CLINICAL APPLICATION OF THERMOGRAPHY TO PATIENTS WITH VIBRATION DISEASE

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Received for publication July 31, 1979

Vibration disease results from the usage of vibrating tools such as chain saws or pneumatic hammers for a long period. One of the principal manifestations of this disease is Raynaud's phenomenon in the fingers. In order to examine peripheral circulatory functions, a thermography was applied to the patients with vibration disease. The distribution of skin temperature in digits was clearly demonstrated by a thermography. By combination with auditory stimuli, a thermography showed dynamic changes of skin temperature in time. The recovery time course of skin temperature once reduced by auditory stimuli was related to the activity level of the autonomic nerve. However, this relation was not observed in cold water immersion test which was used as one of the peripheral circulatory function tests. These results suggest that a thermography combined with auditory stimuli is useful to detect not only the distribution of skin temperature but also the activity level of the autonomic nerve.

INTRODUCTION

Since 1911, it has been known that the usage of vibrating tools such as pneumatic hammers, chain saws, or electrical grinders leads to injuries of the peripheral blood vessels and nerves, giving rise to Raynaud's phenomenon in the fingers (Taylor, 1974). Also, there are primary lesions in bones, joints and muscles of the arm (Marschall et al., 1954; Smith and Allen, 1969; Stewart and Goda, 1970; Wasserman and Badger, 1973). Recently, this disease has been considered as a systemic disease, associated with disorders of the central nervous system, especially the higher center of the autonomic nervous system (Дрогичина, 1971; Matoba et al., 1977). The patients are afflicted with insomnia, headache, palmar hyperhidrosis, tinnitus, impotence, etc. These disturbances are induced by vibration, noise and cold (Matoba et al., 1977).

Raynaud's phenomenon occurs on exposure of the whole body to environmental temperature of 12-15°C. Such a clinical evidence suggests a possibility that Raynaud's phenomenon is related to disorders of the autonomic nervous system, as well as disturbances of the peripheral circulatory and nervous functions.

In general, the change of cutaneous temperature reflects the functional level of the central nervous system (Normell and Wallin, 1974; Matsumoto et al., 1975). Noise as a stressor excites the hypothalamus and the limbic lobe of the cerebral cortex, where the higher
center of the autonomic nervous system resides (Kluge and Friedel, 1933; Lehman, 1957; Sakamoto, 1957). Therefore, the changes of cutaneous temperature induced by auditory stimulation could indicate the tonic level of the higher center of the autonomic nervous system.

The aim of this study is to demonstrate a clinical application of thermography to patients with vibration disease.

SUBJECTS AND METHODS

The study was performed on 26 male inpatients with vibration disease, not associated with other disorders, especially with primary Raynaud's syndrome. All subjects had been engaged in forestry as chain saw operators for five years or more. Their average age was 45 ± 4.8 (mean ± S. D.), ranging from 35 to 55. The severity of the disease was III grade in all subjects according to Matoba's criteria (Matoba et al., 1975). Their mean blood pressure was 125.5 ± 10.5 mmHg in systole and 76.5 ± 10.2 mmHg in diastole.

In order to measure the cutaneous temperature of the fingers, thermography was employed. The procedures were: First, the subject was kept at a sound-proof room with a constant temperature of 22 to 23°C for at least 30 min. Second, both hands of the subject were put on a small table situated at the level of his heart in a sitting position. After cutaneous temperature had been stabilized at a constant value, auditory stimulation was given to the subject through headphones for 10 sec. The signal was the noise recorded from a chain saw, having the intensity of 98 to 102 dB. Fig. 1A shows the area where skin temperature was measured by a thermograph (Fujitsu 102A). The skin temperature was expressed as radiant power (watt/cm²). However, the numbers obtained in "total radiant power" were calculated as percentage of the initial value because no calibration was made in this thermograph. Changes in skin temperature were observed for 6 min after cessation of the stimulation.

The cold water immersion test as a

![Fig. 1.](image-url)
circulatory function test was also performed on all patients. A hand was immersed into cold water of 10°C for 10 min up to the wrist joint, and the recovery of the skin temperature with lapse of time was observed for 10 min after stopping immersion.

The activity level of the autonomic nervous system was estimated by fingertip plethysmography combined with auditory stimulus (Matoba et al., 1975). The procedures of the plethysmography were as follows: After the amplitude of the finger-tip plethysmogram had been stabilized, the auditory stimulus was given through the headphones for 10 sec. The recovery course of the amplitude of the plethysmogram once reduced by the stimulation was observed for 60 sec. The pattern of the recovery was classified into 4 types as shown in Fig. 2. Normal (N) type was that the amplitude reduced by the stimulation recovered within 30 sec after cessation of the stimulus. Intermediate (I) type was that the recovery was more than 80 percent of the initial amplitude at 60 sec. In delayed (D) type, the recovery was poor, up to 80 percent or less of the initial amplitude at 60 sec. Poor response (P) type showed only minimum reduction (within 30%) in amplitude on the auditory stimulus.

All measurements were carried out at a room temperature (21-23°C).

