OBSERVATIONS ON SYMPATHETIC VASOMOTOR PATHWAYS

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During recent years there has been a widespread interest in the surgical treatment of a group of diseases which manifest themselves by a dysfunction of the sympathetic vasomotor system. While the good results following operative procedures have been steadily increasing, they have not always fulfilled expectations. This may be explained, in part, on the basis of poor selection of cases and as more exact means of demonstrating vasomotor dysfunction have been developed the results from operative procedures on the sympathetic system have accordingly improved. Another source of error has been the use of operative procedures by which the sympathetic vasomotor pathways have not been adequately removed or interrupted. This was particularly evident during the developmental phases of the surgery of the sympathetic nervous system. While the need for more exact operative procedures has stimulated investigation of the pathways by which these fibres reach the peripheral blood-vessels the central connections of the sympathetic ganglia have not in recent years received as much attention. It is the purpose of this paper to report some observations on the central connections of the sympathetic vasomotor fibres in man as well as in laboratory animals.

Case Record.—Symptoms suggesting Raynaud's syndrome with generalized vasomotor dysfunction and superficial gangrene of the right hand and left foot. Dorsal sympathectomy right arm and lumbar sympathectomy left leg. Relief of symptoms but six months later novocaine injection of peripheral nerves caused rise of temperature in right arm and left leg.

Admission.—March 17, 1931 (Unit No. A-849), Mr. A. B., aged forty years, referred by Dr. Wilder Tileston, of New Haven, with the complaint of pain and ulceration of the left great toe.

Anamnesis.—The patient, a plumber, had been in good health until 1927, when he noticed "rheumatism" in his legs. (Noted as stiffness and pain on arising in morning and relieved by exercise.) In 1929, he developed pain in the calves of his legs after walking about a hundred yards, the pain always being relieved by rest. These symptoms increased until about six months before entry to the hospital, at which time he consulted an orthopædist who prescribed arch supports which completely relieved the pain in his legs. Coldness of the feet was first noted in December, 1929, following severe exposure while out of doors. During the year preceding admission he had noted marked color changes of both the hands and feet. This was particularly marked in the feet after exposure to cold water, when they became very cyanotic. Four months prior to admission several small blisters developed on the first and fifth toes of the left foot. These blisters discharged a small amount of serum and on healing left a small pit in the skin which for some time remained tender. Some of the larger of these blisters developed into ulcerative lesions which healed slowly. Coincidental with the skin lesions he developed a dull throbbing pain in the left great toe.

Physical Examination.—This showed a rather undernourished man with no abnormal findings except in the extremities. The upper extremities were normal except for a few small blisters two to three millimetres in diameter on the index finger and thumb of the right hand. On the plantar surface of the left great toe, there was a partially healed superficial ulceration. The first and fifth toes showed numerous small scars in the skin at the base of the nails. The nails also showed evidence of retarded growth. There was no evidence of arteriosclerosis either on physical examination of all the palpable arteries or by röntgenographical examination. The dorsalis pedis arteries could not be palpated in either foot but there was good pulsation of the posterior tibial arteries. Röntgenograms of the feet showed slight atrophic changes of both the tarsal and metatarsal bones and some slight irregularity of the articular surfaces. All the other laboratory findings, including blood, urine and serological examinations, were negative.

Subsequent Course.—The vasomotor responses were studied in a constant temperature room by means of the Leeds and Northrup Multiple Point Temperature Recorders. These findings are shown in Chart I and in general demonstrated a mild type of vaso-

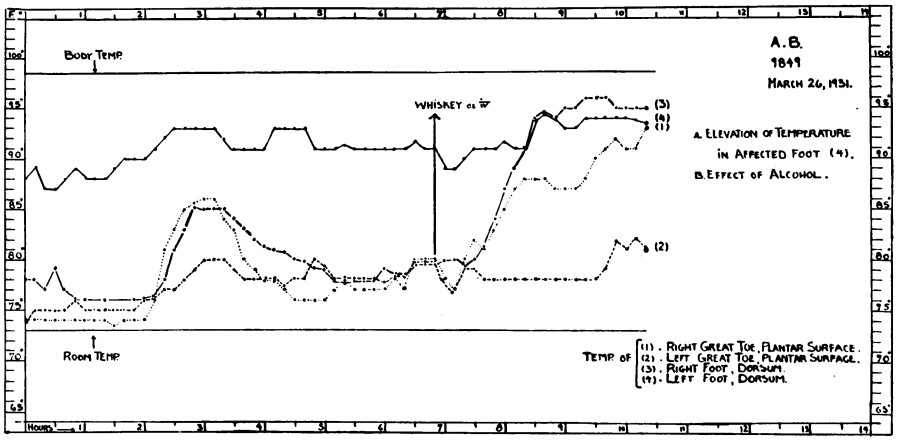

CHART I.

