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BIOPHYSICS OF THERMAL INJURY

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Experiments on rats showed that thermal radiation causes a much sharper increase in the subcutaneous temperature in an area of skin separated from the underlying tissues by a layer of felt than in an area of skin separated from surrounding and underlying tissues and immediately resutured in situ, or an area of intact skin. In the authors' opinion the results indicate that the blood flow does not play an essential role in the removal of heat from the skin following its exposure to radiant heat. The ability of the underlying tissues to conduct and accumulate heat is much more important.
KEY WORDS: skin; temperature regulation; thermal injury.

According to Moritz [7] the surface (critical) temperature, exposure for 8 h to which leads to total necrosis of the skin throughout its thickness, is 44°C. A similar figure is given by Fraser [3]. In the investigations of Mendelsohn and Rositter [6] and also of Henriques and Moritz [5] the difference between the surface and subcutaneous temperatures was 6-18°C. It is unnecessary to prove that this difference is due to reflection of heat by the skin surface, the cooling action of the external environment, and the absorption of heat by the various layers of the skin. The latter leads to necrosis of the cells.

Other conditions being equal, the depth of burn damage depends on the duration of thermal action and the magnitude of its deviation from the critical value given above [1, 7]. The writers' previous investigations [9] show that in the case of radiant heat, besides the above-mentioned factor, the intensity of the inflow of heat also plays an important role.

According to some workers [2-4] the degree of thermal damage to the skin depends to a definite degree on the state of the local circulation. However, Stolwijk and Hardy [10] showed that even during the first 10-15 sec, before the circulation in the skin had been disturbed by the developing necrosis, no cooling action of the blood was manifested.

With the more penetrating study of this problem the question arises of the role played by heat transmission to other parts of the body and to tissues lying under the damaged skin surface in the formation of the skin temperature. The importance of the problem, in the writers' opinion, and also according to Moserova et al. [8] is that the degree of thermal injury is affected by all factors that can reduce the skin temperature.

EXPERIMENTAL METHOD

Experiments were carried out on albino rats weighing 170-220 g (50% females and 50% males). Radiant heat was generated by a heating stove with a hole measuring 4 × 4 cm in its front wall. The temperature in the heating stove was 650°C. The temperature in the radiating aperture was monitored by a radiometric system. The power of irradiation was 1.0 W/cm^2.

The skin on the dorsal surface to be burned was depilated by means of hair clippers. Before fixation to the frame the animals were anesthetized by intraperitoneal injection of thialbarbital. The interval between the beginning of injection and irradiation in each case was 25 min. A thermistor, fixed in the midline (Fig. 1), was introduced beneath the skin of the dorsal surface, which was to be burned, from the caudal side. The readings of the thermistor were recorded every 10 sec. The scheme of the measuring system was described previously [9].

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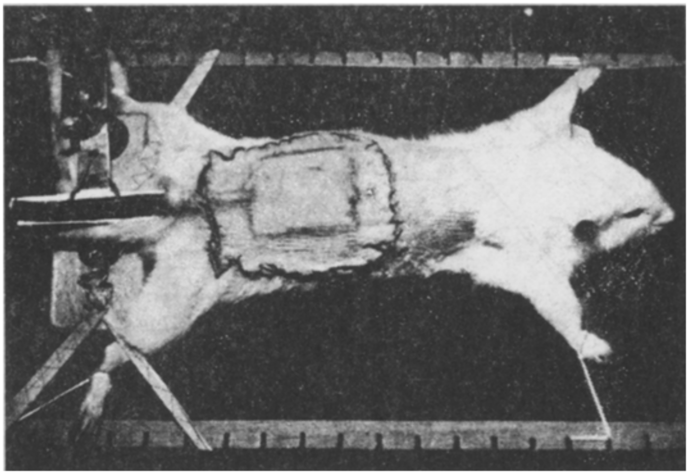

Fig. 1. Method of measuring the subcutaneous temperature.

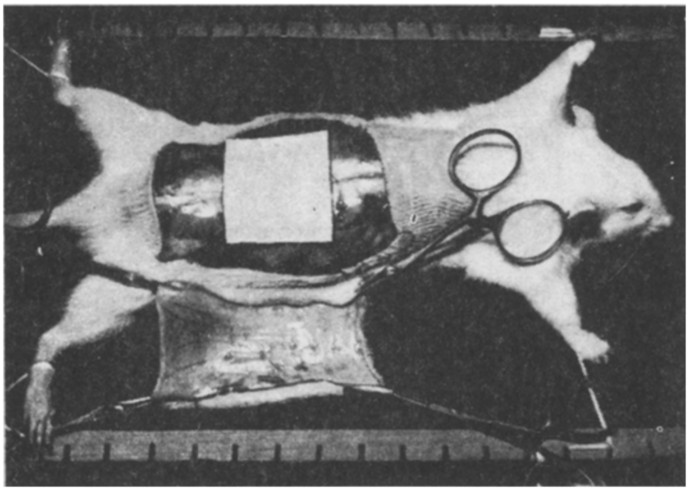

Fig. 2. Technique of isolating skin from underlying tissues. Explanation in text.

