# SOME IMMUNE REACTIONS IN CONVECTION AND RADIATION COOLING

(UDC 612.592:612.017.1]-084)

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Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 58, No. 8,
pp. 101-105, August, 1964
Original article submitted June 19, 1963

Thermal regulation will take place in a manner depending upon the way in which heat is lost during the action of cold, and has the effect that heat lost by irradiation causes a much greater cooling of the deep tissues than does heat lost by convection [4, 5], and the after effects are more prolonged [3].

We have shown previously that the loss of heat by radiation reduces the temperature of muscle tissue and venous blood more intensely than does convection. The results we obtained on muscle tissue are in line with what has been found previously [4]. Also we have demonstrated the long after-effects associated with radiation cooling; in these cases the temperature of muscle tissue and of venous blood did not recover to the original temperature for 1 or 2 h after the cooling had ceased. With convection cooling the temperature of the muscle tissue and venous blood rapidly returned to the starting point [3].

We were drawn to study the immune reaction of the organism under conditions of normal stress evoked by radiation or convection cooling.

The immune reaction, being a general physiological reaction, gives an indication of the resistance of the organism not only to infections, but to some extent to general disorders [2].

## EXPERIMENTAL METHOD

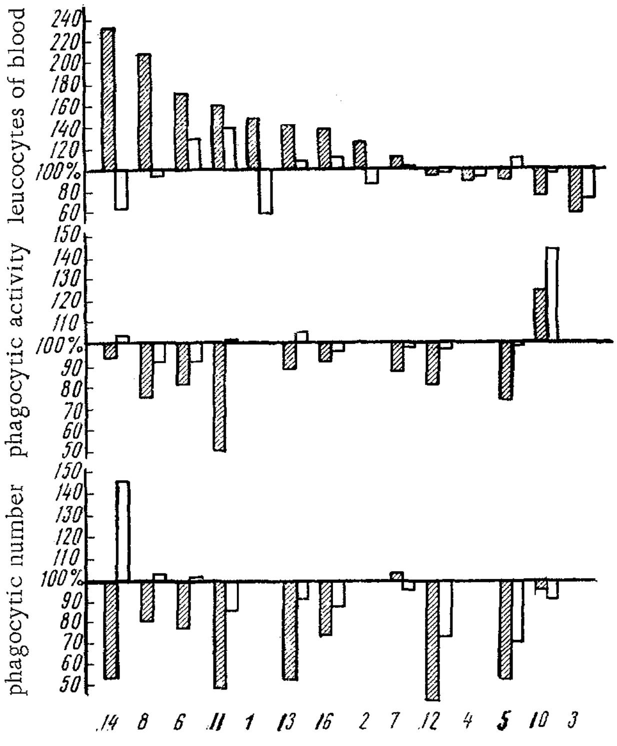
As an index of the potential immune response we used the opsonic and phagocytic indices (percentage of active and of phagocytic leucocytes). These indices give a reliable objective measure of the change in immunologic reactivity [6, 8, 9, 12]. We must also note another very important aspect of phagocytic function; the ability to react rapidly to powerful transient stimuli [10].

The experiments were carried out on unanesthetized rabbits in a room kept at 24-25°, a temperature which corresponded to the basal metabolic rate [11]. Before the experiment the rabbits were kept for 5-7 days at 12-14°. Before the experiment fur was removed from an area of 300 $cm^2$ over one half of the body, as far as the median line. The animal was allowed to assume its normal position, but movements were restricted. For radiation cooling we used a metal vessel having a polished wall, and containing a mixture of ice and salt at -6 or -7° which was placed 10-12 cm from the shaven cutaneous surface. Convection cooling of the same surface was produced by a current of air from a fan. The 2 methods of cooling were equated by the following calculation. The heat lost by radiation was determined from the formula of Vitte: $q_r = 0.093 \cdot \Pi \cdot (t_{cm} - t_n)$ kcal/min; heat lost by convection was calculated from the formula:

$$q_k = \alpha_k \cdot S \cdot (t - t_b) \cdot \tau.$$

A control over the correctness of these calculated quantities was obtained by observing the same rate of fall of temperature at the cutaneous surface exposed to the cooling [4, 14].

Before and after a 3 h period of cooling the number of leucocytes and the opsonic and phagocytic indices were




Percentage change in some immune reactions after a 3 h convection or radiation cooling. Shaded columns - response to radiation cooling; unshaded columns - response to convection cooling.

determined. The number of phagocytic leucocytes and the phagocytic activity were determined by carrying out the phagocytic reaction in vitro. Blood was collected from an ear vein, and a micro-pipette was used to measure out equal quantities of blood, of a 4% solution of sodium citrate, and 1 ml of a 24 h culture of E. coli communis in 1 ml of fluid.

The contents of the tube were carefully mixed, and the tube was then placed in a water-bath at 37°. After 30 min a smear of the contents was made which was then stained red by Romanowsky-Giemsa, using Phillipson's method. In the smears a count was made of 100 pseudo-eosinophils, and the 2 indices-the phagocytic activity (percentage of phagocytic pseudo-eosinophils), and the number of phagocytic leucocytes (the mean number of microbial cells phagocytized per pseudo-eosinophil) were determined. Also we followed the changes in the total number of leucocytes per mm of blood, in the temperature of the cooled cutaneous surface, of the skin of the ear, and of the rectum. The rabbits were cooled by convection or by radiation on different days, a change being made after 24 or 48 h, and various sequences were used (radiation - convection: convection - radiation).

