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EFFECT OF VIBRATION ON THE CEREBRAL BLOOD FLOW

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ABSTRACT

The cerebral blood flow (CBF) of 107 patients with vibration disease was investigated, and in order to evaluate the effects of vibration on cerebral vasoreaction, vibration exposure experiments were carried out using 10 healthy men. The CBF of some areas of the brain was measured by a four-electrode impedance plethysmograph (rheoencephalography). In an experimental study the vasoreaction of a finger was also measured using the same impedance method. Vibration with frequencies of 32 Hz, 64 Hz, 140 Hz and 250 Hz and an acceleration level of 98 m/sec^2 were applied to the hand with a static force of 5 kg for 20 minutes. Quantitative and qualitative indices of the pulse were calculated and used to analyse the data. These were compared with those of the control.

The results showed that the brain vessels of the examined patients were only functionally contracted; however, at the advanced stage the vessels of the basilar area seemed to be slightly organically contracted.

The results of the experiments showed that even exposure to local vibration may cause vasoreaction not only in the finger but also in the brain, and that vasoreactive patterns depend on the vibration frequencies, i.e. vasodilation was observed when low frequency (32 Hz) and vasoconstriction when high frequency (140 Hz and 250 Hz) was applied.

Vibration disease seen in workers who use vibration tools is one of the most serious occupational diseases in Japan. Patients with this disease often show symptoms similar to the dysfunction of the central nervous system. It is suggested that disturbance of the cerebral blood flow (CBF) may play an important role in the genesis of these symptoms.

In this study the CBF of patients suffering from vibration disease was investigated. Moreover, in order to evaluate the effects of vibration on vasoreaction, vibration exposure experiments were carried out.

SUBJECTS AND METHODS

A total of 107 patients aged from 37 to 69 (30s – 12, 40s – 33, 50s – 48, 60s – 14) were examined, 94 of whom were chain saw operators in forests and 13,

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jack hammer operators working on rock. The classification of the severity by Andreeva-Garanina's criteria showed 0 in Grade I, 28 in Grade II, 59 in Grade III, and 20 in Grade IV.

The CBF of the frontal, occipital and basilar areas was measured in rest condition, and after nitroglycerin (NG) administration (0.3 mg) the frontal and basilar areas were measured simultaneously using four-electrode impedance plethysmography (rheoencephalography) in the sitting position.

The silver electrodes used were 3×4 cm in size as input electrodes and 2×3 cm as output electrodes.

As control the CBF was also measured of 26 healthy forest workers aged 32 to 69 (30s – 6, 40s – 7, 50s – 7, 60s – 6) who did not use vibration tools or were exposed to vibration for only negligibly short periods.

The wave form pattern and quantitative indices obtained from the rheoencephalogram (REGm), upstroke time (UT), dicrotic index (DI), rate of upstroke time to pulse time (UR) and minute volume of the pulse (MV)[2] were analysed statistically.

Ten healthy students aged 19 to 26 were examined to clarify whether any local vibration stimuli may affect the vasoreaction in the brain. The left hand was exposed to vibrations with frequencies of 32 Hz, 64 Hz, 140 Hz and 250 Hz and an acceleration level of 98 m/sec^2, which is often seen in actual working conditions, and the static force on the vibrating grip was 5 kg for 20 minutes in the sitting position.

The vasoreaction of each subject was also measured in the control state which was exactly the same as that of the experimental state except for the absence of actual vibration stimuli. Vasoreaction of the frontal area was examined before and after vibration exposure, and vasoreaction of a left finger was examined simultaneously by the same impedance method using aluminum foil electrodes.

Rb was calculated from the REGm, and 1/Rb was used as the blood flow index for analysing the data[2].

RESULTS

Tonic waves were more frequently seen in the patients than in the control group: 91.1% in the frontal area, 84.4% in the occipital area, and 80.6% in the basilar area, while in the control group the rates were 73.1%, 53.9% and 53.9%, respectively. These differences were statistically significant ($p < 0.05$).

