the
joints (Marshall et al. 1954; Smith and Allen 1969; Stewart and Goda 1970;
Wasserman and Badger 1973). The investigators in Russia have emphasized
that the central nervous system may be affected in the disease (cf. Ref. 2).

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Although clinical observations with regard to the peripheral lesions were described by many authors, clinical features of the disorder of the autonomic nervous system and treatments for patients with vibration disease have scarcely been reported.

In the present study, clinical features and laboratory findings of 300 patients with vibration disease due to operating chain saws or pneumatic hammers have been reviewed in an attempt to clarify the pathophysiology and the therapy for the disease.

SUBJECTS AND METHODS

The clinical features and the laboratory findings of 300 male patients hospitalized with vibration disease were analyzed. Table 1 shows the data of the subjects. The severity of vibration disease was judged on the basis of our criteria, consisting of four stages (Matoba et al. 1975b).

The data of subjective symptoms and objective findings analyzed were those taken before and after treatments. The treatments consisted of therapeutic exercises, hot spring bathing and pharmaceutical therapies (Matoba et al. 1975a).

The examinations of the peripheral nervous and circulatory functions were as follows: threshold for vibration sensation in the finger pulps of digital phalanxes, threshold for pain in the back of the fingers, cold immersion test (one hand was immersed up to the wrist in cold water at 10°C for 10 min, and after that rewarmed rates were measured at 5 and 10 min), grip strength and tapping test of fingers (to tap with one finger for 10 sec). The microphotographic examination of capillaries in the dorsal part of the digital phalanx of a finger was also carried out. Roentgenographically, cervical and lumbar vertebrae, elbows and hands were examined.

Electroencephalograms were recorded with a 12-channel electroencephalograph, using unipolar and bipolar leads. The level of the activity of the autonomic nervous system was evaluated by means of the digital plethysmography combined with auditory stimuli (Matoba et al. 1975c). Auditory acuity, electrocardiograms, blood chemistry, blood cell counts and urine composition were also examined.

All measurements were performed at room temperature (22–24°C).

TABLE 1. Data of 300 patients in the study

<table>
<thead>
<tr>
<th></th>
<th>Stage II</th>
<th>Stage III</th>
<th>Stage IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>50</td>
<td>242</td>
<td>8</td>
</tr>
<tr>
<td>Age (mean±s.d.)</td>
<td>45.7±7.7</td>
<td>42±7.4</td>
<td>47±11.7</td>
</tr>
<tr>
<td>Duration of usage of vibrating tools (years; mean±s.d.)</td>
<td>10.8±3.7</td>
<td>*10.4±4.1</td>
<td>8.9±3.9</td>
</tr>
<tr>
<td>Kinds of vibrating tools</td>
<td>chain saw</td>
<td>23</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>pneumatic hammer</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>Duration of hospitalization (days; mean±s.d.)</td>
<td>80±21.6</td>
<td>†103±32.0</td>
<td>‡209±36.2</td>
</tr>
</tbody>
</table>

*p<0.01, †p<0.002, ‡p<0.001 by t-test.

RESULTS

Subjective symptoms and physical findings

The major subjective symptoms related to the disturbances of the peripheral circulatory and nervous functions were Raynaud’s phenomenon, numbness, pain,
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Fig. 1. Subjective symptoms related to the peripheral disturbances. Open and stippled bars show the incidence on admission, and solid bars show the incidence on discharge. Most of them have subsided by treatments with the significant differences. No marks show no statistical significances. *p<0.05, †p<0.01, by $x^2$ test.

Fig. 2. Subjective symptoms related to the disorders of the central nervous system and the higher center of the autonomic nervous system. Open and stippled bars show the incidence on admission, and solid bars show the incidence on discharge. Most of them have recovered by treatments with the significant differences. However, the incidence of impotence has not been confirmed on discharge. *p<0.05, †p<0.01 by $x^2$ test.

cold sensation and stiffness in the fingers or arms. Orthopedically, the complaints of pain in the neck and elbows, stiffness of shoulders and lumbago were observed in more than 50% of the patients. The incidences of those complaints in each stage of the disease are shown in Fig. 1. Raynaud’s phenomenon was usually observed at the late stage II. These complaints were markedly subsided by treatments, and the effectiveness of most of the treatments were significant statistically.

Fig. 2 shows the subjective symptoms related to the disorders of the central nervous system and the autonomic nervous system, including heavy feeling in the head, dyssomnia, palmar hyperhidrosis, irritability, depressive mood, suppressed motivation, fatiguability, tinnitus, and so on. These complaints tended to
increase in proportion to the severity. According to our clinical experiences, these disorders of the autonomic nervous system seemed to appear remarkably at the stage III. Treatments for about 3 months resulted in a decrease in the incidences of these complaints. The recovery rates of all the complaints showed the statistical significance (p<0.05 to 0.01). However, the incidence of impotence after treatment could not be confirmed.

