EFFECTS OF ENVIRONMENTAL TEMPERATURE, ANESTHESIA AND LUMBAR SYMPATHETIC GANGLIONECTOMY ON THE TEMPERATURES OF THE EXTREMITIES OF ANIMALS

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Research Article

EFFECTS OF ENVIRONMENTAL TEMPERATURE, ANES-THESIA AND LUMBAR SYMPATHETIC GANGLIO-NECTOMY ON THE TEMPERATURES OF THE EXTREMITIES OF ANIMALS[1]

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INTRODUCTION

The reports of alleviation of symptoms following sympathetic gang-lionectomy and trunk resection in certain cases of peripheral vascular diseases, arthritis and scleroderma have created a noticeable interest in the underlying physiology of the sympathetic nervous system when functioning in a normal or abnormal fashion. From clinical as well as experimental data the changes which take place following sympathetic ganglionectomy with trunk resection have proved to be chiefly vasomotor. The relief of pain in certain cases may be brought about by this same mechanism or may be the result of interrupted sensory pathways. The postoperative vasomotor changes consist mainly of lessened vasoconstric-tion. This can be demonstrated in the extremities of animals as well as of patients with normal blood vessels through the use of physical appara-tus for measuring the changes in superficial temperatures produced by operation. Believing that this vasomotor action is present in vascular diseases of the peripheral vessels in varying amounts dependent on the interplay of environmental conditions and nervous mechanism, Morton and Scott (1) called attention to a definite temperature gradient beginning proximally and increasing distally (vasoconstrictor gradient) in persons with normal peripheral vessels and that, "after spinal anesthesia, there is usually a rapid rise in surface temperature on the feet so that all surface areas of the body reach approximately the same level (normal vasodilata-tion level)." Superficial temperatures also showed rapid changes in normal persons under inhalation anesthesia. In vascular diseases, there-fore, the use of spinal anesthesia produces a selective effect on the vaso-constrictors and the degree of vasocontraction may be measured by the

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changes in the superficial temperatures of the extremities. White (2) also recently advocated blocking the sympathetic nerves to the extremities to determine the presence or absence of vasoconstriction.

PURPOSE OF THE INVESTIGATIONS

In addition to observing the reactions of the vasomotor mechanism as shown by changes of superficial, subcutaneous and interdigital temperatures of the extremities of animals (dogs) under various types of anesthesia in a fairly constant environment (24° to 28° C.), we were interested in producing a rapidly changing environment and in making observations on the vasomotor reactions obtained in the same dogs in normal and anesthetized states when under similar constant or rapidly changing environmental conditions. After determining the reactions of the normal vasomotor activities with and without anesthesia to a rapidly changing environment, similar procedures were carried out following sympathetic denervation of one hind extremity in order to determine whether there was a marked difference in vasoconstriction in the two extremities demonstrated peripherally or in the tissues by measurements of superficial, subcutaneous and intermetatarsal temperatures with thermocouples.

EXPERIMENTAL METHODS AND SURGICAL PROCEDURES

Measurements of temperature by thermocouples. Superficial, subcutaneous and intermetatarsal temperatures were measured by means of the electromotive thermometer devised and described by Sheard (3). This instrument is equipped with numerous thermocouples, each of which is inserted in a needle with the thermojunction near the tip or on the surface of a fiber or hard rubber button. Diagrammatic sketches of the electromotive thermometer are shown in Figure 1. A thermojunction, connected to all the thermojunctions which may be used for obtaining measurements of temperature, is inserted in a thermostat maintained electrically at a given, constant temperature. The readings of the galvanometer included in the thermocouple circuits are converted into equivalent thermal readings. Having calibrated the deflections of the galvanometer in equivalent thermal readings, any of the various thermocouples with which the apparatus is equipped may be applied to or inserted into the body and the temperatures read directly from the calibrated scale. By means of this ensemble it is possible to read the temperature indicated by any of the thermocouples applied to or inserted in the body in about ten seconds of time. Figure 2 is a photograph of the instrument used in these investigations. Each switch is connected to the common thermojunction and to a specified thermocouple. Some of the forms of thermojunctions for the measurement of superficial, subcutaneous and intermetatarsal temperatures are shown.

