TISSUE TEMPERATURE IN RABBITS DURING APPLICATION OF HEAT-EVOLVING PAD

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Novel heat-evolving pads were prepared and applied to the back of rabbits to measure the temperatures of the skin surface, subcutaneous tissue (about 3 mm in depth), muscle (about 8 mm in depth) under the applied area and the rectum. The application of the pad caused an increase in the skin surface temperature, which was accompanied with an increase in the subcutaneous and muscular temperature. When the pads immediately after initiation of heat evolution were applied, the skin surface, subcutaneous tissue and muscle reached the respective plateau temperatures of about 43, 42 and 41 °C in 40 minutes. These temperatures were maintained for 1.5 to 2.0 hours. When the pads 30 minutes after initiation of heat evolution were applied, the skin surface, subcutaneous and muscular temperatures were increased to the respective plateau temperatures only in 20 minutes.

INTRODUCTION

A novel heat-evolving pad has recently been developed as a medical device for thermotherapy. Kida (1978) reported that the skin surface temperature may be elevated when the pad is applied on the skin of human and various laboratory animals, and that application of the pad accompanied with an analgetic and anti-inflammatory poultice is effective in relieving various pains of orthopedic diseases (Tomonaga et al., 1978). In addition, the pad has been found to improve remarkably the subjective symptoms of vibration diseases (Tomita, 1979). These suggest that the thermal effect of the pad may reach the subcutaneous layer. In the present study, we have applied the pad to the back of rabbits to measure the temperature of the skin surface, sub-

cutaneous tissue and muscle under the applied area, as well as the rectum.

MATERIALS AND METHODS

1) *Heat-evolving pad*

The pad, containing a thin heat-evolving plate which consists mainly of Na₂S, iron carbide and carbon black, was 10 cm × 14 cm in area and about 5 mm in thickness. Each pad was packed and sealed in a pouch of aluminium foil in an atmosphere of nitrogen. When the pad was taken out of the pouch, it came in direct contact with air and evolved heat to elevate and keep its surface temperature at about 47°C.

2) *Measurement of surface temperature of the pad*

A plastic plate shown in Fig. 1 was used for measurement of surface temperature of the pad. The surface of the plastic plate was previously kept at 34°C by circulating water. Four sheets of gauze were placed in layers on the plate, and on the gauze 3 sheets of the pad were further placed side by side. Thermosensors were inserted under the center of the pads to measure temperature changes with the elapse of time. A thermometer with a sensor RO-60-12 (Chino Manufacturing Co., Kyoto, Japan) was used for measurement of temperature.

Fig. 1. Plastic plate for temperature measurement.

3) Animal

Ten male rabbits of New Zealand-white strain weighing 2.5 to 3.0 kg were used. The animals were anesthetized by intravenous injection of pentobarbital sodium at the dose of 25 mg per kg, and secured in a ventricumbent position. After the hair was clipped from the skin of the back, the animals were treated subcutaneously with 10 ml of 30 % urethane.

4) Measurement of temperature of the skin surface, subcutaneous tissue, muscle and rectum.

A thermosensor was placed and fixed to the hair-clipped skin of the back by using adhesive tapes to measure skin

temperature. The skin over the longissimus dorsi corresponding to the edge of applied area was cut 3 mm in length. From this cut, needle sensors were punctured obliquely and their terminal ends were situated in the subcutaneous tissue (about 3 mm in depth from the skin surface) and in the longissimus dorsi (about 8 mm in depth from the skin surface) to measure subcutaneous and muscular temperature. A sensor was inserted into the rectum 8 cm in depth and fixed to measure body temperature.

After fixation of the sensors, four sheets of gauze were placed on these sites, and the pad was further placed on the gauze and fixed. The pads immediately after heat evolution were applied to 4 rabbits and the temperature of each site was measured every 5 minutes for the first 30 minutes and every 10 minutes for the rest 240 minutes. The pads in 30 minutes after heat evolution were applied to the 6 other rabbits and temperature of each site was measured every 5 minutes for the first 30 minutes and every 10 minutes for the rest 120 minutes. After measurement of temperature, incision were made on the skin and muscle which were punctured with the sensors to measure the depth of the terminal end of the sensor from the skin surface. The temperature of the room where the experiments were performed, was kept at about 25°C during experiment.

The following thermometers and sensors were used for measurement of temperature.

a) Skin temperature: Takara thermometer A-700 with sensor ZL manufactured by Takara Thermister Instruments Co., Tokyo, Japan.

b) Subcutaneous temperature: Thermo-finer thermometer TF-DN with sensor KNP-1, needle type 3 manufactured by Termo Co., Tokyo, Japan.