RESULTS

1. Distribution of cutaneous temperature measured by a thermograph

Fig. 3 shows the distribution of skin temperature in both hands of
male patients with vibration disease. In the figure (a), left 2nd finger and the area of metacarpophalangeal joints demonstrated a decrease in skin temperature. In the figure (b), the skin temperature on the tips of both 2nd to 5th fingers reduced markedly, showing high gradient of temperature. Thus, the thermography can detect the distribution of skin temperature in detail.

2. Changes of skin temperature of the digits induced by auditory stimulus

Fig. 4 shows typical thermographic responses to auditory stimulus during 6 min after cessation of the stimulus. Auditory stimulus elicited a transient decrease in skin temperature. The skin temperature once reduced by auditory stimulus reverted to the prestimulation value in time, describing a sine curve.

Fig. 4. A typical thermographic response to auditory stimulation. Note the area circumscribed with square. Skin temperature in the fingers is markedly reduced by auditory stimuli after 1 min (b) and 2 min (c). After 4 min, skin temperature is almost recovered (d). Complete recovery to the prestimulation values is observed at 6 min (e).
The time courses of the recovery were different in each individual.

3. Thermographic responses to auditory stimulus at each activity level of the autonomic nerve

As the change of skin temperature was related to the autonomic nerve activity (Normell and Wallin, 1974; Matsumoto et al., 1975), the time course of the recovery to the prestimulation value was analyzed on the basis of the activity level of the autonomic nervous system.

The activity levels of the autonomic nerve were classified into three by the responses to the finger-tip plethysmography combined with auditory stimulus: normoreactive (N) (8 cases), hyperreactive (D) (8 cases) and hyporeactive types (P) (10 cases). The mean age of each type was 46 ± 6.6 (mean ± S.D.), 45 ± 3.7 and 47 ± 5.9, respectively.

Fig. 5 shows that the auditory stimulus led to a decrease in skin temperature in N and D types, and minimum changes in P type. After passing the nadir at 1 min, N type showed a quick recovery, rising above the prestimulation level even after 10 min. P type, on the other hand, showed no reduction after the auditory stimulus, and, on the contrary, a small rise in skin temperature. The time course in D or P type was statistically different from that in N type (p<0.05 to 0.001).

4. Relationship between cold immersion test and the activity level of the autonomic nerve

Fig. 6. Changes of cutaneous temperature induced by cold water (10°C) immersion for 10 min. The responses of each type of the activity level of the autonomic nerve disclose almost same patterns. Each point and bar shows the mean value ± S.E. The statistically significant difference is not seen between them.
Cold immersion test was employed as an usual method for the peripheral circulation test.

Fig. 6 shows changes of skin temperature during and after the immersion in each activity level of the autonomic nerve. By cold water immersion, skin temperature decreased rapidly. Cessation of the immersion led to a rise of temperature. However, there was a delay of the recovery of skin temperature. The skin temperature could not recover to the pre-immersion value even at 10 min. There were no statistically significant differences between three types of the activity level of the autonomic nerve.

DISCUSSION

Raynaud's phenomenon is one of the principal symptoms found in vibration disease. The mechanism of this phenomenon was postulated by some investigators: Chronic exposure to vibration causes vasoconstriction in small arteries of the fingers, leading to hypoxia in the cells and the tissues. Consequently, degeneration, hypertrophy and other changes occur in the arterial walls and the endings of nerve fibers. In the underlying conditions, cold elicits Raynaud's phenomenon (Ashe et al., 1962; Magos and Okos, 1963). However, abnormalities of arterial walls in the fingers have not always been observed in angiographic studies (Nishimura, 1975).

In general, cutaneous temperature of fingers in vibration disease is comparatively low. The patients complain of numbness and cold sensation subsequent to Raynaud's phenomenon in the fingers. Therefore, to detect the distribution of skin temperature in the fingers may be useful for the treatment. A thermography is a non-invasive method, and can measure cutaneous temperature in detail as indicated in our results.

The cutaneous temperature may indirectly reflects the functional level of the central nervous system (Normell and Wallin, 1974; Matsumoto et al., 1975). Cutaneous temperature is mostly regulated by the blood current of the skin, and also by feedback system from the thermoregulatory center in the hypothalamus (Keel and Neil, 1971). It is well-known that the auditory stimuli exert an influence on the hypothalamus and the limbic lobe of the cerebral cortex, which play an important role in the regulation of the autonomic nerve activity and thermoregulation (Kluge and Friedel, 1933; Lehman, 1957; Sakamoto, 1957; Green, 1972). Therefore, the excitation of the higher center of the autonomic nervous system by auditory stimulation may cause the vasoconstriction of small arteries in the fingers, leading to a decrease in skin temperature.

According to our results, the recovery time course of skin temperature once reduced by auditory stimulation reflected the activity level of the autonomic nerve. On the contrary, cold water immersion test did not reflect the activity level. Moreover, cold water elicited pain in the finger and elevated blood pressure. Namely, application of a thermography combined with auditory stimuli leads to demonstrate the distribution of skin temperature and the activity level of the autonomic nerve.

Thus, the thermography combined with auditory stimuli would be useful to clarify the pathogenesis and to observe the clinical course for the treatment of patients with vibration disease.
REFERENCES