Situation of the thermocouples. In general a thermocouple was applied to or inserted in each of the two hind extremities as follows: (1)

subcutaneously, on the inner side of the leg and above the patella; (2) superficially, between the toes, and (3) intermetatarsally, that is, in an interosseous position but relatively near the surface of the skin of the foot.

In the presentation of our experimental data we shall refer to the situation of the various thermocouples as: (1) left interdigital, (2) right interdigital, (3) left subcutaneous, (4) right subcutaneous, (5) environmental temperature of hind extremities, (6) right intermetatarsal, and (7) left intermetatarsal.
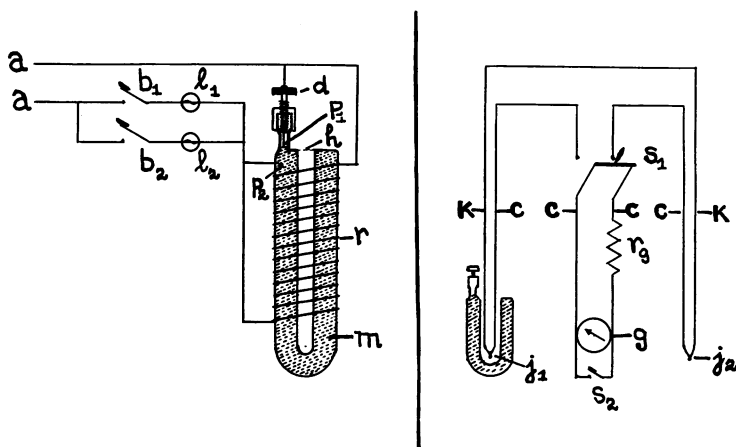

FIG. 1. ELECTROMOTIVE THERMOMETER

Left-hand diagram shows the thermostat and heating circuit: $a-a$, 110 volt circuit; b_1 and b_2, switches for inserting auxiliary resistances (incandescent lamp bulbs) l_1 and l_2 in the circuit; d, adjustable screw to set the temperature of the thermostat; p_1 and p_2, platinum wires which, with mercury, form the thermostatic control; h, inner tube of thermostat which carries one set of thermojunctions or one thermojunction common to all junctions; r, resistance for heating the thermostat; m, mercury; right-hand diagram shows the circuit containing the thermocouple and the galvanometer: j_1 and j_2, thermojunctions of copper, c, and constantan, k; r_g, auxiliary resistance in galvanometric system; g, galvanometer; s_1, switch for including the galvanometer in the thermo-electric circuit; s_2, shunt to damp the galvanometer quickly.

Method of rapidly changing the environmental temperature. In general, the temperature of the room in which the various operations and measurements of temperature were made ranged from 23° to 27° C. The initial portions of the curves numbered 5 in the various portions of Figures 4 and 5 record the values of the environmental temperatures during the ten to twenty minutes of the different experiments. After the data had been obtained on the values of the superficial, subcutaneous and intermetatarsal temperatures under the conditions of the temperature of the room, the environmental temperatures of the lower extremities were reduced rapidly from room temperature to approximately 0° C. The lower extremities

