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Spinal Cord and Hypothalamus as Parallel Core Sensors of Temperature in the Dog

by
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INTRODUCTION

The spinal cord of warm-blooded animals contains thermosensitive structures which are linked to the temperature regulating system. Selective thermal stimulation of the spine has been shown to activate the complete pattern of thermoregulatory responses such as shivering (Jessen and Mayer, 1971; Simon et al., 1963), panting (Jessen, 1967), sweating (Hales and Jessen, 1969) and changes in cutaneous blood flow (Jessen, Meurer and Simon, 1967). These findings suggest some similarity between the spinal cord and the hypothalamus as the classic core sensor of temperature, but put the question, on the other hand, how to fit the thermosensitivity of the spine into current concepts of temperature regulation. Is the hypothalamic temperature the basic regulated parameter within the body core and is the spine part of a second line defense involved in temperature regulation under monitoring by the preoptic region, or have spinal cord and hypothalamus to be regarded as providing analogous and equivalent inputs into one controlling system?

METHOD

Two dogs were prepared with spinal and hypothalamic thermodes (Hellstrøm and Hammel, 1967). In the conscious and unrestrained animals 15 experiments were performed at constant external conditions. In these experiments, the temperatures of spinal cord or hypothalamus were varied over a wide range and were correlated with heat production. Thus, stimulus-response-curves for selective cooling of spinal cord or hypothalamus were obtained. These curves were constructed on the base of the averaged heat production during the second, third and fourth minute of a period, plotted against the mean spinal cord temperature and the hypothalamic temperature respectively at the same time. For all periods, linear regressions were calculated. Their slopes show the increases of the effector responses per degree change of temperature. The intersection points between the regressions and control values define the threshold temperatures.

RESULTS

The results obtained in one of the two dogs at an air temperature of 18°C are shown in Fig. 1. The filled circles in the upper part represent the effect of spinal cooling. Each circle is related to one stimulation period and shows the heat production plotted against mean spinal cord temperature. The mean value and standard deviation of heat production during all control periods of the complete series are represented by three lines parallel to the abscissa.

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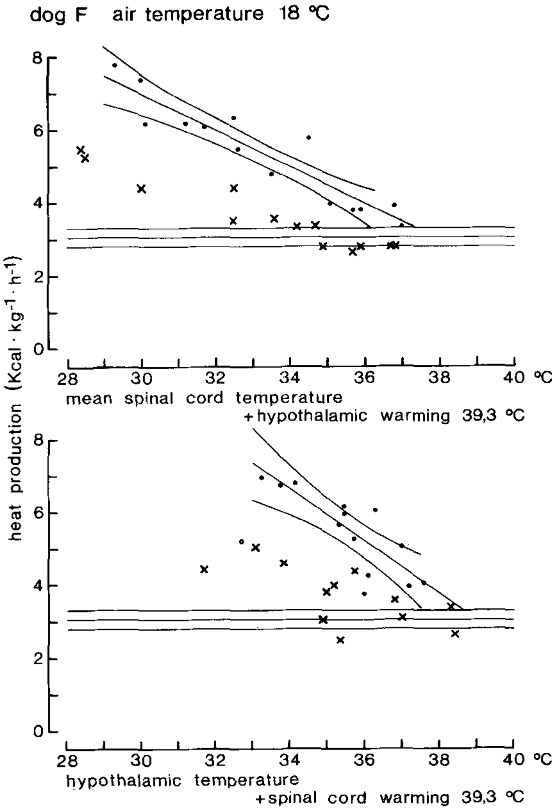

Fig. 1. Heat production related to mean spinal cord temperature (above) and hypothalamic temperature (below) during selective cooling (filled circles) and combined opposite temperature changes (crosses) of the corresponding thermosensitive areas. 43 stimulation periods in one conscious dog at an air temperature of 18°C. Further details see text.

Spinal cooling acted as a strong stimulus to heat production. The regression line cuts the upper limit of the resting values at a mean spinal cord temperature of 37.3°C. This is, therefore, the threshold temperature for the increase of heat production by spinal cooling in this animal and at these environmental conditions. Below the threshold, the heat production increased by -0.6 Kcal/(kg·h·°C) with decreasing spinal cord temperature.

As is shown by the filled circles and the regression line in the lower part of the figure, selective cooling of the anterior hypothalamus in the same dog led to a marked increase in heat production. The threshold temperature was 38.75°C. Below the threshold, the heat production rose by -0.7 Kcal/(kg·h·°C).

Comparison of the upper and the lower part of the figure shows that cooling of spinal cord or hypothalamus is able to elicit responses of the heat producing mechanisms, which are of the same order of magnitude for both thermosensitive sites. Furthermore, the results supply standards for evaluating the effects of opposite temperature changes applied simultaneously to both thermosensitive sites. This special type of thermal stimulation should be able to show whether the heat production is predominantly correlated to the temperature of one of both thermosensitive sites.

The crosses in the upper part of the figure show the results of spinal cooling combined with hypothalamic heating. During each period, the hypothalamus was constantly heated to a fixed value of 39.3°C T_{hy}, while the spine was cooled to different levels, as is shown by the abscissa. All these periods are far outside the confidence belt for selective cooling of the spinal cord. Thus, by a small constant heating of the hypothalamus, the response to spinal cooling became clearly reduced.

The lower part of the figure shows the reverse arrangement of stimuli. During each period of hypothalamic cooling, whose intensity is shown on the abscissa, the spinal cord was heated to a constant value of 39.3°C. Again the crosses are well below the filled circles, which represent the effect of hypothalamic cooling without spinal heating.

Taken together, these results show that the increase of heat production due to shivering and induced by single cooling of either spinal cord or hypothalamus, can be markedly reduced even by slight heating of the other thermosensitive area. The activity of the heat producing effector system appears to be correlated with the proportion of opposite temperature signals generated simultaneously in the spinal cord and the hypothalamus. No matter whether spinal cord or hypothalamus was exposed to cold or warm stimuli, the result was the same and the thermosensitive areas proved to be interchangeable. Thus, the results appear to support the concept of spinal cord and hypothalamus as providing equivalent and analogous inputs into the temperature regulating system of the conscious dog.

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