Physical examinations revealed muscular weakness or atrophy, primary lesion in the ulnar and median nerves with or without a claw hand, and tenosynovitis. Neurologically, some patients proved to be positive in the Romberg test. However, nystagmus was not found in any patients.

Clinical laboratory findings

Peripheral circulatory, nervous and muscular functions. Less than 50% of the patients showed normal values in all tests. Above all, abnormal values of the threshold for pain in the fingers and arms were seen in about 75% of the patients in stage III. In the cold immersion test, abnormal values were also found in 60% of the patients in the same stage.

Fig. 3 shows the improvements of these abnormalities by treatments. In all tests, more than 70% of all patients showed normal or improved values (p<0.001).

The microphotoscopic findings of capillaries in the dorsal part of the distal phalanx of a finger revealed smaller and tortuous capillaries as compared with those of healthy subjects.

Roentgenographic findings of the bones and the joints. Most patients had callus formations in the epiphyses of the cervical and lumbar vertebrae. Some patients had osteoarthritic changes at the elbow joints. The incidence of changes of elbows and lumbar vertebrae increased in proportion to the severity, having a significant difference between stage II and stage III (p<0.025). Kienböck's disease was found in two patients. The callus formation at the groove of the humerus where the ulnar nerve lay resulted in paralysis or paresis of the ulnar nerve.

![Fig. 3. Improvements of the peripheral nervous function (pain sensation and vibration sensation), the peripheral circulatory function (cold water immersion test) and the peripheral motility (tapping test) by treatment.](image-url)
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TABLE 2. Incidences of the roentgenographical changes of bones and joints

<table>
<thead>
<tr>
<th></th>
<th>Stage II</th>
<th>Stage III</th>
<th>Stage IV</th>
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<tbody>
<tr>
<td>Cervical vertebrae</td>
<td>54.0%</td>
<td>61.6%</td>
<td>25.0%</td>
</tr>
<tr>
<td>Elbow regions</td>
<td>42.0</td>
<td>60.3</td>
<td>62.5</td>
</tr>
<tr>
<td>Lumbar vertebrae</td>
<td>70.0</td>
<td>85.1</td>
<td>62.5</td>
</tr>
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*p<0.025 by x²-test.

Fig. 4. Microphotoscopic findings of capillaries in the drosal part of the distal phalanx of a finger before (a) and after (b) treatment. After treatment, the capillaries reveal larger and more vivid blood perfusion.

with or without a claw hand. The paralysis and paresis were demonstrated in 25 patients (8.3%).

Auditory acuity. Normal audiograms were shown in only 67 patients (22.3%). The reduction of the auditory acuity was observed mainly at 4,000 and 8,000 Hz. One third of the patients who showed abnormal audiograms had hearing loss of more than 60 dB. These abnormal audiograms could not be improved by our treatments. However, tinnitus associated with hearing loss was subsided (p <0.001).

Electroencephalographic findings. The characteristic fast waves of 20 to 30 Hz was observed in the frontal and the anterior temporal areas of the patients. This fast activities appeared in a spindle form as shown in Fig. 5. However, the spindle-shaped fast activity was different from the spindle waves of 14 Hz which generally appeared in the early stage of sleep. The suppression of the basic alpha waves in most patients elicited the spindle-shaped fast activity appearing sporadically or diffusely or continuously. The amplitude and the duration of the fast activity were about 25 μV and less than 1 sec. The incidence of the fast activity was 54 of all the patients (18.0%). It appeared at stage II and increased in proportion to the severity of the disease: stages II, III and IV had 6.0%, 19.0% and 62.5%, respectively. The treatments resulted in the subsidence of the spindle-shaped fast activity in 20 out of 54 patients (53.7%). This was significant statistically (p<0.001). Photic stimulation accelerated harmonic drivings especially in high frequency.
The level of the autonomic nerve activity. The level of the autonomic nerve activity as expressed by the digital plethysmography with auditory stimulus was classified into 4 types: normal type (normoreactive, N type), intermediate and delayed type (hyperreactive, I and D types) and poor response type (hyporeactive, P type) (Matoba et al. 1975c). The distribution of the levels of the autonomic nerve activity in 172 patients on admission was: N type 43 (25.0%), I type 40 (23.3%), D type 38 (22.1%) and P type 51 (29.6%). The abnormal level of the autonomic nerve activity was normalized after treatments in 59 out of 129 patients who showed abnormal levels (45.7%). This was statistically significant ($p<0.001$).

Cardiovascular system. According to the WHO’s criteria for hypertension, 23 (7.7%) of all the patients had hypertension and 57 (19.0%) had border-line hypertension. Bradycardia (heart rate less than 50/min) was found in 35 patients (11.7%). Abnormal electrocardiographic findings including prolonged PQ interval (2.0%), complete right bundle branch block (2.0%), the abnormalities of ST-T segments (14.0%) and left ventricular hypertrophy (11.7%) were observed. In chest X-ray film, enlarged heart (CTR was more than 0.5) was found in 60 patients (20.0%).