With NG administration, the waves in the frontal area dilated by 45.8% and in the basilar area by 74.3%, and in the control group by 60.9% and 91.3%, respectively. The differences were statistically significant in the basilar area ($p < 0.05$). Tonic waves could still be seen in the frontal area (18.8%) and in the basilar area (3.7%), (control group: 13.0% and 0%, respectively). The differences were not statistically significant in either area.

Each mean value of the indices of the patients and the control were compared according to age (Table 1) and severity of the disease (Table 2). An

TABLE 1
t-Test of the mean values between the patients and the control subjects according to age.

	Age	DI		UT		UR		MV	
		Rest	NG	Rest	NG	Rest	NG	Rest	NG
Frontal	30 – 39	–	–	–	–	–	–	–	–
	40 – 49	–	–	–	–	–	–	↓	↓
	50 – 59	–	–	↑↑↑	–	↑↑↑↑	–	↓	–
	60 – 69	–	–	–	–	–	–	–	↓↓↓
	All	–	–	↑↑↑	–	↑↑↑↑	–	↓↓↓	↓↓
Occipital	30 – 39	–	/	–	/	–	/	–	/
	40 – 49	↑↑↑	/	↑↑↑	/	↑↑↑↑	/	–	/
	50 – 59	↑	/	–	/	–	/	↓↓↓↓	/
	60 – 69	–	/	–	/	–	/	↓	/
	All	↑↑↑	/	↑↑↑	/	↑↑↑↑	/	↓↓↓↓	/
Basilar	30 – 39	–	–	–	–	–	–	–	–
	40 – 49	–	–	↑↑	–	–	–	–	↓
	50 – 59	↑	–	↑↑↑	–	↑↑↑↑	–	↓	–
	60 – 69	–	–	–	–	–	–	–	–
	All	–	↑↑↑	↑↑↑↑	–	↑↑↑↑	–	–	↓↓↓↓

DI = dicrotic index; UT = upstroke time; UR = rate of upstroke time; MV = minute volume; NG = nitroglycerin; ↑or↓: mean value of the index of the patients is significantly larger or smaller than that of the control. ↑↑↑↑or↓↓↓↓: $p < 0.001$; ↑↑↑or↓↓↓: $p < 0.01$; ↑↑or↓↓: $p < 0.025$; ↑or↓: $p < 0.05$.

TABLE 2
t-Test of the mean values between the patients and the control subjects according to the severity of the vibration disease.

	Grade	DI		UT		UR		MV	
		Rest	NG	Rest	NG	Rest	NG	Rest	NG
Frontal	I + II	–	–	↑↑	–	↑↑↑	–	–	–
	III	↑	–	↑↑	–	↑↑↑↑	–	↓↓↓↓	↓↓↓
	IV	–	–	↑	–	↑↑↑↑	–	↓↓↓↓	↓↓↓↓
Occipital	I + II	↑	/	↑↑↑	/	↑↑↑	/	↓↓	/
	III	↑↑↑↑	/	↑↑↑↑	/	↑↑	/	↓↓↓	/
	IV	–	/	↑↑↑↑	/	↑↑	/	↓↓↓	/
Basilar	I + II	–	↑↑	↑↑↑	–	↑↑↑	–	–	–
	III	–	–	↑↑↑↑	–	↑↑↑↑	–	↓↓↓	↓↓↓↓
	IV	–	↑↑↑↑	↑↑↑↑	↑	↑↑↑↑	–	–	↓↓↓

DI = dicrotic index; UT = upstroke time; UR = rate of upstroke time; MV = minute volume; NG = nitroglycerin; ↑or↓: mean value of the index of the patients is significantly larger or smaller than that of the control. ↑↑↑↑or↓↓↓↓: $p < 0.001$; ↑↑↑or↓↓↓: $p < 0.01$; ↑↑or↓↓: $p < 0.025$; ↑or↓: $p < 0.05$.

increase of UT and UR and a decrease of MV were often seen in the groups above 40 but never in that below 40, in all measured areas. However, after NG administration, a statistically significant change was observed mostly in the MV index. Moreover, in the basilar area the percental difference of MV after vibration regressed with age.

