

Changes of Current Perception Threshold on Sensory Nerve Fiber in Thermotherapy

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温熱療法における知覚神経線維の閾値の変化

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抄 録

温熱療法による疼痛軽減効果の客観的報告は少なく、温熱刺激が直接作用しているのか、体循環などを介し間接的にも作用するのかも明らかでない。そこで間接的温熱刺激も疼痛緩和に効果があるのかを知る目的で、健常者を対象に電流知覚閾値を $A\beta \cdot A\delta \cdot C$ 線維に分けて検査できる CPT (Current Perception Threshold) 装置を用いて測定した。

方法は左上肢を除いた全身温浴で、直接加温は右第 2 指、間接加温は左第 2 指を測

定部位に、施行前・直後・15分後に閾値を測定した。また、ホットパックを用いた局所直接加温も行い対照とした。

結果、直接全身加温および局所加温時、 $A\beta \cdot A\delta \cdot C$ 線維すべて施行直後に閾値の上昇を認めた。間接加温では、各線維の閾値に変化はなかった。

従って、間接加温では効果がなく、直接加温で知覚閾値が上昇し、その際、 $A\beta \cdot A\delta \cdot C$ 線維すべての閾値上昇が関与していることが示唆された。

Key words : current perception threshold, pain, thermotherapy, sensory nerve

Abstract

There is less objective information of pain reduction effect by thermotherapy, it is neither clear as to whether thermal stimulation acts directly nor acts indirectly via general circulation. Thus, for the purpose of knowing whether there is an effect of indirect thermal stimulation for pain reduction, it was measured by using Current Perception Threshold (CPT) device available to inspect current perception threshold dividedly as $A\beta \cdot A\delta \cdot C$ fiber for in healthy.

A method is whole body warm bathing except for left upper extremity, a measuring part of direct heating is right index finger, a measuring part of indirect heating is a left index finger, and thresholds were measured at pre-operation, immediately after, and after 15 minutes. Further, a local direct heating by using a hot pack is compared.

As a result, at the times of direct whole body heating and local heating, it was acknowledged that the thresholds were increased to all $A\beta \cdot A\delta \cdot C$ fiber were acknowledged immediately after operation. In the indirect heating, there were no changes of threshold of the respective fibers.

Therefore, there is no effect in the indirect heating, perception thresholds were increased in the direct heating, and at this time, it was suggested that thresholds rising of all $A\beta \cdot A\delta \cdot C$ fiber is concerned.

I. INTRODUCTION

One of the effects of thermotherapy is the increase in pain threshold¹⁾. However, it is considered difficult to measure pain threshold actually as an objective value as many subjective factors are also involved²⁾. Moreover, there is hardly a report stating a change in threshold of sensory nerve fiber induced by temperature change in healthy subjects^{3,4)}

Thus, we used a current perception threshold (CPT) apparatus⁵⁾ which can examine current perception thresholds in $A\beta$, $A\delta$ and C fibers to examine a threshold change objectively. We report the effects on pain obtained by measuring the current perception thresholds at the finger tips heated directly and indirectly by full immersion bathing as well as that in the upper arm after thermotherapy by a hot pack.

II. CPT APPARATUS

Fig. 1 shows the CPT apparatus used in the measurement.

On the right side of the figure, there is a big machine which is the body of the apparatus and, on the left, there is a gold plated electrode attached to tape and a small machine which is switch for a compulsive selection in a double-blind test. For determination of a threshold, stimuli of different intensities are given to measurement sites and a subject presses the switch for the stronger stimulus.

This apparatus can select three nervous fibers by specifying the frequency of alternate current to be passed at a measurement site to 2000, 250 or 5 hertz.

The frequency of 2000 hertz selects $A\beta$ fibers which are thick myelinated fibers and respond to sharp perception such as a flight reflex. The frequency of 250 hertz selects $A\delta$ fibers which are thin myelinated fibers and respond to pallesthesia threshold and a stinging pain. The 5 hertz frequency stimulated C fibers selectively and respond to autonomic nerve functions, thermal perception and slow pain and all these are measurable separately. Three types of sine waves are passed from the skin of the test site and the minimum current detected is expressed as the threshold (1 to 999 μ A). We measured thresholds by utilizing the above characteristics and examined changes in thresholds after heating by comparison.

In the present study concerning the change in thresholds by temperature difference, it was assumed that 1. perspiration made current pass easily between the electrodes on the skin surface increasing threshold greatly, and 2. swelling of the skin would increase the threshold. Thus, the following preliminary experiment was performed.

