HYPOTHERMIA AND PIAL CIRCULATION*

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Prompted by the increasing use of hypothermia¹⁰,¹¹ in physiological investigation as well as in the operating room, a study of the pial vessels by the cinephotomicrographic means was undertaken. The recent literature concerning the metabolic, electroencephalographic, electrocardiographic and blood-flow changes during hypothermia was reviewed.⁸ This paper deals with the dynamic changes of the pial vessels (50–200 micra) under the conditions of lowered temperature.¹⁴

METHOD

Thirteen experiments were carried out using 1 mongrel dog and 10 Rhesus monkeys. Intravenous sodium pentobarbital was used for anesthesia in all experiments. The blood pressure was recorded from the femoral artery with a Statham strain gage. Electrocardiographic and respiratory tracings were obtained. In 7 animals an electroencephalogram was recorded. The temperatures were measured rectally, both with thermistor and laboratory thermometer. Body cooling was accomplished by the use of the cooling blanket and machine manufactured by the Therm-O-Rite Products Corporation.

The pial vessels were exposed for study through a trephine opening made in the parietal area. In 3 experiments a glass dipping cone (Leitz) was used between the objective and the pial surface. In 2 experiments a water-tight window,⁷ fashioned into the trephine opening by means of plastic, was used; and in the remaining 8 experiments, a round glass cover slip was inserted between the dura mater and the pia-arachnoid through a cruciate incision. The dura mater was then sutured in a purse-string fashion about the periphery of the cover slip. On several occasions a cover slip with an etched scale of 0.05 mm. was used. The vessels could then be studied under conditions similar to the normal closed dural state. Photographic resolution and vascular dynamic changes did not appear to be affected by the interchange of these three methods.

Photographic records were obtained on 16 mm. Kodachrome type A film, using a Kodak Cine Special camera. The Leitz Ultropak equipment was used as the camera objective. A 534 watt, 110 volt, alternating-current carbon arc lamp was used for light source. A Bausch and Lomb 85/15 per cent beam splitter was used between the camera and the objective to permit continuous observation during photography. The vessels were observed at magnifications of 21–120 times and were recorded on the film at enlargements of 4.2–12 times.

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610
RESULTS

Cooling was accomplished quite uniformly at a rate of approximately 1°C. every 5 minutes. Under the conditions of light pentobarbital anesthesia, shivering occurred in several animals requiring the use of additional anesthesia. This had the undesirable effect of depressing respiration.\(^5\)

Five monkeys were cooled to 10°C., or lower. Of this group, 1 animal died of irreversible ventricular fibrillation, 2 animals were intentionally sacrificed, and 2 animals were permitted to survive the experiment. Of the 2 animals who survived the temperature below 10°C., the only observable abnormality was a marked gangrene of the lower extremity in which the femoral artery had been cannulated for blood-pressure readings. One additional monkey was cooled to a rectal temperature of 2.8°C. This animal was likewise permitted to survive after sustaining a period of asystole for 15 minutes at this low temperature. The animal survived the experiment without discernible cerebral abnormality, but was sacrificed at the end of a week and one-half because of marked frost-bite gangrene of both lower extremities and tail.

The electrocardiogram showed a progressive bradycardia. Prolongation of the P-R and Q-T intervals, elevation of the S-T segment and inversion of the T wave as shown by Bering et al.,\(^5\) were seen in our recordings. In addition, bizarre T-wave changes and disorganized ventricular complexes became apparent at low temperatures (15°C. and lower). The abnormalities reversed on warming.

The pulse rate decreased in direct proportion to the temperature drop.\(^11\) No arrhythmias were noted above 15°C. Ventricular fibrillation was a major problem in 2 animals at 9° and 10°C. In 1 animal artificial respiration with 100 per cent oxygen was used. Ventricular fibrillation became irreversible and the animal expired. In another animal spontaneous respirations continued even at 9°C., and in this experiment the fibrillation was of short duration and regular cardiac activity resumed. Although the use of hyperventilation has been suggested by Swan et al.,\(^12\) others\(^13\) have not felt that it is needed. Bigelow et al.,\(^3\) found that the use of 5 per cent carbon dioxide was useful in prolonged survival in hypothermic dogs. Accordingly, we used 5 per cent carbon-dioxide artificial respirations on two later occasions when respiratory aid was needed. Ventricular fibrillation occurred in 1 animal (6.5°C.) but spontaneously returned to regular rhythm. In the other animal, at 2.8°C., asystole occurred after 10 minutes of a bradycardia of 1 to 2 per minute. The asystole lasted for 15 minutes during which time the blood pressure was zero. Then the animal was stimulated with a 150 volt, monopolar 10 millisecond square wave at a frequency of 60 times per minute. The blood pressure rose with each stimulation. After 10 minutes of stimulation it was 10-12/0 mm. of mercury. Stimulation was then stopped and the heart continued to beat in a regular fashion. As warming progressed the electrocardiogram returned to a normal pattern. This animal survived without apparent abnormality, save for frost-bite gangrene as noted above.