were housed in a chamber made of two parts. The lower portion of this cooling chamber is an extension of, or addition to, the frame to which the dog was attached by means of gauze taping. The extremities rested on a metallic netting which occupied the width of the frame. Underneath the sheet of wire mesh was placed a small cylinder of carbon dioxide which was used for lowering the temperature of the chamber. The neck of the cylinder fitted into and through a suitable opening in the side of the frame and in such fashion that the flow of gas from the cylinder into the chamber could be controlled from the outside. After the insertion or attachment of the various thermocouples, the cover was placed in position and the opening in the end which fitted over the body of the dog was blanketed. A mercury thermometer inserted through the top of the chamber registered the temperature within the chamber.
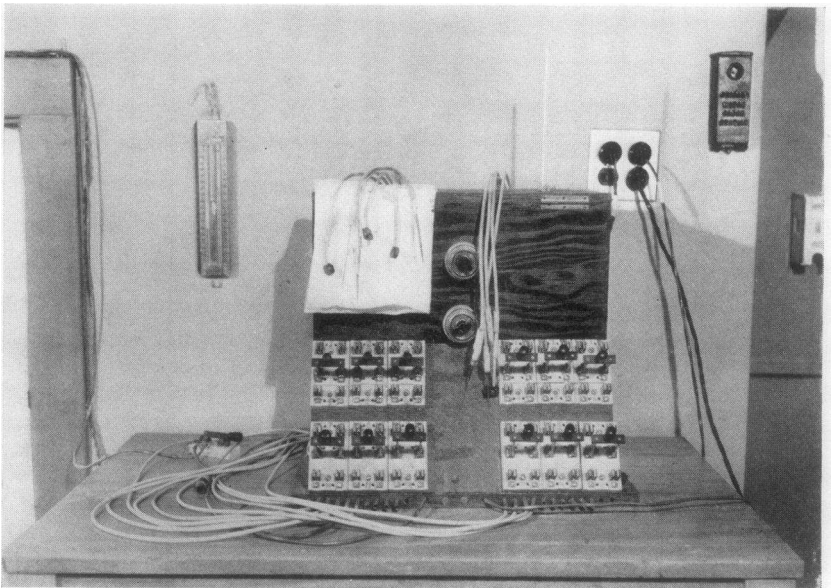

FIG. 2. ELECTROMOTIVE THERMOMETER, TYPES OF THERMOJUNCTIONS AND SWITCHES CONNECTED TO EACH OF THE THERMOCOUPLES, RESPECTIVELY

Figure 3 is a photograph of a cylinder (size D) of carbon dioxide to which is attached, by means of a yoke, a metallic tube which is closed at its distal end and which is punctured with a number of fine holes. When the tank is opened, the gas at fairly high pressure escapes through the numerous small openings in the metallic pipe. By reason of the rapid expansion of the gas as it issues into the air at atmospheric pressure the temperature of the surrounding air is reduced rapidly. The temperature of the chamber could be reduced from 25° C. to the neighborhood of the freezing point in from one minute to two minutes. The curves

marked 5 in the various portions of Figures 4 to 6 inclusive show the course of the relationship between the time in minutes and the environmental temperature.

Surgical procedures and data. Five dogs were used in these experiments. After determining the reactions of the normal vasomotor activity, as evidenced by measurements of temperature, to a changing environment and with and without anesthesia, similar sets of observations were made following sympathetic denervation of one of the hind extremities. The experimental data obtained under ether administered by inhalation, amytal intravenously, and procaine intraspinally were considered basic. In four of the animals the lumbar sympathetic ganglia were removed on the left side and in the fifth dog on the right side.
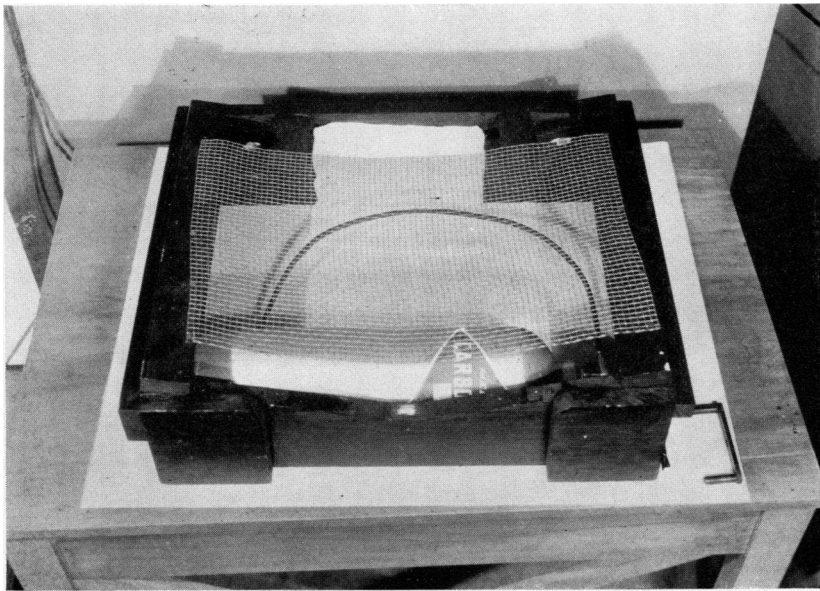

FIG. 3. LOWER HALF OF THE COOLING CHAMBER; THE TANK OF CARBON DIOXIDE AND METALLIC TUBE IN POSITION ARE SHOWN

Experiment 1: October 9, 1930, under general anesthesia, a left abdominal incision was made through the skin and muscles, and the peritoneal cavity was opened. After retraction of the viscera and incision of the posterior peritoneum, the lumbar sympathetic chain was exposed and removed.