According to severity, UT and UR increased in each Grade in all measured areas and MV often decreased. After NG administration, a decrease of MV was observed in Grades III and IV, while the percentage difference of MV after vibration was statistically smaller than that of the control: 155.2% in I + II and 144.4% in IV (192.3% in control).

No statistically significant differences between the Grades were observed, and regression with age was often seen in UT and UR, both in patients and the control group.

The results of the experimental study are shown in Figure 1. Vasodilation and vasoconstriction were observed when low frequency (32 Hz) and high

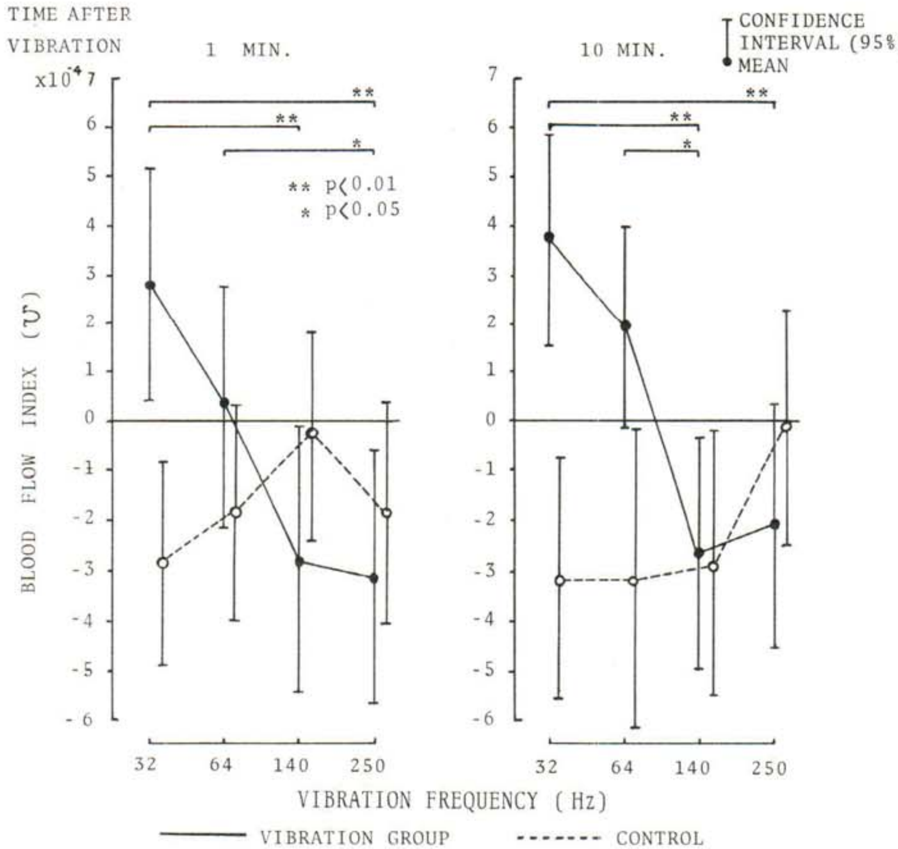

FIG. 1 – Effect of vibration exposure on the cerebral blood flow. Asterisks show statistically significant changes between the vibration exposure groups.

frequency (140 Hz and 250 Hz) vibrations were given respectively. The vasoreactive patterns of the brain were almost the same as those of the finger (Fig. 2).