motor instability which was somewhat more marked in the lower extremities. The ulcers on the feet rapidly improved under a short period of conservative treatment, and the patient was discharged to await further developments. For a short while there was some improvement but again the symptoms returned worse than ever and he was advised to enter the hospital for sympathectomy. Two days before the date set for his second admission he entered the hospital with an attack of acute appendicitis. Following the removal of an acute appendix under ethylene anæsthesia the patient made an uneventful convalescence and was discharged home June 15, 1931, to return later for sympathectomy. During the next few months his appetite improved and he gained twenty pounds. He stated he had not felt so well for years and his symptoms of vascular disease completely disappeared. He continued to work at his trade as plumber, until September, 1931, when, coincident with loss of appetite and twenty pounds in weight, the vascular symptoms returned in an even more exaggerated form and he entered the hospital October 5, 1931, for sympathectomy.

During this last attack the lesions had become more pronounced in the upper extremities and especially in the right hand. The vasomotor disturbances were more pronounced in both the hands and feet and he now presented a fairly typical Raynaud's syndrome. Atrophic changes were pronounced in the left great toe and the right index finger, in both of which the skin was a tense shiny red and both presented ulcerations at the base

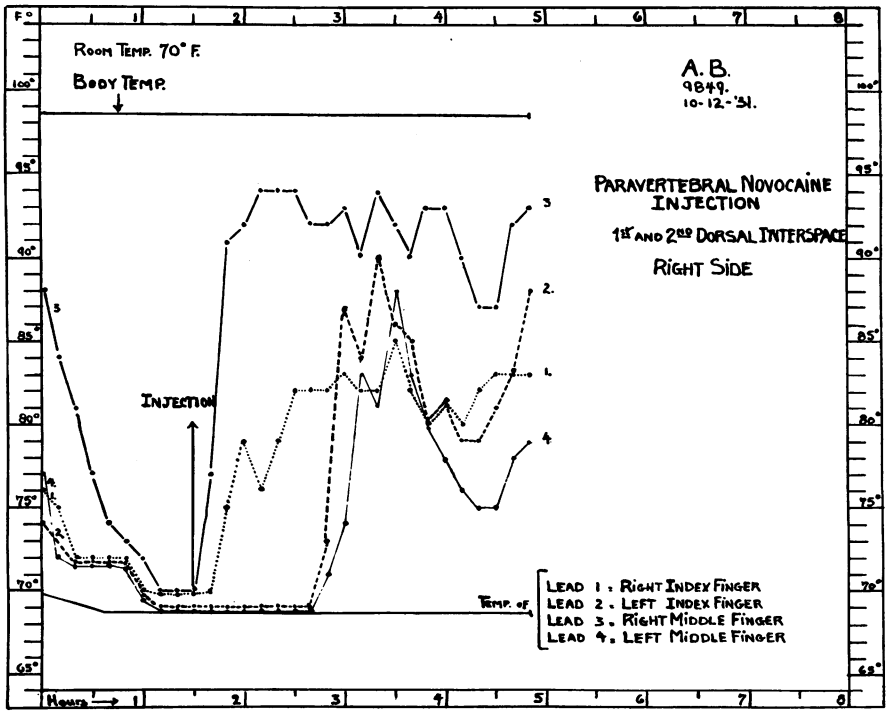

Chart II.