Blood chemistry, hematology and urinalysis. Measurements were made of total serum protein, the ratio of albumin to globulin, SGOT, SGPT, alkaline phosphatase, total serum cholesterol, serum triglyceride, urea nitrogen, $^{131}$I-tridiodothyronine resin test, serum sodium, serum potassium, serum calcium and serum chloride. Hematological examination included red blood cell count, white blood cell count, hemoglobin and hematocrit. The values were all within normal limits before and after the treatments.

Urinalyses disclosed nothing particular.
**Treatments**

The treatments consisted of physical and pharmaceutical therapies (Matoba et al. 1975c). The physical therapy aimed at the enhancements of blood circulation and restoration of nervous reflexes, and it included gymnastic exercise employing a wooden pole or a ball. It also included swimming in a hot water pool, body massage and paraffin bath. In the drug therapy, we used vasodilator drugs and an agent accelerating nervous metabolism. Specific therapies other than the above therapies were also given: administration of soporifics, blocking of the stellate ganglion by procain, cervical traction, etc. One course of these therapies lasted for six weeks. The regimen during hospitalization was to keep body warm and not to smoke.

By the above-mentioned therapies, most of the patients were discharged on the average 106±34.8th day of the hospitalization after improvements of their subjective symptoms and laboratory findings.

**DISCUSSION**

Since 1911, the usage of vibrating tools such as pneumatic chippers, chain saws, and electrical grinders has been recognized to injure the peripheral blood vessels and nerves, provoking Raynaud's phenomenon or "white fingers". Also reported have been cases of changes in bones, muscular weakness or muscle atrophy, tenosynovitis, and temporary or permanent ear damage (Marshall et al. 1954; Smith and Allen 1969; Stewart and Goda 1970; Yamamura 1970; Wasserman and Badger 1973).

In the present study, the analyses of clinical features of 300 cases of vibration disease have clarified that the disease affects not only the peripheral nervous and circulatory systems but also the central nervous system, especially the higher center of the autonomic nervous system. Namely, there have been high incidences of complaints such as headache, insomnia, palmar hyperhidrosis, forgetfulness, depressive mood, tinnitus, impotence, and so on. Such subjective symptoms can be considered to be induced by the disturbance of the central nervous system, even if they are secondary. For example, it may be the primary cause of insomnia that the sleeping center in the limbic system in the brain is functionally exited by the stressors, that is, noise and vibration, and the secondary cause is pain associated with the lesions of the muscles or the joints.

Objective evidences for the disorders of the central nervous system were also obtained. Most of the patients had abnormal levels of the autonomic nerve activity as expressed by the response of the digital plethysmography caused by auditory stimulus (Matoba et al. 1976). The hyperreactive or hyporeactive level of the autonomic nerve activity was significantly improved to normal level by the treatment. Insomnia and palmar hyperhidrosis were also improved by the administration of sulpiride (Matoba and Kusumoto 1975). Such improvements would show the existence of the functional disorder of the higher center of the
autonomic nervous system.

Raynaud's phenomenon may occur under the condition of the damage of the vessel walls, nerve endings and biochemical regulation (Magos and Okos 1963). However, the disorder of the higher center of the autonomic nervous system can be related to the occurrence of Raynaud's phenomenon (Matoba and Kusumoto 1976).

The abnormality of the electroencephalogram, including spindle-shaped fast activity, was mostly observed in the frontal area. Is the spindle-shaped fast activity regarded as a characteristic pattern in vibration disease? Firstly, this activity differs from the spindle-shaped activity in the early stage of sleep. As for the frequency, the one is 25 Hz and the other is 14 Hz. Secondly, it differs from the fast activity which is produced by the administration of barbiturate. The fast activity by barbiturate is observed in all leads. Thirdly, the treatments lead to a decrease in the amplitude and the appearance of the spindle-shaped fast activity. These findings may rule out the possibility that the spindle-shaped fast activity is induced by some drugs. However, the origin of this fast activity has not yet been clarified. Photic stimulation has caused a harmonic driving, especially in high frequency. This phenomenon can be explained by that the hypothalamus is in an excitement (Maundy-Castle 1953).

As to the cardiovascular aspects, the high incidence of bradycardia and cardiac enlargement and comparatively low blood pressure were noted. These findings may show cardiac responses against the stressors.

Thus, vibration and noise generated by vibrating tools and cold act on a human body as stressors, and affect not only the peripheral nervous and circulatory functions but also the central nervous system, especially the higher center of the autonomic nervous system. In other words, vibration disease can be considered as a systemic disease, and also called a new-civilization disease in which the three factors of vibration, noise and cold are combined. In the treatment, it should be emphasized that adequate physical exercise is more important than medication, because adequate physical exercise can regulate the activity of the autonomic nervous system (Ekblom et al. 1973).

References