Fig. 2. Temperature change of plastic plate after application of heat-evolving pad. The plate is previously kept at 34°C by circulating water.

TABLE 1

Temperature change of skin surface, subcutaneous tissue, muscle and rectum after application of heat-evolving pad in rabbits

Time (min)	Temperature (°C)*			
	Skin	Subcutaneous tissue	Muscle	Rectum
-30	34.2±0.3	37.7±0.2	39.0±0.4	39.5±0.1
-25	35.8±0.3	38.1±0.2	39.0±0.5	39.6±0.1
-20	36.0±0.3	38.2±0.2	39.1±0.5	39.6±0.1
-15	36.0±0.4	38.2±0.2	39.1±0.5	39.5±0.2
-10	35.8±0.5	38.1±0.2	39.0±0.5	39.5±0.2
-5	35.8±0.5	38.0±0.2	39.0±0.5	39.5±0.2
0	35.8±0.4	38.0±0.2	38.9±0.5	39.5±0.3
5	38.5±0.5	38.3±0.2	38.9±0.5	39.5±0.3
10	40.0±0.5	39.2±0.4	39.3±0.3	39.5±0.3
20	42.2±0.5	40.9±0.2	40.3±0.3	39.4±0.3
25	42.8±0.6	41.4±0.3	40.6±0.4	39.3±0.4
30	43.1±0.6	41.7±0.2	40.8±0.4	39.3±0.4
60	43.4±0.7	41.9±0.2	41.0±0.6	39.2±0.5
90	43.4±0.7	41.9±0.2	41.0±0.6	39.2±0.5
120	43.2±0.7	41.9±0.3	40.9±0.7	39.2±0.6
150	42.6±0.9	41.5±0.6	40.9±0.8	39.0±0.6
180	41.6±1.2	40.7±1.0	40.6±0.9	38.9±0.6
210	40.0±1.3	39.7±1.0	40.0±0.8	38.8±0.6
240	38.5±1.2	38.6±0.9	39.3±0.6	38.7±0.5
270	37.4±0.8	38.0±0.8	38.7±0.5	38.6±0.5

* Values represent the mean±S.D. of four male rabbits. Sensors were punctured approximately 3 and 8 mm in depth from the skin surface to measure the subcutaneous tissue and muscle, respectively.

c) Intra-muscular temperature : Thermometer MGA-III-21p with sensor NST, needle type.

d) Rectal temperature : Termo electrothermometer N-1 with sensor N-1-0550 manufactured by Termo Co., Tokyo, Japan.

RESULTS

As shown in Fig. 2, the surface temperature of the pad placed on the plastic plate reached plateau temperatures of 45 to 47°C 20 minutes after initiation of heat evolution and these temperatures were kept for about 2.5 hours.

Temperature changes of the skin surface, subcutaneous tissue (about 3 mm in depth), muscle (about 8 mm in depth) and rectum measured before and after application of the pad immediately after initiation of heat evolution were shown Table 1 and Fig. 3.

The temperature of the skin surface was raised from about 36°C to about 43°C 40 minutes after application of the pad. Subcutaneous temperature, corresponding to this elevation, was raised from about 38°C to about 42°C and muscular temperature from about 39°C to about 41°C. These elevated temperatures were kept for 1.5 to 2 hours, and fell down, accompanied with a decrease in skin surface temperature. Subcutaneous temperature first became lower than muscular temperature 190 minutes after application, and subsequently skin surface temperature became lower than muscular temperature 220 minutes after application. Skin surface temperature was the same as subcutaneous temperature 240 minutes after application, and fell down lower than body temperature. Subcutaneous and muscular temperatures were maintained higher than body temperature for about 200 minutes.

Fig. 3. Temperature change of skin surface, subcutaneous tissue, muscle and rectum after application of heat-evolving pad in rabbit. Each point represents the mean of six male rabbits. Sensors were punctured approximately 3 and 8 mm in depth from the skin surface to measure the subcutaneous tissue and muscle, respectively.

TABLE 2

Temperature change of skin surface, subcutaneous tissue, muscle and rectum after application of heat-evolving pad in rabbits