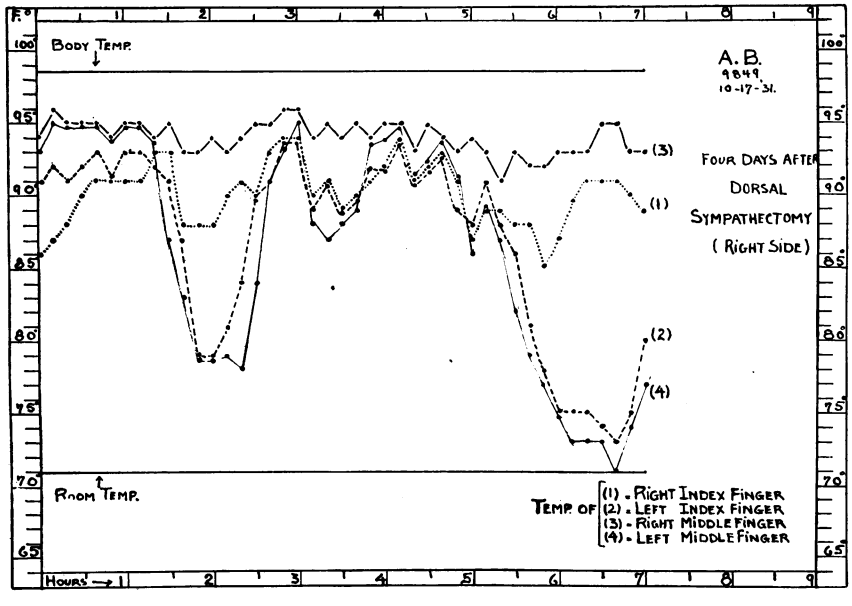

Chart III.

of the nails. Chart II shows the effect of paravertebral novocaine injection of the upper thoracic ganglia.

Dorsal Sympathectomy.—October 13, 1931, avertin-novocaine anæsthesia. Through a transverse incision over the second rib posterior the thoracic sympathetic chain was exposed on the right and the stellate ganglion and the trunk as far down as and including the second thoracic ganglion was removed.

Post-operative Notes.—The patient made an uneventful recovery and Chart III shows the temperature record of the extremities on the fourth post-operative day. There

FIG. 1.

was also marked subjective improvement. Figure 1 shows the areas over which there was complete absence of sweating indicating that the sympathectomy had been complete. It is interesting to note that this patient did not show a Horner's syndrome.

Lumbar Sympahectomy.—October 24, 1931, gas oxygen-ether anæsthesia. Through a left rectus incision the lumbar sympathetic trunk was exposed and a portion of it removed, including the second, third, fourth and fifth ganglia.

Post-operative Notes.—Following this operation he developed a mild pneumonic process which quickly cleared. There was marked subjective and objective improvement

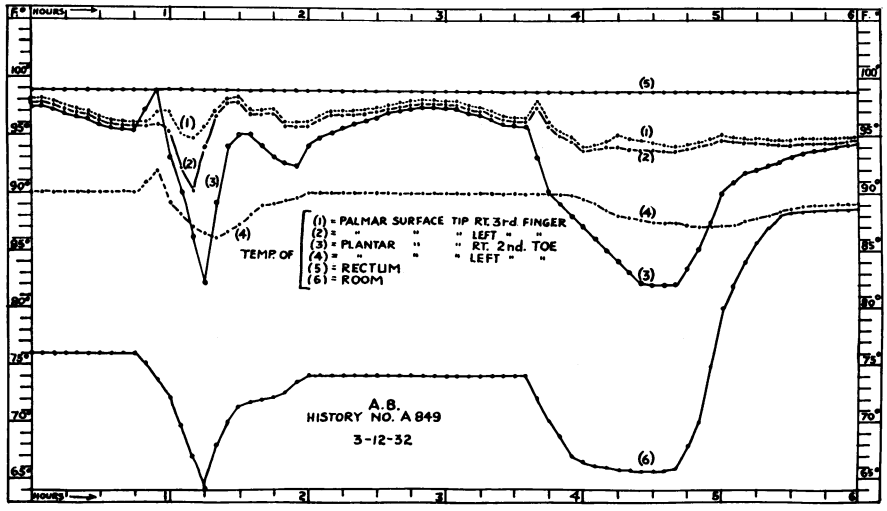

CHART IV.