The experiments were carried out on 14 healthy adult rabbits. We performed 28 experiments (14 with convection and 14 with radiation). In addition we performed 6 experiments with repeated cooling (3 convection, and 3 radiation).

## EXPERIMENTAL RESULTS

The results we obtained are shown in the figure from which it can be seen that the leucocytic reaction in response to the radiation cooling was very marked: of the 14 experiments, in 8 there was an increase of from 127 to 232% in the number of leucocytes, in 2 there was a leukopenia, and in 4 the variation was within the possible counting error. With convection cooling in all cases the reaction was much less well shown, and in 9 of the 14 experiments the change did not exceed the possible experimental errors, i.e., it was almost non-existent.

Difference in Rectal Temperature Between the Beginning and End of Convection or Radiation Cooling

| Number of Expt. | Change in rectal temperature above or below original value | |
|---|---|---|
| | Radiation cooling | Convection cooling |
| 1 | -3.4 | -1.8 |
| 2 | -3.3 | -1.5 |
| 3 | 0 | +0.1 |
| 4 | +0.6 | +0.6 |
| 5 | -2.5 | +2.0 |
| 6 | -1.9 | +0.2 |
| 7 | -1.4 | -0.3 |
| 8 | -1.1 | -0.3 |
| 9 | -1.8 | 0 |
| 10 | -1.4 | +0.6 |
| 11 | -1.1 | -1.4 |
| 12 | -0.6 | -0.9 |
| 13 | -1.8 | +0.3 |
| 14 | -1.2 | -0.8 |
| 15 | -0.9 | +0.4 |
| 16 | -0.6 | 0 |
| 17 | -0.4 | -0.1 |

The more marked suppression of the phagocytic activity in the case of radiation cooling stood out particularly clearly. In every experiment except one it was more than with convection cooling, and as a rule considerably below the original level. This results is in line with published reports of cooling in which no account was taken of whether it was applied by radiation or convection. With convection cooling, in 4 experiments out of 10 we found an enhanced phagocytic activity, in 4 a slight reduction, and in 2 it amounted to 90% of the original activity.

The same relationship was observed in the changes in the number of phagocytes. With radiation cooling, in 8 of the 10 cases the number was reduced to 80 - 45% of the original level, i.e., by a far greater amount than was produced by convection cooling. With convection cooling, in 3 experiments out of 10 we observed an increased number of phagocytes, in 5 a small reduction, and only in 2 did the reduction drop as low as 70% of the original value. It is worthwhile to note the change in the rectal temperature after a 3 h exposure to radiation cooling, and to compare this value with what was obtained by convection cooling (see table).

With radiation cooling the mean change of rectal temperature was 1.34± 0.2°, and with convection cooling it was 0.17± 0.19°. This difference in the means is statistically significant (X = 1.1± 0.28).

Of the 3 experiments with repeated cooling, in 2 there was a reduction in the leucocytic reaction in the case of the radiation cooling (the first reaction was a leucocytosis, the second a leukopenia). With convection cooling these changes were insignificant. In all 3 experiments the phagocytic reaction was still further reduced by repeated radiation cooling, and in the case of convection cooling no difference could be observed between the first and second reactions. Repetition of the cooling by either method somewhat reduced the number of phagocytic cells.

The results of our experiments show that in the case of radiation cooling the phagocytic activity of the leucocytes is reduced more than with convection cooling. It is known that the maximum activity of the leucocytes is shown at normal body temperature, but the optimum temperature for the amoeboid movements of the leucocytes is 36-38°. At this temperature the movements of the leucocytes in vitro are more active and more prolonged [1]. Tsukamoto [15] found that the polymorphonuclear leucocytes of the rabbit are most active at 40 - 42.5°.

To explain the greater reduction of phagocytic activity of the leucocytes with radiation cooling we attribute chief significance to the greater degree of cooling of the whole body, and the greater fall in the temperature of the blood in the subcutaneous veins [3] and in the muscle tissue [3, 4] at a depth of 10-12 mm from the surface of the skin. According to Barton and Edholm [13] the superficial layer of tissues at a depth of 2.5 cm contains 50% of all human tissue, and the reactions of the organism to thermal stimulation depend in large measure on the temperature drop of this layer. Apparently the reduction in phagocytic activity of the leucocytes produced by radiation cooling should be more prolonged; according to our previous studies radiation cooling produces a prolonged aftereffect, because after a 30-min exposure, the temperature of the venous blood and muscle tissue did not return to the original level for 1-2 h. However, with convection cooling the corresponding temperatures rapidly returned to normal.

The results we have obtained indicate that the more profound cooling produced by radiation as compared with convection is associated with a leucocytosis. Evidently, this index represents an adaptive reaction to a strong stimulus, and by this means the organism compensates for the weakened protective mechanisms designed to combat the etiological factor.

Apparently a disturbance of the optimal temperature regime, i.e., a reduction of body temperature below normal, particularly a drop in the superficial tissues and subcutaneous veins plays an important part in the reduction of such indices as the phagocytic number and phagocytic activity. N. V. Puchkov [8] showed that the phagocytic reaction is controlled by the sympathetic and parasympathetic mediators adrenalin and acetylcholine. It seems to us that the development of these mediators depends to a large extent upon information from the periphery, information derived from cutaneous, and especially from venous receptors [7]. On these lines it seems possible to explain the difference in the immune reactions to convection and radiation cooling. We must suppose that in convection cooling considerably more sympathin is elaborated than with radiation cooling, when the thermo-regulatory processes are less effective.

## SUMMARY

It was shown in 28 experiments on rabbits that cooling by means of radiation depressed the immune response of the animals more strongly than when the cooling was by convection.

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