TABLE 1. Changes in Subcutaneous Temperature during Thermal Irradiation (M ±m)

Time after beginning of irradiation, sec	Group of animals		
	1	2	3
0	35,00±0,22	34,88±0	33,19±0,22
10	37,03±0,38	37,07±0,44	38,69±0,38
20	40,11±0,58	40,96±0,56	45,07±0,80
30	42,92±0,74	42,61±0,68	48,92±0,84
40	45,65±0,76	45,65±0,76	54,30±0,80
50	48,15±0,64	46,69±0,82	56,57±0,70
60	50,61±1,05	51,19±1,00	58,27±0,70
70	53,12±0,69	53,65±0,84	60,03±0,70
80	55,5±0,82	56,03±0,86	61,61±0,76
90	57,92±1,04	58,24±0,86	63,34±0.78
100	60,19±1,08	60,64±0,94	65,07±0,82

Note. Results of 26 measurements are given.

All the animals were divided into three groups, with 30 rats in each group. The circulation of the region of skin to be burned was disturbed in the animals of group 1 by division of all its connections with the sur-

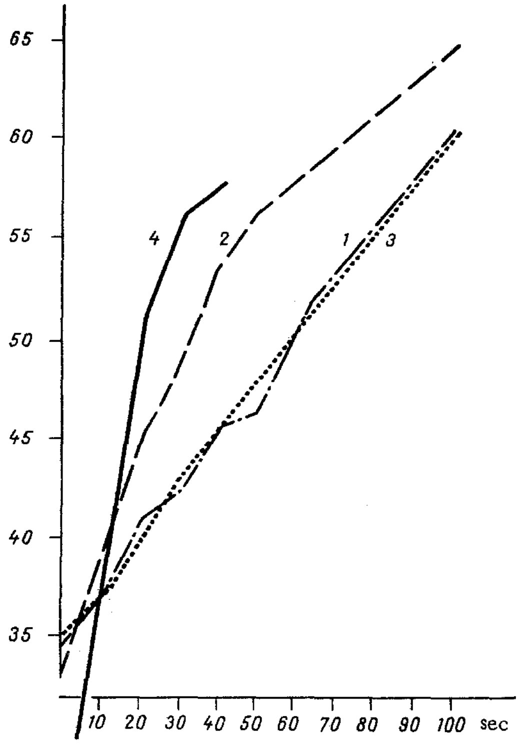

Fig. 3. Changes in subcutaneous temperature of rats during exposure to radiant heat. Abscissa, time of recording thermistor readings (in sec); ordinate, subcutaneous temperature (in °C). 1) Skin removed and sutured, not in situ but with a layer of felt between the skin and underlying tissues; 3) skin uninjured (control); 4) isolated skin fixed to frame.

rounding and underlying tissues, after which the skin was immediately reattached by continuous sutures. In the rats of group 2 the circulation of the skin surface to be burned also was disturbed, but in this case a layer of felt measuring 4 × 4 cm and 3 mm thick was inserted beneath the skin between it and the muscles (Fig. 2). In this case the thermistor was introduced between the skin and the felt. In the rats of group 3 (control) connections of the area of skin to be burned were undisturbed.

In a separate series of experiments the temperature of an area of isolated skin, fixed to a frame, was measured under similar conditions.

The experimental results were subjected to statistical analysis.

EXPERIMENTAL RESULTS

In the course of irradiation, which lasted 100 sec, the subcutaneous temperature of the rats rose almost in a straight line from 35 to 60°C. Similar changes in the subcutaneous temperature were observed in the animals of group 1, in which the skin had first been removed and then resutured in situ (Table 1).

The subcutaneous temperature in the area isolated from underlying tissues by the layer of felt differed considerably from than in the control (Table 1). The subcutaneous temperature began to rise rapidly in this case, and after 40 sec it was about 54°C (compared with 45-46°C in the other two groups), but then it rose even more, so that after 100 sec it was about 5°C higher than the level observed in the rats of groups 1 and 3 (Fig. 3).

The sharpest rise in temperature was found in the experiments with isolated skin fixed to the frame (Fig. 3).

The results of these measurements thus showed that the subcutaneous temperature varies during exposure to heat in the same way regardless of whether the circulation in that region is intact or not. However, if an insulating layer (felt) was inserted between the burned area of skin and the underlying tissues, a much sharper rise in subcutaneous temperature was observed.

The fact that the subcutaneous temperature in the experiments with injured and uninjured skin (groups 1 and 3) changed virtually identically is surprising, for authors cited previously consider that the blood flow has a cooling action. If this were true, a marked difference between groups 1 and 3 would be expected.

The present investigations suggest that during the exposure of the skin to heat the blood flow either has no cooling action or it plays a negligible role. In the group in which the muscle tissue and skin were isolated from one another, however, results which differed considerably from the control were obtained. Under these conditions the subcutaneous temperature rose faster than in the absence of insulation, evidence of the important role of the subcutaneous tissues in the removal of heat.

The heat-removal effect may be associated with the ability of tissues in contact with the skin to carry away or accumulate heat, and in turn, this is closely connected with the mass of the subcutaneous tissues. For example, allowance must be made in this connection for differences in ability to remove heat in the case of exposure of the skin of the trunk and upper limb to a raised temperature. It can be concluded from the facts described above that the tissue necrosis which develops when the skin is exposed to a high temperature depends not only on the thickness of the blood supply and other individual factors of the skin in different parts of the body, but also on the ability of the subcutaneous tissues to carry away and accumulate heat.

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