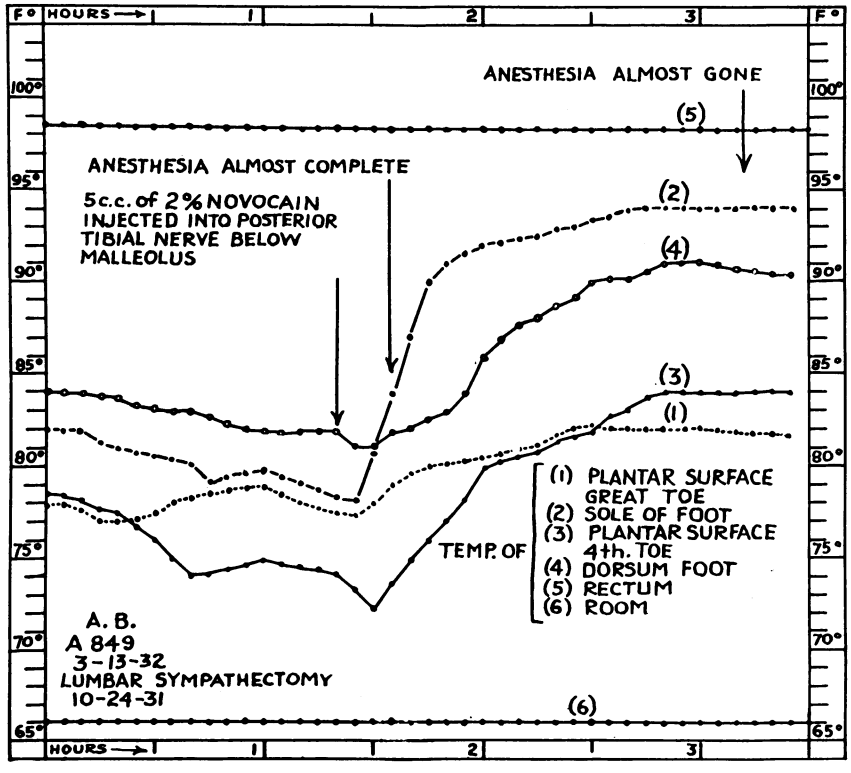

CHART V.

of the left foot and the pain in the left great toe disappeared. On washing the right hand in cold water three weeks after the dorsal sympathectomy there was distinct evidence of vasomotor spasm but of a mild degree. The patient was discharged home on November 7, 1931.

Interval Notes.—March 15, 1932. Since leaving the hospital he had gained twenty pounds, although he was still ten pounds under his maximum weight. There had been subjective and objective improvement in all extremities but particularly marked in the right arm and left leg. He had noted that the left hand still underwent marked color phases and occasionally on exposure to cold water he had noted slight color changes in the right hand. All ulcerative lesions had completely healed. There had been a marked increase in the rate of growth of the nails in the sympathectomized extremities particularly on the left foot, where it was necessary to cut the nails three to four times more often than on the right foot. He had noted no evidence of perspiration on the right

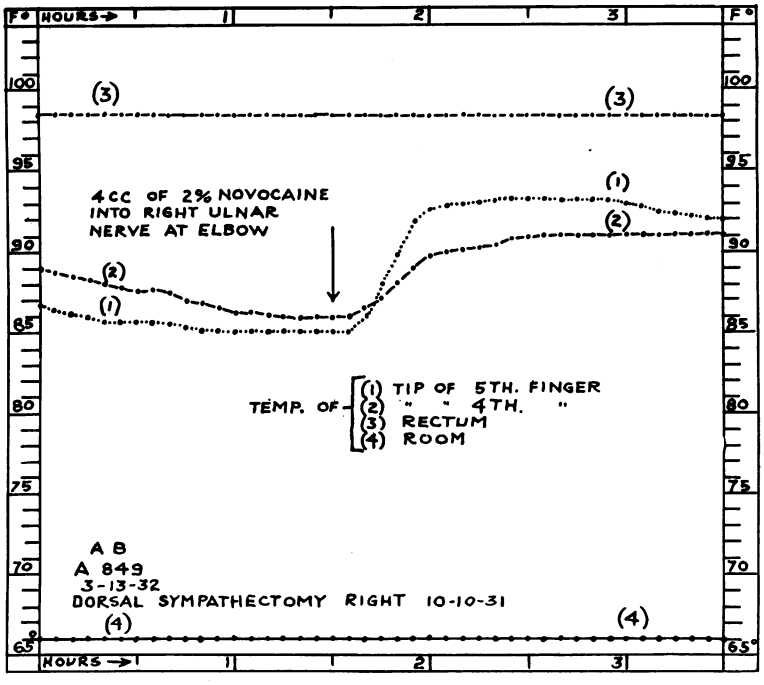

CHART VI.

hand but had occasionally noted one spot of perspiration on the sole of the left foot. There was a marked subjective feeling of warmth in the right hand and left foot.

