VASOMOTOR AND REFLEX SEQUELÆ OF UNILATERAL CERVICAL AND LUMBAR RAMISECTOMY IN A CASE OF RAYNAUD'S DISEASE, WITH OBSERVATIONS ON TONUS

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The reflex changes ensuing upon sympathetic ramisectomy have for some years been under discussion among physiologists and surgeons. Many physiologists have been unwilling to admit that reflexes become altered following such procedures (see Forbes and his co-workers, 1926; Adrian, 1920; Cobb, 1925, etc.), while certain surgeons (Royle, 1926, 1927; Stewart, 1927, and others) have adduced strongly suggestive evidence that such changes do in fact occur. All are agreed, however, concerning the character of the vasomotor changes (see especially G. E. Brown, 1926; Adson, 1926; Adson and Brown, 1925; Davis and Kanavel, 1926). As the following case, which was studied with great care both before and after operation, seemed to throw light upon certain questions which are still unsettled, I felt that it was desirable to report it now rather than to await further collective evidence.

Case I.—*P. B. B. H. Surg. Nos. 27524, 28273, 28574. Chilblains in childhood; difficult first pregnancy with emotional disturbance, excessive lactation and profuse perspiration; onset of ischæmic symptoms in digits and toes after puerperium; pustule formation and gradual sloughing of terminal digits of index fingers for seventeen years; right radial periarterial "sympathectomy" with no relief; right-sided cervical and lumbar ramisectomy; relief of symptoms in lower extremity, reflex changes.*

Ruth M., an American housewife of forty-two, referred by Dr. C. L. Payzant of West Medford, Mass., was first admitted on October 29, 1926. She presented unmistakable symptoms of Raynaud's disease.

Clinical History (summarized from information obtained during three successive hospital entries).—There was no history of neurotic instability or of Raynaud's disease among her ancestors or in any member of the family. Patient had been married nineteen years, and had had three children with no miscarriages or stillbirths.

Onset of Present Illness.—Prior to her marriage the patient had always been a cheerful, even-tempered individual whose general health had been unusually good. Her habits were excellent and she had never smoked. There was nothing to suggest paroxysmal hæmoglobinuria. In childhood, however, her feet had been subject to chilblains, but for ten to twelve years before the onset of her present trouble she had not been so troubled. At seventeen she had had a running ear. Her present illness began four to five months after the birth of her first baby. The pregnancy had been uneventful and the patient was pleased over the prospect of having her first child. As her marital life was then and has continued a happy one, there was therefore no background of domestic discontent. However, the birth was extremely difficult, the patient having been in labor for three to four days, and when finally delivered she suffered an extensive third-degree tear. From the beginning of her confinement she had lost confidence in her obstetrician and attributed her misfortune to improper care. The puerperium lasted six weeks, during which time she ran a high fever, and for a year afterward was "worn out" and unable to take care of her child. For several months after this pregnancy she was troubled by

an excess of milk; it came in great quantities and a pump had to be used three to four times daily for a month or more in order to draw off the excess which the baby could not take. She also perspired profusely while nursing the child, and she was also subject to palpitation which was brought on by any slight excitement. Easily upset emotionally, she often wept without adequate cause; reading a tragic novel made her uncontrollably lachrymose. Emotional instability has continued without great modification until the present time. There were slight exacerbations of symptoms during her two succeeding pregnancies which occurred respectively ten and sixteen years after the first.

Symptoms of Ischæmia.—About four months after her first pregnancy she noticed a sore spot on her left fore-finger which was thought to be a felon. Poulticing the finger aggravated her symptoms. A week later the skin of the tip of the finger and also the deeper tissues sloughed off and did not heal for nearly a year. Since this first experience she has had many more sloughing pustules, involving at one time or another all of the fingers on her two hands except her two ring fingers and thumbs. Two weeks prior to her first entry her right foot had become similarly involved, though for four to five years she had noticed occasional cyanosis and blanching of both lower extremities. In the course of a day her upper extremities are ordinarily subject to repeated attacks of ischæmia. These begin with a sensation of numbness and tingling associated with marked cyanosis, which in turn is followed by blanching which may last for a half hour or more. Anything which makes her nervous or excited will regularly bring on an attack of ischæmia. Thus, when Doctor Cushing showed her to a clinic, the immediate effect of the ordeal was a complete blanching of all four extremities with a sensation of numbness, and after the clinic she wept copiously and wept yet again when telling of it two days afterwards.