Experiment 2: November 25, 1930, left sympathetic ganglionectomy and trunk resection were performed.

Experiment 3: January 7, 1931, left sympathetic ganglionectomy and trunk resection were performed.

Experiment 4: February 6, 1931, under general anesthesia, a right abdominal incision was made through the skin and muscle and the peritoneal cavity was opened.   After retraction of the viscera and abdominal vessels, the right lumbar sympathetic ganglia were removed.

Experiment 5: February 25, 1931, left lumbar sympathetic ganglionectomy and trunk resection were performed.

EXPERIMENTAL DATA AND RESULTS

Figures 4 and 5 present in graphic form the data obtained through the measurements of temperature by thermocouples in experiment 4 and in experiment 5 (Fig. 5).   In all portions of both figures the curves numbered 5 show the course of the changes in environmental temperature.   Curves 1, 3 and 7 refer to the time-temperature relationships obtained inter-digitally on the left foot, subcutaneously in the region of the patella and intermetatarsally in the left foot, respectively.   Curves 2, 4 and 6 have similar significance with reference to the right hind extremity.

Figures 4 (I) and 5 (I) show the course of the time-temperature relationship and the environmental temperature without anesthesia: Figures 4 (II) and 5 (II), under ether anesthesia, Figures 4 (III) and 5 (III), under ether anesthesia after lumbar sympathetic ganglionectomy (operation performed on the right side in Fig. 4 and on the left in Fig. 5), and Figures 4 (IV) and 5 (IV), after lumbar sympathetic ganglionectomy and without anesthesia.

The curves of Figures 4 and 5 indicate the following salient points:

1. In the normal animal, there was marked vasoconstriction evidenced in the interdigital and intermetatarsal portions of the hind feet when the environmental temperature was rapidly lowered from room temperature (about 25° C.) approximately to the freezing point.   This vasoconstriction, as indicated by lowered thermal readings on the thermocouples (curves 1 and 2), persisted for from twenty to sixty minutes, lagged behind the readings of the environmental temperature (which returned fairly rapidly to that of the room as shown in curve 5), and finally recovered to a state which was normal or slightly above normal.

2. In the normal animal, the time-temperature relationship of the subcutaneous areas near the patella (curves 3 and 4) paralleled the course of the environmental temperature.