Comment on Temperature Studies.—March 15, 1932. The patient was placed in the constant-temperature room, and records were made of the temperatures of both upper and lower extremities. Chart IV shows the response of the temperature of the extremities to changes in room temperature. In general there was a tendency for the right hand and the left foot to remain at a higher temperature as a result of the interruption of the sympathetic fibres to these extremities. This was particularly noticeable when there was a rapid change of environmental temperature demonstrating a greater range of temperature variation in the normal limbs. It was furthermore found that if the extremities were exposed to a lower room temperature (that is, 65° to 70°), there was a slow fall of temperature of the sympathectomized limb. After the temperature of the left foot had reached a low level, the left posterior tibial nerve was injected with novo-

caine just below the malleolus, and, as shown in Chart V, there was an immediate rapid rise in the temperature of the foot accompanied by subjective and objective evidence of vasodilatation. There was some difficulty in demonstrating this phenomenon in the right hand, and the temperature changes were never as great. However, they were likewise present. (Chart VI.) These findings suggest that there are still vasomotor fibres intact in the peripheral nerve to the extremities and that when these are blocked with novocaine that there is a release of vasoconstriction, with the resulting rise in temperature in these extremities. Because of the extent of the operative procedures and the number of ganglia removed and because of the sweating reaction obtained after operation, it had been thought that the sympathetic vasomotor fibres in the extremities had been interrupted. The above findings suggest that there are sympathetic pathways which are not interrupted by the usual operative procedures, and it seemed desirable to further investigate this phenomenon by experimentation on laboratory animals.

OBSERVATIONS ON SYMPATHETIC VASOMOTOR PATHWAYS IN DOGS

It is not within the limits of this paper to completely review the work which has been done in determining the course of sympathetic vasomotor fibres in laboratory animals, but rather merely to present a summary of the findings of some of our experiments, which will later be reported elsewhere in detail. Dogs were used in these experiments because of the fact that most of the previous investigations on the course of the vasomotor fibres have been carried out on this animal. In recent years the pathways by which sympathetic vasomotor fibres reach the peripheral blood-vessels after leaving the paravertebral chain have been carefully investigated. Since the work of the English anatomists and physiologists, namely Gaskell, Langley, Bayliss and Bradford, the levels at which the sympathetic vasomotor fibres leave the spinal cord and join the main sympathetic chain have been considered well-established facts. Langley carried out most of his investigation using the cat as a laboratory animal. The procedure by which he demonstrated the levels at which connector fibres left the spinal cord was to isolate the spinal roots and stimulate these at various levels; at the same time observing the appearance of sweat droplets on the footpad. He also used some animals having white footpads in which flushing as a result of vasodilatation could be observed. Gaskell used anatomical methods, and in the dog studied the distribution of the small medullated fibres in the anterior roots and the relation of their distribution at various levels to the presence of these fibres in the gray rami. Bayliss and Bradford, also using the dog as the experimental animal, studied the effect of stimulation of individual nerve roots as measured by the increase in size of the limb contained in a plethysmograph. These studies all indicated that the majority of the sympathetic vasomotor fibres left the spinal cord in the anterior root from the level of the first thoracic to the third or fourth lumbar vertebræ.

In the experiments carried out in this laboratory, the temperature changes in the feet were used as an index of the blood flow in the extremities. It was found that in dogs under amytal anæsthesia when the femoral artery was ligated below Poupart's ligament there was a fall in the temperature of the extremity. Following this if the spinal cord was transected in the thoracic region there was an immediate rise in the temperature of the extremity. It was also found that transection of the cord as low as the fifth or sixth lumbar vertebræ resulted in an immediate rise in the temperature of the foot as shown in Chart VII.