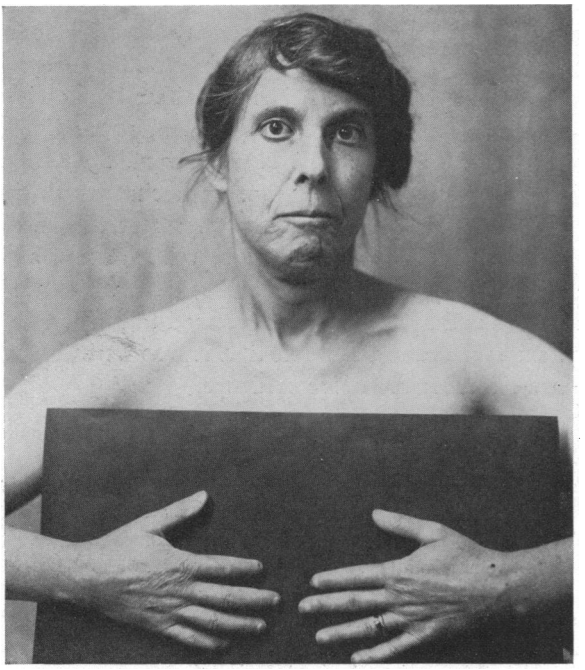

FIG. 1.—Patient's upper extremities showing marked sloughing of the terminal phalanges of both index fingers (pre-operative).

The patient's hands have proved to be a barometer of the weather, being much worse when cold or moist weather is impending. She always dreads the coming of winter. On a winter's morning while still in bed she feels no distress at all, but on arising her hands and feet become almost immediately blue except for the tips of her fingers which usually become dead white without initial cyanosis. Such attacks, especially those occurring in the morning, were associated with an agonizing ache of her hands, the movements incident to putting on her clothes with her hands in this state being particularly painful. She is accustomed to taking violent exercise in order to warm up her extremities, and this indeed has become a morning chore. Three or four times in the course of the day she soaks her hands in warm water, which usually relieves the pain. When her arms hang pendant she is conscious of a sensation of tightness in her fingers, and on account of this is inclined to walk and to sleep with her arms in a flexed position.

First Entry.—Examination showed a somewhat irritable but healthy-looking and intelligent woman whose hands were covered with white gloves for the sake of increased warmth. Blood pressure 104/72. Urine and blood showed nothing remarkable. Heart sounds normal. Peripheral arteries not thickened and pulsation in peripheral arteries apparently normal. The only important positive findings were in her hands and feet. Proximal to the metatarsalphalangeal joints her hands appeared to be fairly normal. The fingers, however, were grossly affected; they were shiny, and the skin covering them was thin and atrophic. The nail of the right index finger had practically disappeared, evidently as a result of repeated small areas of necrosis, which the patient herself called "sore spots." At times the fingers were a deep blue with white spots on the tips of the