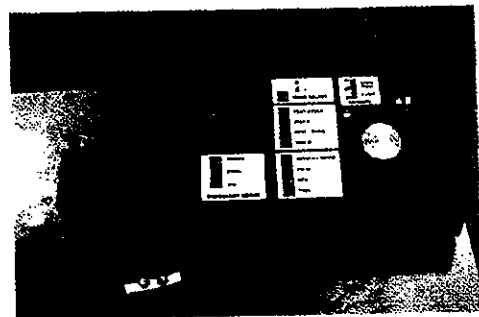


Fig. 1 Current perception threshold (CPT) apparatus

III. PRELIMINARY EXPERIMENT

1. Method

Perception thresholds of the three nerve fibers were measured by CPT apparatus under the following three conditions (①(a), (b), ②); ① Without heating, (a) the skin between the electrodes on its surface was wetted with an isotonic sodium chloride solution, (b) the skin on the upper arm was swollen by heating in a water bath at the same temperature as the body (indifferent temperature) for 15 minutes, and ② heating by dry-heat using electric hair dryer not influencing the skin condition. The subjects were two healthy women (aged 21 and 22 years old) and measurement was made three times in each subject.

2. Results

As shown in Table 1, thresholds tended to increase on the whole although only A δ fibers showed a significant difference in the Wilcoxon's test under the condition of ① (b) before and after the experiment given in ①. The thresholds of the respective fibers also showed increasing tendencies under the condition of ② and a significant difference was shown by C fiber.

Table 1 Changes in thresholds of three nerve fibers in the preliminary experiment (n = 6)

condition		Control	After the treatment	p value
①a	A β	187.8 \pm 10.8	164.0 \pm 20.9	0.1
	A δ	55.3 \pm 8.6	62.0 \pm 8.2	0.07
	C	31.0 \pm 7.2	33.7 \pm 10.0	0.6
①b	A β	59.0 \pm 7.2	84.2 \pm 9.1	0.05
	A δ	21.3 \pm 4.3	35.8 \pm 3.7	<0.05*
	C	11.2 \pm 3.3	17.8 \pm 2.2	0.09
②	A β	129.2 \pm 28.0	143.0 \pm 26.0	0.3
	A δ	44.3 \pm 8.9	47.8 \pm 10.3	0.7
	C	21.8 \pm 5.0	36.2 \pm 7.1	<0.05*

IV. CONTROLLED EXPERIMENT

1) Subjects and method

To examine the effects of perception training, the thresholds of three nerve fibers after 0, 15 and 30 minutes without a treatment in seven healthy women (the mean age: 22.3 years) as the control group.

2) Results

Fig. 2 shows the results.

V. MAIN EXPERIMENT

Based on the above preliminary and controlled experiments, the main experiment was conducted as follows.

VI. SUBJECTS

Subjects were seven healthy women (mean age: 22.3 ± 3.4 years) without perception disorder in the full immersion warm bathing and six healthy women (mean age: 22.3 ± 1.0 years) in the local heating.

VII. METHOD

The CPT apparatus was set up in such a way that the subjects could not see the measurement values. While the subjects were instructed to sit comfortably, the study method was explained to them. After confirming that there was not a traumatic wound on the skin at the measurement site, the skin paste was applied and the excess was wiped off. To the measurement sites, gold-plated electrodes of 1 cm in diameter and with the conduction gel applied thinly were fixed with tape. For the measurement, double-blind forced selection method was employed and the room temperature was kept at 23 to 25°C.

1) Full immersion warm bathing

The subjects had full immersion warm bathing at 41°C except the left upper extremity for 15 minutes. The temperature by direct heating was measured at the right index finger while that indirect heating was measured at the left index finger which not bathed. Perception thresholds of three types were measured before bathing and immediately and 15 minutes after it.

2) Local thermostimulation

Hot packs used frequently in ordinary clinical practice were employed. The thick of the brachial muscle which provided sufficient area of contact was selected as the measurement site to get constant thermostimulation on the skin. For thermostimulation, a hot pack heated to 78°C was covered with six sheets of towels and placed on the brachial muscle for 15 minutes. Similarly to the previous experiment, measurements were made before the stimulation and immediately and 15 minutes after it.

VIII. RESULTS

1) Full immersion warm bathing

As in Fig. 3, the time-serial changes in the thresholds of $A\beta$, $A\delta$ and C fibers showed increasing tendencies after direct heating. The statistical analysis by Friedman's test revealed significant differences in the thresholds of $A\beta$ and C fibers immediately after heating compared to the baseline values. Although no significant difference was shown by $A\delta$ fibers, an increasing tendency was shown immediately after heating compared to the baseline values.