The work of previous investigators had shown that the majority of these fibres left the spinal cord between the level of the tenth thoracic and third lumbar vertebræ. Under the same conditions as previously stated it was found that if the spinal roots were sectioned extradurally from the level of the eleventh thoracic to the third lumbar, there might or might not be a rise in the temperature of the extremity. Following

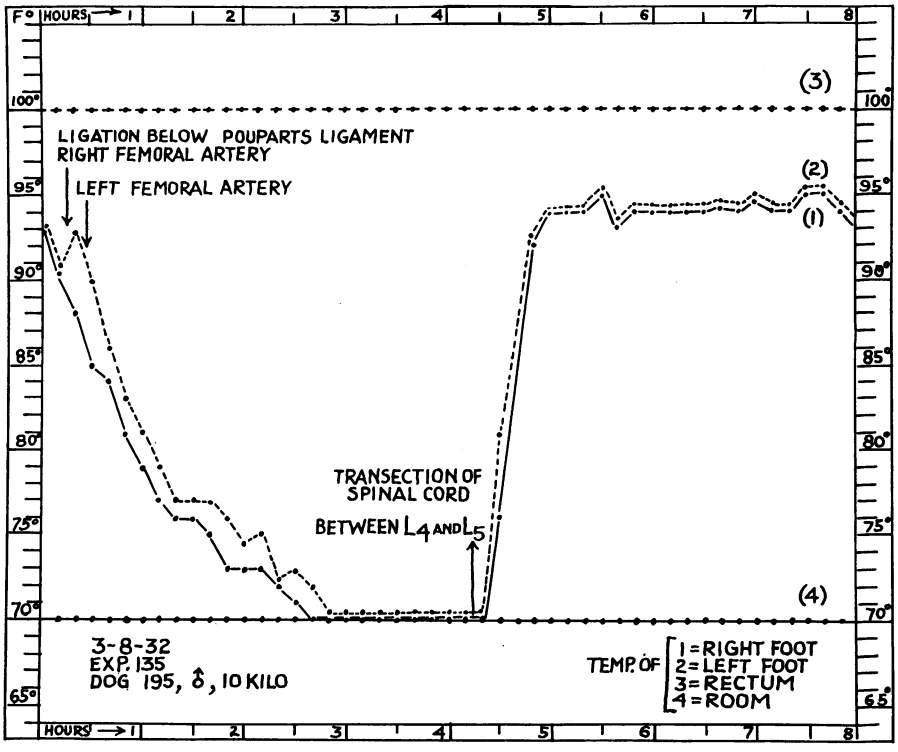

CHART VII.

this if the sciatic nerve was divided (Chart VIII) there resulted an immediate rise in the temperature of the extremity if none had previously taken place or an increase in the temperature when a previous rise had occurred. This indicated that there were

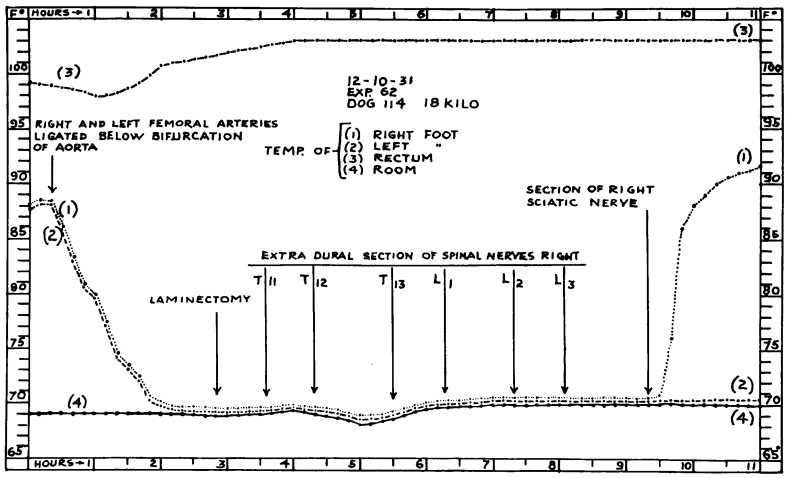

CHART VIII.

vasomotor fibres leaving the cord at levels other than between the eleventh thoracic and third lumbar. A third group of experiments was carried out in which the spinal roots

supplying the sciatic nerve only was sectioned, namely, from the fourth lumbar to the second sacral, and in these experiments also there resulted a rise in the temperature of the extremity. (Chart IX.) These experiments all suggest that there are vasomotor