3. In the normal dog under ether anesthesia, all subcutaneous and superficial time-temperature curves (curves 1, 2, 3 and 4) showed that there was no evidence of vasoconstriction.   In general, the recovery to normal temperature was more rapid than the course of the environmental temperature (curve 5).   Also, the drop in subcutaneous and superficial temperatures under ether anesthesia was less than in the normal animal without anesthesia.
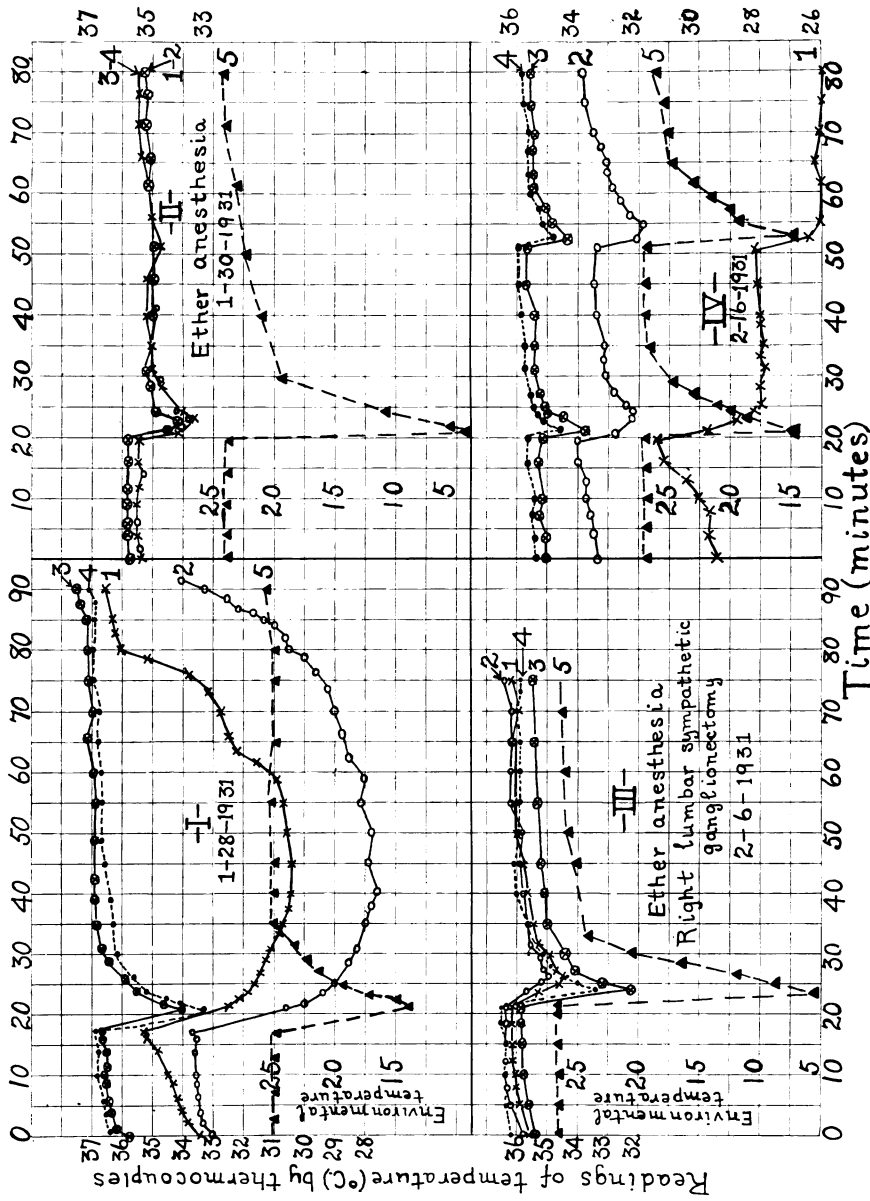
FIG. 4. TIME-TEMPERATURE RECORDS: I, NORMAL ANIMAL WITHOUT ANESTHESIA; II, UNDER ETHER ANESTHESIA; III, AFTER RIGHT LUMBAR SYMPATHETIC GANGLIONECTOMY AND UNDER ETHER ANESTHESIA; IV, AFTER OPERATION AND WITHOUT ANESTHESIA.

In all portions of this figure, the significance of the numbers on the curves is: (1) left interdigital, (2) right interdigital, (3) left subcutaneous, (4) right subcutaneous, (5) environmental temperature, (6) right intermetatarsal, and (7) left intermetatarsal. All of these observations were made on one dog.

4. After lumbar (right or left) sympathetic ganglionectomy with trunk resection and under ether anesthesia, the time-temperature relationships of the subcutaneous, superficial and intermetatarsal temperatures closely paralleled the course of the environmental temperature but again evidenced a somewhat more rapid return to normal subcutaneous temperatures in the limbs than in the case of the normal animal without anesthesia and prior to operation.