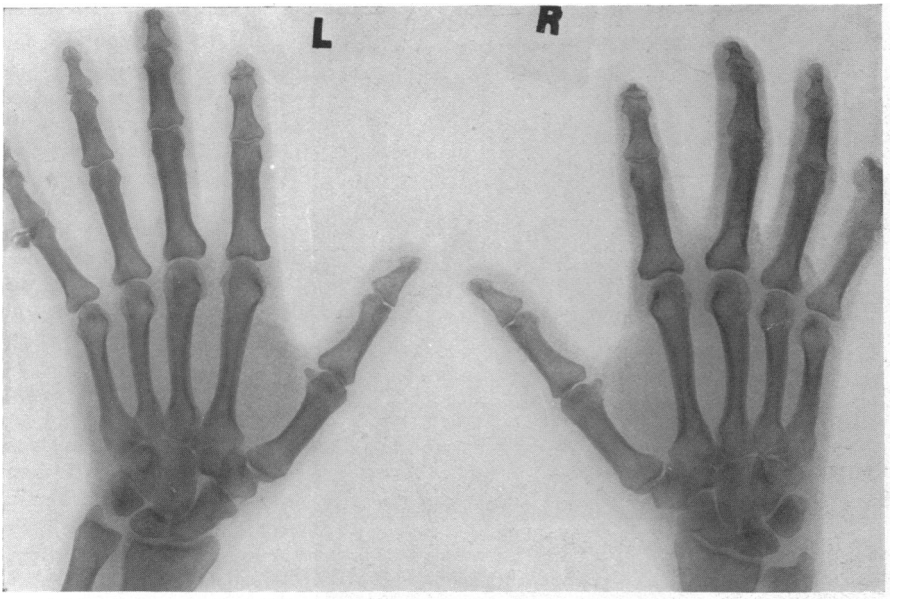

FIG. 2.—An X-ray of patient's hands showing the flattening of the terminal phalanges of index and middle fingers.

fingers, at other times they were red with the same white spots present on the tips. Her hands were always cold. They did not grow pale when held up in the air, but became cyanotic when hung down. There was no sign of organic obliteration in her radial arteries. Her *feet* were cold, moist and clammy. Most of the toes were dead-white in color except for several which were a dark mottled blue. There was a slight swelling of the right fourth toe, the dorsal aspect of which was habitually shiny and was covered in places with scaly cornifications. This, the patient explained, was the remains of a sore spot which occurred three to four weeks before. *After hanging her legs over the edge of the bed they both became intensely blue.* X-ray of the hands showed portions of the terminal phalanges of both index fingers and of the right middle finger missing. The bones elsewhere and those of the feet were normal. Photographs of her hands and feet are shown in figures 1 and 3, and X-rays of her hand in figure 2.

During nine days' stay in the hospital the patient had daily application of Esmarch's tourniquet to her right arm, three times for three minutes at a time with about five minutes in between each application (see Cushing, 1902). After several days the "flush," on release of the tourniquet, passed rapidly down the right upper extremity to the metacarpophalangeal joint, then more slowly to the tips of the fingers. During the first days in

which the tourniquet was used, the tips of the fingers were not affected by the flush, and the patient felt that this régime had made her right hand more comfortable during the day. Doctor Cushing also prescribed a hot toddy of brandy every morning (before arising). With due allowances for mental concomitants, it was obvious to the patient and to those who examined her that the brandy diminished the frequency and severity of her ischæmic attacks for a period of at least two hours after it was taken. She was accordingly discharged with directions to continue the tourniquet and morning hot toddies.

FIG. 3.—Patient's lower extremities before operation.

Second Entry.—Four months later (February 24, 1927) the patient returned, and reported that though the hot toddy-tourniquet régime had made her more comfortable she was still having a great deal of pain, especially in her right arm. She was accordingly readmitted, and physical examination at this time was as before except that several new small sloughing sores had formed on her fingers (second and fifth on the right). On March 2, 1927, Dr. John Homans carried out a periarterial operation on her right radial artery. During this manipulation the artery shrunk so that no pulsation could be felt. Following the operation her skin temperatures were carefully studied with galvanometer and thermocouple. No material alteration in the temperature of her hands was made out. From subsequent observations it was evident that the operation had accomplished nothing.

Third Entry.—Patient returned to the hospital for further observation on April 9, 1927, and as Dr. Norman Royle of Sydney was visiting Boston at that time, it seemed desirable to give the patient the benefit of a right-sided cervical ramisectomy, and Doctor Royle was accordingly invited to make the operation.

Pre-operative Examination.—The patient was studied carefully by three observers prior to operation, but only such findings will be recorded here as proved of significance to her post-operative picture.

Eyes.—Pupils were equal, regular, large, and reacted normally to light and to accommodation. Extra-ocular movements normal. No strabismus, ptosis or enophthalmus. Ophthalmoscopic examination showed sharply-outlined discs and unusually small arteries, in places being almost thread-like. The calibre of the retinal vessels was equal on the two sides.

Peripheral Pulses.—Various observers noted periodic fluctuations in the amplitude of her peripheral pulses. One examiner made the following note. "Her radial and ulnar pulses are equal and full on the two sides, though from time to time their intensity varies considerably. The femoral, popliteal and posterior tibial pulses were palpable on both sides, though the posterior tibial was felt with difficulty on the right. On one occasion the right posterior tibial was not palpable at all, while on the left it was vigorous. The dorsalis pedis could not be felt at 4 P.M., April 9, though at 3 P.M. when the patient was out of bed, Doctor Homans stated that he could feel it readily, and Doctor Royle had felt it the day before. At 9 P.M., April 10, the right posterior tibial was again impalpable."