The time-serial changes in the thresholds of $A\beta$, $A\delta$ and C fibers by indirect heating were almost negligible as in Fig. 4. Friedman's test did not show a significant difference before and after heating, either ($P = 0.5$).

2) Local thermostimulation

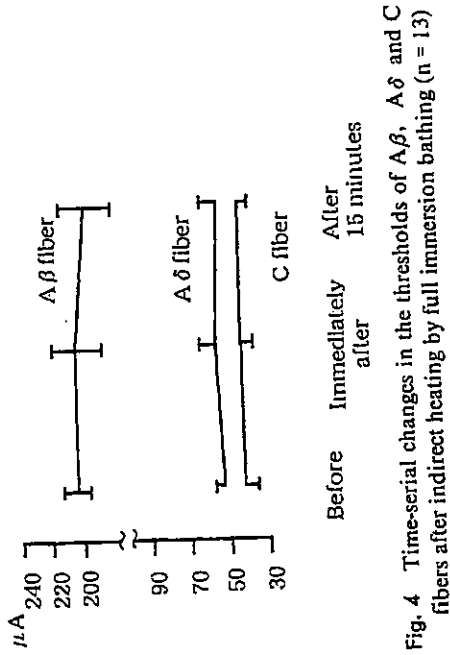


Fig. 4 Time-serial changes in the thresholds of Aβ, Aδ and C fibers after indirect heating by full immersion bathing (n = 13)

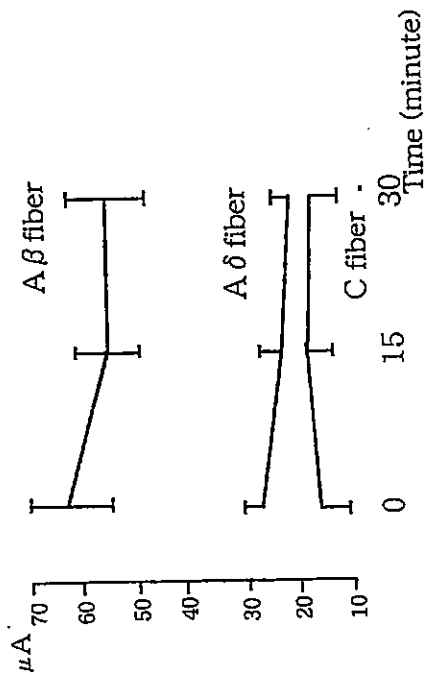


Fig. 2 Control group (n = 7)

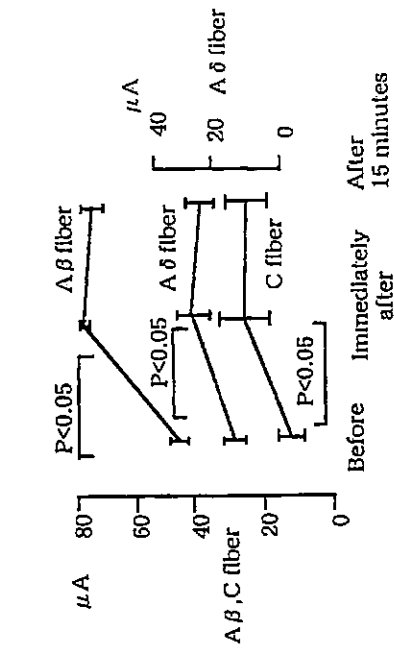


Fig. 5 Time-serial changes in the thresholds of Aβ, Aδ and C fibers after local thermostimulation (n = 5)

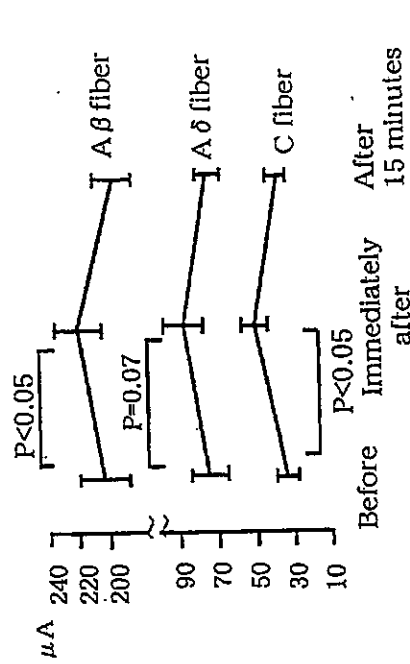


Fig. 3 Time-serial changes in the thresholds of Aβ, Aδ and C fibers after direct heating by full immersion bathing (n = 13)

As in Fig. 5, the time-serial changes in the thresholds of $A\beta$, $A\delta$ and C fibers showed significant differences immediately after stimulation compared to the baseline values.