5. After lumbar sympathetic ganglionectomy and without ether anesthesia, the curves in Figures 4 (IV) and 5 (IV) definitely show that, when the environmental temperature was lowered, vasoconstriction occurred in the hind extremity not operated on so far as the superficial or
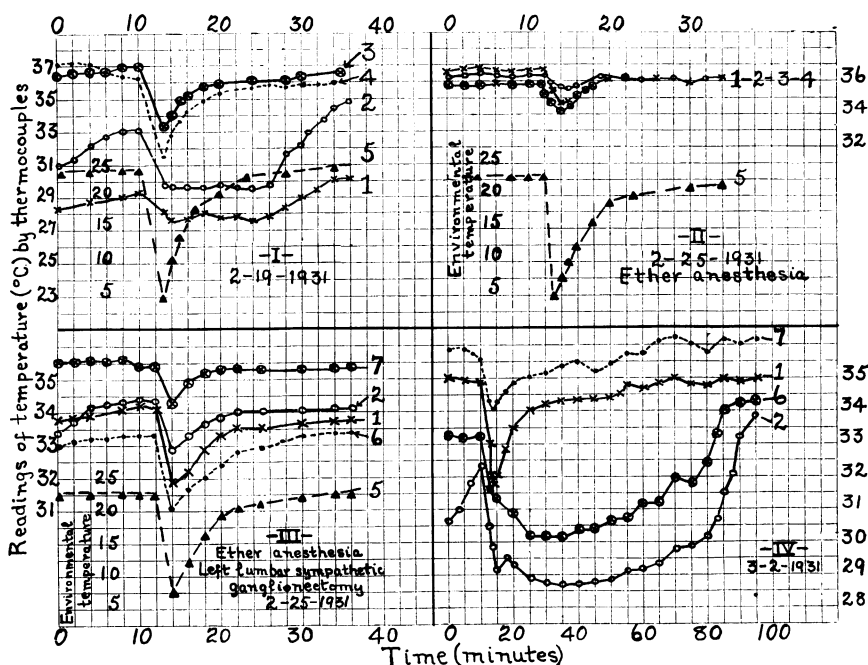

FIG. 5.   TIME-TEMPERATURE RECORDS OF ANOTHER DOG BEFORE AND AFTER LEFT LUMBAR GANGLIONECTOMY, WITH AND WITHOUT ANESTHESIA (FOR EXPLANATION OF NUMERALS REFER TO FIGURE 4).

intermetatarsal temperatures of the foot were concerned, but that little if any effect was produced by sympathectomy on the temperatures in the subcutaneous regions in the neighborhood of the patella.

By far the greater part of our experimental work was carried out under ether anesthesia whenever an anesthetic was employed.   Investigations made with amytal or procaine showed that the results obtained were similar to those secured under ether anesthesia.   It seems logical to conclude

that any drug which, when administered, inhibits the functioning of the central nervous system, would produce the same results as did ether, amytal or spinal anesthesia.

Figure 6 shows the interdigital and intermetatarsal time-temperature relationships (curves 1, 2, 6 and 7) for the feet of the dog in experiment 4 (right lumbar sympathetic ganglionectomy performed February 6, 1931) obtained March 25, 1931, after the administration of 50 mgm. of amytal for each kilogram of body weight.   Curve 5 shows the course of the
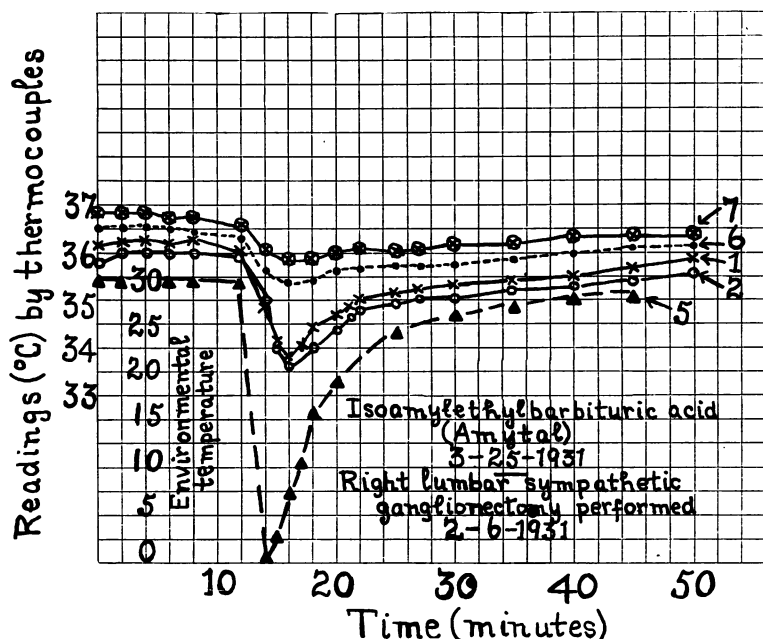

FIG. 6. TIME-TEMPERATURE DATA ON THE INTERDIGITAL (CURVES 1 AND 2) AND INTERMETATARSAL (CURVES 6 AND 7) TEMPERATURES OF THE HIND EXTREMITIES OF A DOG AFTER RIGHT LUMBAR SYMPATHETIC GANGLIONECTOMY AND UNDER AMYTAL.

change of environmental temperature from 30° to − 3° C. and the return within fifteen minutes to 27° C.   The results are similar in every respect to those obtained on the same dog under ether anesthesia (Fig. 4 (III)).