Blood Pressure.—As there was some diversity of opinion concerning her blood pressure readings, they were taken on several occasions, and the same observer found them to vary from ten to twenty points even when taken in the same limb with patient prone. This was probably to be associated with the varied intensity of the pulse. There was also marked discrepancy in her blood pressure as determined in her leg and in her arm. Thus, on April 9, between 4 and 5 P.M. the following readings were obtained: right arm, 100/70; 95/60; 90/45; left arm, 90/70; 80/40; 95/50. At 9 P.M., April 10, left leg (popliteal space), 160/105; 155/110; 160/100; right leg (popliteal space), 140/75; 145/80; 135/78. The arms taken immediately afterward gave the following readings: right arm, 95/60; 90/55; 98/55; left arm, 85/50 on three occasions.

Extremities.—The fingers of the two hands had changed but little since the conditions described in the first entry. The middle three fingers were cold, shiny and stiff, and during ischæmic spasms looked like tallow candles. Both index fingers showed marked evidence of atrophy of the terminal phalanx with necrosis of the nail. Pain and temperature perception was greatly diminished in the terminal phalanges. It was noted in the feet that any slight manipulation tended to bring on an attack of cyanosis.

Cutaneous temperature readings with thermocouple-and-galvanometer technique were made of face, trunk and extremities before and on several occasions after operation. These findings are recorded below in Table I. It will be noted that prior to operation, temperature in corresponding points on the two sides of the body were nearly equal. Thus the average temperature of five points on the feet was 31.3 on each side (April 10th).

Reflexes: Biceps, triceps, knee and ankle jerks were all equal and rather unusually active. Doctor Royle called our attention to the fact that when the patient sat on the edge of a table with her legs hanging pendant, the phase of relaxation of the jerk on each side was somewhat more prolonged than that of a normal individual under the same circumstances. The biceps jerks also were somewhat slow to relax, and by successive taps on the tendon at three to four per second the arm became completely flexed at the elbow, while in a normal individual it was not possible to produce such fusion of separate tendon responses. Kymographic records were obtained of the knee jerks, but owing to inaccuracies attendant upon records in which the inertia of the leg must be overcome, the measurements of duration of the response are of little value. Slow-speed cinematograph films were also taken of her knee jerks.

Muscular Strength.—With an ergometer patient was able to squeeze 25 kilos with her right hand and 25 to 27 with her left. Power was equal in both lower extremities.

Operation (April 11, 1927, Doctor Royle and Doctor Horrax).—With the patient on her back, head rotated to the left, an incision two inches long was made just above the clavicle at an angle with it of about 45 degrees. On separation of the muscles the brachial plexus was exposed, and the rami running from the fifth, sixth, seventh and eighth trunks to the superior cervical ganglion were divided. The rami from the first thoracic trunk were also divided. The patient was then turned on her left side with her flank elevated in the "kidney" position. Through a long incision extending from the costovertebral angle to the anterior superior spine, the latissimus dorsi was divided and the peritoneum reflected inward. The rami of the second, third, and fourth lumbar ganglia were then exposed and divided and the lower end of the sympathetic trunk was also severed.

Post-operative Course.—Patient stood the operation well and made a prompt post-operative recovery. The lumbar rami were sectioned at 3:07 P.M. Ether was discontinued at 3:15, and at 3:30, Doctor Cushing tested her knee jerks and observed that while the left was still brisk and prolonged, the right was noticeably brief and difficult to elicit. At 3:40 it was noted that the circulation in the right fingers appeared somewhat better than in the left, and when the finger-nail was pressed color returned in three seconds on the right and in five seconds on the left. At 3:41 *both* posterior tibial pulses were equal and ample, while immediately before operation the right posterior tibial could scarcely be felt. At 3:46 blood pressure of right arm was 108/70; left, 100/60. At 3:55 inequality of knee jerks was much more marked than at 3:40, the right being very difficult to elicit. The toes of the right foot were much pinker than those of the left. At 4:01 Doctor Royle demonstrated the difference in "tonus" of the two limbs by placing his hand in the popliteal space and raising the knee quickly. On the operated side the heel tended to drag along the operating table. On the normal side a contraction was evoked in quadriceps by the sudden elevation of the leg, and this caused the heel to be raised from the operating table for one or two seconds before it fell back. This difference between the two sides was striking and continued to manifest itself throughout her entire stay at the hospital. At 5:00 P.M. she was taken to the galvanometer room for readings of skin temperature on the two sides, where it was found that the temperature of her right hand was of an average of 1.5 degrees higher than that of the left. In the feet, however, a difference of 3.2 degrees was evident *just two hours after the rami had been cut* (left foot, 31.0°; right foot, 34.2°; average of five positions on each foot).