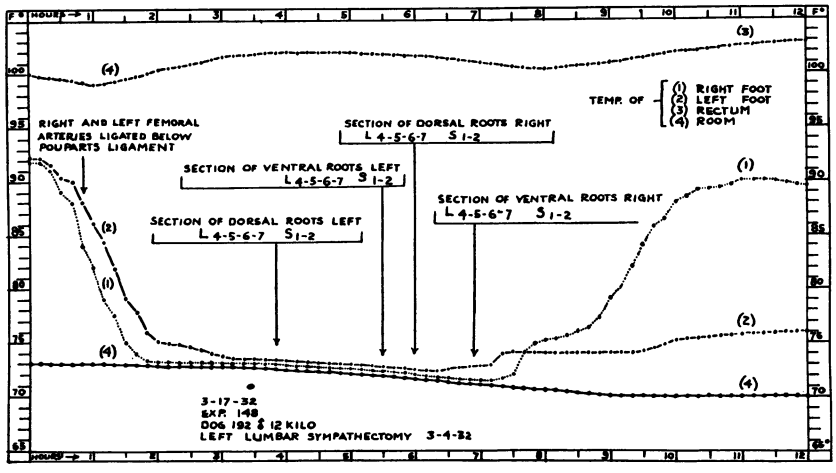

CHART IX.

connector fibres leaving the spinal cord at lower levels than have previously been assumed.

In addition, another group of experiments was designed to study the effect of removing the lumbar sympathetic chain in dogs. (Chart X.) In these experiments the sympathetic chain was extirpated from the level of the second lumbar vertebra to the level of the third or fourth sacral vertebra. Following this there was an immediate

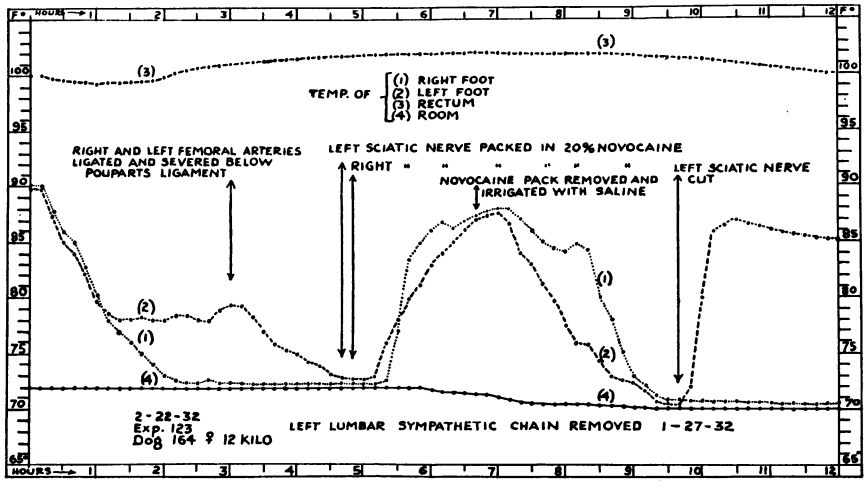

CHART X.

vasodilatation. Temperature studies were carried out over a period of weeks, and in general it was found that this vasodilatation became less and less marked until at a period from two to six weeks following operation the temperature of the sympathectomized limb, when the animal was kept in a constant environment of 70°, was essentially the same as the normal limb. If the sciatic nerve was then packed in novocaine or

sectioned, there was an immediate rise in the temperature of the extremity. In some dogs even at the end of two months there was still a considerable vasodilatation in the sympathectomized limb. In all of the dogs the difference in the two limbs could be demonstrated by differences in response to exercise or rapid temperature changes. Also the degree of response after section of the sciatic nerve varied considerably.

At present we are unable to interpret these findings but they suggest that possibly there are sympathetic vasomotor pathways which do not pass through the paravertebral ganglionic chain.

Summary.—(1) The varied results obtained by operative procedures designed to interrupt sympathetic vasomotor pathways may in part be explained by our lack of knowledge of the exact course pursued by these fibres and particularly the levels at which they leave the spinal cord.

(2) Evidence has been presented which suggests that the connector fibres between the spinal cord and sympathetic chain have much wider distribution than has formerly been supposed.

(3) In view of this fact, it is suggested that operations designed to remove a portion of the sympathetic ganglionic chain should be made even more extensive and particularly in lumbar sympathectomy, the ganglia should be removed to as low as the level of the second sacral vertebra.

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