Figure 7 shows the results obtained on the interdigital and intermetatarsal temperatures of the hind feet of a normal dog that was given an injection, April 10, 1931, of 2 cc. of a 5 per cent solution of pantocaine over a period of four seconds.   The injection was made between the third and fourth lumbar vertebrae.   The contrast in the results obtained is more noticeable by comparison with the curves of Figures 4 (I) and 5 (I).
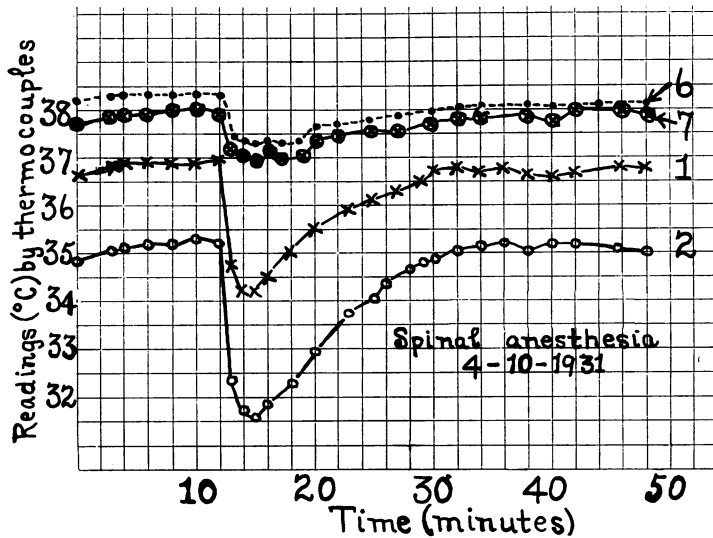
FIG. 7. TIME-TEMPERATURE DATA ON THE INTERDIGITAL (CURVES 1 AND 2) AND INTERMETATARSAL (CURVES 6 AND 7) TEMPERATURES OF THE HIND EXTREMITIES OF A NORMAL DOG UNDER SPINAL ANESTHESIA.

SUMMARY

Simultaneous measurements on the subcutaneous, interdigital and intermetatarsal temperatures of the hind extremities of dogs were made with thermocouples and a series of data was obtained regarding the thermal changes produced by environmental temperature, anesthesia and lumbar sympathetic ganglionectomy with trunk resection. The results showed that, in normal dogs, there was a marked drop in the superficial temperatures of the feet which was maintained over a considerable period when the environmental temperature of the apparatus housing the extremities was quickly lowered from temperatures of 23° to 27° C. to the neighborhood of the freezing point. Subcutaneous temperatures of the limbs closely followed changes in the environmental temperature. The temperature-time relations of the intermetatarsal tissues of the feet paralleled the results obtained interdigitally.

Under ether, amytal or spinal anesthesia, superficial, subcutaneous and intermetatarsal temperatures paralleled the course of the changes in the environmental temperature and indicated absence of vasoconstriction under sudden changes in the environmental temperature.

Significant differences were not found in the course of any of the time-temperature relations following lumbar sympathetic ganglionectomy and trunk resection when the animal was under ether, amytal or spinal anesthesia. Without anesthesia, however, the time-temperature relations for the superficial and subcutaneous temperatures of the foot on the operated side showed the usual small decrease of temperature followed by

a rapid rise to normal conditions with changes in environmental temperature and indicated absence of vasoconstriction.   Records of the changes of temperature of the foot on the side which was not operated on were similar to those obtained in the normal animal and indicated the presence of vasoconstriction which may persist from twenty minutes to an hour.

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