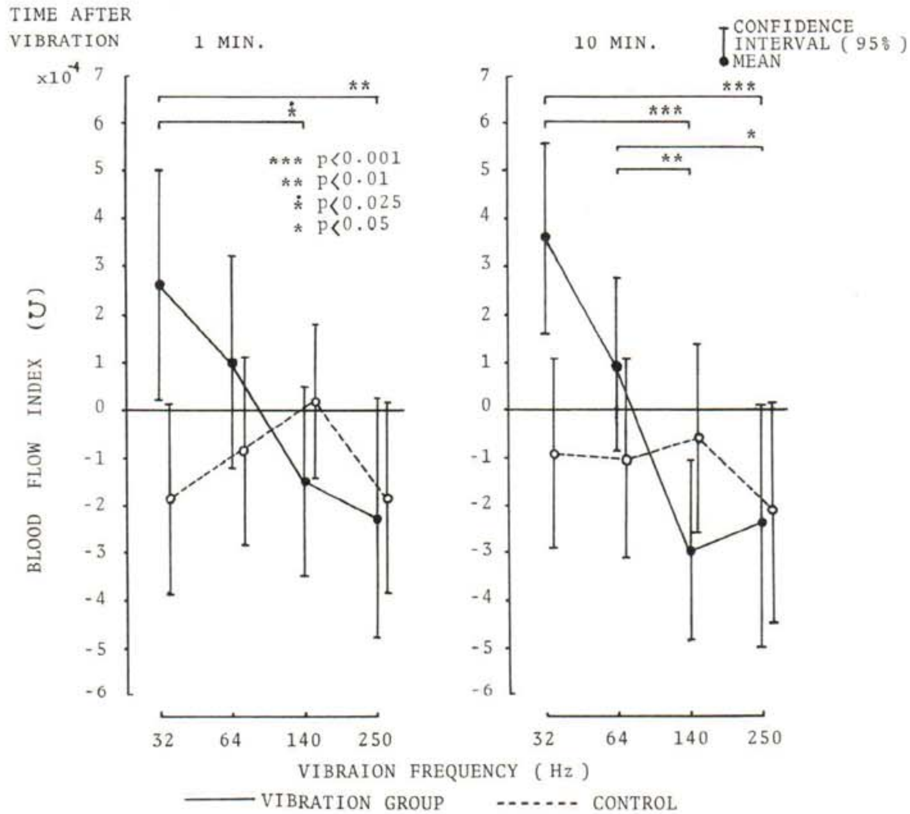

FIG. 2 – Effect of vibration exposure on the finger blood flow. Asterisks show statistically significant changes between the vibration exposure groups.

DISCUSSION

To know the state of the cerebral blood flow CBF of patients with vibration disease is important not only clinically but also hygienically, i.e., it is necessary for estimating the working capacity of the patient.

We could evaluate fully the CBF of the patients by comparing it to a control group of the same occupation. Almost all quantitative and qualitative indices showed that the patients' brain vessels were tonic and that the CBF decreased in all areas. Moreover, we found that the incidence of tonic waves of the frontal vessels (91.4%) was higher than that of the basilar vessels (80.6%). This was also observed after NG administration. In the control there was a tendency similar to that among the patients, but it was not statistically significant.

Analysis according to age often showed statistically significant changes in the 40s group, and especially in the 50s. This seemed to be due to the high incidence of patients of Grade IV, i.e., 46.6% in the 40s and 66.3% in the 50s.

Nitroglycerin dilated the vessels in all areas of the brain. However, the changes of DI, UT and MV were still statistically significant only in the basilar area of Grade IV patients. As DI reflects the caliber of the vessels, basilar vessels seemed to be organically slightly contracted.

The obtained results suggested that most of the characteristic changes of the vessels of the observed patients with vibration disease were mainly functional contractions; moreover, the basilar area, where vibration might be induced directly, appeared the most affected, while in the advanced stage the vessels contracted organically as well. These results agree with the findings of Ostapenko and Pjatakovich[3].

The experimental study showed that the vibration applied locally causes vasoreaction not only in the finger but also in the brain and that vasoreactive patterns were dependent on the vibration frequency.

It is interesting to note that the results coincided with the clinical features of the vibration disease, i.e. the disturbance of the vessels was of atonic type at low frequencies and of spastic type at high frequencies[1].

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