IX. DISCUSSION

1. Specificity of CPT test

Concerning nerve selectivity of CPT test, nerve fibers of different sizes have characteristic refractory periods. C fiber with the smallest diameter not only has the longest refractory period but also the highest threshold and, thus, requires the longest depolarization for generation of active electric potential⁶⁾. CPT test utilizes the characteristics that depolarization is dependent on the frequency of electric waves and is considered to raise nerve selectivity by the use of frequencies of different electric stimulation by sine waves⁷⁾. In the double-blind compulsory selection test, consistency and accuracy of the measurement values are preserved and objectivity of the test is raised by instructing the subjects to select actual stimuli and placebo stimuli given randomly to them.

Nerve selectivity among the stimuli of 2000, 250 and 5 Hz was demonstrated during the experiment as the way of feeling after a stimulus was given and time before perception corresponded to the respective $A\beta$, $A\delta$ and C fibers and they were closely correlated to subjective perceptions of the respective fibers.

During measurement, similarly to the state of autonomic nerve system including perspiration and respiration and application of electric stimuli, influence of skin impedance affected by other physical parameters cannot be ignored⁵⁾. Thus, in the present experiment, the influence of resistance based on the state of skin was minimized by applying both skin paste and conduction gel to common gold plated electrodes. Moreover, as constant current output was used instead of constant voltage and a constant current feedback circuit in CPT test, factors such as thickness of the skin, body temperature or tissue edema influencing the test were minimized.

2. Changes in threshold due to the states of skin

When the change in threshold based on temperature change was examined, it was assumed that 1. perspiration made current pass easily between the electrodes on the skin surface increasing threshold greatly, and 2. swelling of the skin would increase the threshold. Thus, measurements were under a resembling environment and the results demonstrated these as the thresholds tended to increase by perspiration and swelling of the skin. In addition, the respective thresholds also tended to increase under a condition of increased temperature alone and it seemed necessary to attempt interpretation of the changes in thresholds by thermostimulation taking the influence of skin condition.

3. Change in thresholds of the respective nerve fibers by thermostimulation

According to the gait control theory, thermostimulation is said to increase conduction velocity of perception nerves and to decrease the threshold of $A\delta$ fiber resulting in the increase of the threshold of C fiber by intervention⁸⁾. C fibers showed changes similar to those given in the previous result and pain relief by thermostimulation was consid-

ered to act effectively⁹⁾. In our study results, however, $A\delta$ and $A\beta$ fibers showed increasing tendencies of their thresholds by thermostimulation on the contrary. These phenomena agreed with the subjective fact¹⁰⁾ that perception would become insensible by thermostimulation. Threshold in the three perception nerve fibers did not change after indirect thermostimulation probably because intervention by heating was not sufficient for C fibers to show a significant change in threshold, while thermostimulation was not strong enough to raise the thresholds of $A\delta$ and $A\beta$ fibers. Even if the influence of skin condition was taken into account, possibility that thick myelinated nerves were inhibited directly or indirectly by thermostimulation could not be denied. It may also be necessary to consider the effect of improvement¹¹⁾ in the state of circulation in the surrounding soft tissues and relaxation effect.

With a hot pack which exerted particularly strong thermostimulation on the skin, the thresholds of all three fibers increased significantly after thermostimulation and it was demonstrated that heating would induce a change in threshold depending on its size irrespectively whether thermostimulation was local or systemic.

For a therapeutic purpose of pain relief by heating, direct heating was considered more effective than indirect heating. At the same time, the increase in thresholds of all these nerve fibers weakened perception in the region receiving thermostimulation. As a result, it may interfere with defense response which is associated with evasion of a danger and, hence, attention seems to be needed when a physiotherapy is performed.

X. CONCLUSION

To examine the effect of heating on pain, we measured current perception threshold in the arms in healthy women without perception disorder using a CPT apparatus after direct and indirect heating by full immersion bathing and local thermostimulation.

In the results, the threshold of $A\beta$ and C fibers increased significantly immediately after the treatment compared to the baseline values and that of $A\delta$ fibers tended to increase though no significant change was shown. The time-serial changes in the thresholds of $A\beta$, $A\delta$ and C fibers after indirect heating were almost negligible. Local thermostimulation by a hot pack increased the thresholds of all three fibers significantly immediately after stimulation when time-serial changes in their thresholds were examined. For the increase in these thresholds, inhibitory effect of thermostimulation other than the gate control theory was also suggested.

From the above findings, it was demonstrated that threshold would change depending on the size of a stimulation irrespectively whether it was local or systemic. For therapeutic purpose of pain relief by thermostimulation, direct heating seemed more effective than indirect heating.

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