Time (min)	Temperature (°C)*			
	Skin	Subcutaneous tissue	Muscle	Rectum
-30	32.6±1.1	37.3±0.5	39.4±0.1	39.5±0.2
-25	33.8±1.1	37.3±0.5	39.3±0.1	39.4±0.1
-20	33.6±1.0	37.2±0.5	39.1±0.1	39.3±0.1
-15	33.8±1.2	37.1±0.3	39.0±0.1	39.3±0.1
-10	33.9±1.1	37.1±0.3	38.9±0.2	39.3±0.1
-5	33.5±1.0	37.0±0.2	38.8±0.2	39.2±0.2
0	33.2±0.9	36.9±1.1	38.7±0.2	39.1±0.2
5	41.5±1.0	40.1±1.4	39.6±0.2	39.1±0.5
10	42.0±1.0	41.0±1.4	40.1±0.5	39.1±0.5
15	42.6±1.0	41.7±1.5	40.4±0.5	39.0±0.5
20	42.6±1.0	41.7±1.5	40.7±0.4	39.0±0.5
25	42.8±1.0	42.0±1.3	40.8±0.4	38.9±0.5
30	42.8±1.0	42.0±1.5	40.9±0.4	38.9±0.5
60	42.7±1.1	41.9±1.3	40.8±0.4	38.8±0.5
90	43.0±1.0	42.2±1.2	40.9±0.4	38.7±0.5
120	43.1±1.0	42.2±1.2	41.0±0.5	38.6±0.5
150	43.1±1.2	42.4±1.4	40.9±0.5	38.5±0.5

* Values represent the mean ± S.D. of six male rabbits. Sensors were punctured approximately 3 and 8 mm in depth from the skin surface to measure the subcutaneous tissue and muscle, respectively.

Fig. 4. Temperature change of skin surface, subcutaneous tissue, muscle and rectum after application of heat-evolving pad in rabbit. Each point represents the mean of four male rabbits. Sensors were punctured approximately 3 and 8 mm in depth from the skin surface to measure the subcutaneous tissue and muscle, respectively.

As shown in Table 2 and Fig. 4, skin surface, subcutaneous, muscular and rectal temperatures were examined in the rabbits which were treated with the pad 30 minutes after initiation of heat evolution. Twenty minutes after application, skin surface temperature was raised from about 33°C to about 34°C, subcutaneous temperature from about 37°C to about 42°C and muscular temperature from about 39°C to about 41°C. A slight decrease was noted in rectal temperature during experiment.

DISCUSSION

The surface temperature of the pad took about 20 minutes after contact with air to reach plateau temperatures of about 47°C, as shown in Fig. 2. Thus, the pads were used in two different conditions; that is, one is the pads immediately after initiation of heat evolution and the other, the pads in 30 minutes after initiation of heat evolution.

Since puncturing needle sensors were to measure the temperature of the subcutaneous and muscular tissue, the animals were anesthetized to remain at rest during experiments. As shown in Fig. 3, falls in the body temperatures of the animals were noted at about 1°C between before and after experiment, that is, for the observation period of 5 hours. Considering from the fact that the diurnal variations of body temperature were in the range of 0.1 to 0.6 (Muto et al, 1961), it is said that a significant fall in body temperature may not be caused by anesthesia. Almost no change in body temperature was noted by application of the pad.

Temperature gradients were examined in dogs by Spurr et al. (1956), in rats by Bartlett et al. (1958) and in rabbits by Yoshikawa (1961). In all these ex-

periments changes in tissue temperatures corresponding to changes in ambient temperatures were examined by puncturing needle sensors. In the experiment with anesthetized rabbits (Yoshikawa, 1961), it was found that no significant difference was caused in skin surface temperature between under anesthesia and non-anesthesia, and that under anesthesia muscular temperature had a tendency to vary with a change in rectal temperature but not with a change in skin surface temperature. In the present study, however, the skin surface temperature was found to increase with an increase in muscular temperature. This incompatibility would be due to more potent influence of anesthesia in the experiment by Yoshikawa than in the present study, considering from the fact that a noticeable decrease in rectal temperature was noted at temperatures of 0.6 to 1.0°C in the first 30 minutes in former experiment. Although it has been reported that the fixation of animals affects body temperature, almost no effects would possibly be caused in the present study carried out under anesthesia.

Skin surface, subcutaneous and muscular temperatures took 40 minutes to reach each plateau level when the pads immediately after initiation of heat evolution were applied, but only 20 minutes when the pad 30 minutes after initiation of heat evolution were applied. This lag for 20 minutes corresponded to the time required for reaching a plateau temperature of the pad itself. Soh (1975) applied a conventional body warmer to rabbits and pigs for topical thermotherapy of sporotrichosis and measured skin surface and subcutaneous temperatures, each of which reaches a plateau level 20 minutes after application. This is in accordance with the case of applying the pad 30 minutes

after initiation of heat evolution.

It is anticipated that variation of subcutaneous temperature in rabbits may differ from that in humans when heat is loaded on skin surface, considering from the fact that the heat capacity of rabbits is smaller than humans and the whole body of rabbits are covered with furs, and in addition the skin of rabbits has no sweat gland. However, the results obtained in rabbits suggest that heat may also reach the subcutaneous tissues of humans when the pads are applied.

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