The reflex changes observed immediately after operation still persisted the next day. On testing the resting tension of her quadriceps tendon by gently moving the patella laterally, it was found that the left was much less freely movable than the right, indicating a well-marked difference in the resting tonus of the two quadriceps muscles. Patient complained of weakness in her right arm with pain in her shoulder. As later observation showed, the weakness and pain of right upper extremity increased for several days and persisted for three to four months, indicating that some of the roots of her brachial plexus had been traumatized during the operation, probably by retraction. The upper portion of her right trapezius and the belly of the supraspinatus muscle underwent noticeable atrophy, showing that the functional activity of the spinal accessory nerve had also been impaired. For a month she was able to squeeze only 5 kilos on the ergometer with her right hand, as compared with 25 to 30 in her left (and 25 in her right before operation). On June 2 she squeezed 10 kilos with her right hand, on June 22, 16 kilos, and on July 27, 25 to 29 kilos, indicating that by that time her motor power had completely returned. On September 14 she squeezed 31.5 kilos with her right hand.

Several days after operation it was observed that she had developed a marked right-sided Horner's syndrome. The right pupil was 2 mm. smaller than the left, the right globe was less turgid than the left and had sunk noticeably into the orbit. On the 13th of April there was a difference of 3° in the temperature of her two cheeks, but this gradually passed off. No difference in the color of her two cheeks was noted on the record, though it may have existed.

In the preceding notes we have described briefly the immediate effects of the patient's right-sided cervical and lumbar ramisectomy. She was under daily observation in the hospital until discharge (April 26, 1927), after which she was seen and carefully studied at intervals of six weeks during the year. She was last seen on March 30, 1928. The findings of particular significance are those which persisted throughout the year, and we may summarize them as follows:

Circulatory Changes.—The operation of ramisection was carried out primarily to improve the circulatory condition of the patient's extremities. Subjectively patient is now unaware of any difference in the temperature of her two upper extremities. She continues to wear mittens around the house and rejoices now that warm weather has once more commenced. Her fingers still become periodically blue and purple and are extremely

tender, especially in the morning on awakening. In her lower extremities, however, she is conscious of very marked difference in temperature, the right being warmer and more comfortable. Since her operation she has had *no attacks of cyanosis or pallor of her right foot,* but she still continues to have attacks of ischæmia with marked cyanosis in her left foot five to six times a day, and whenever she sits on the edge of a chair or a table with her legs hanging pendant. The patient states that at night in bed she can always feel the difference in temperature between her two legs and warms up the left one with her right. Seven months after the operation she had a small accidental abrasion of her right inner malleolus which healed without scarring after two weeks.

Objectively (a year after operation) the circulatory condition of the two upper extremities showed no obvious difference, the color of the right being if anything a little paler than the left, and the right fingers are stiffer than the left. Radial pulses were equal on the two sides, but from time to time both varied somewhat in intensity. In her lower extremities, on the other hand, there is marked difference in color and moisture, the right being pink and dry, the left usually cyanotic and moist, especially if exposed. When patient was last seen she had, while sitting on the edge of the bed, a typical ischæmic spasm in the left foot with marked cyanosis and slight pallor at the ends of the toes. The posterior tibial pulses could be felt on both sides, but were stronger on the right, especially during the ischæmic attack of the left foot. The dorsalis pedis pulse could not be felt at all on the left and was just perceptible on the right.

Blood Pressure.—Prior to patient's operation a year ago it was noted that the blood pressure of the two arms varied and a great difference in pressure was noted between the arms and the legs. This afternoon the right arm was 95/60, left 90/55; right leg 150/80, left leg 155/95. All these readings were taken with the patient lying prone with her clothes off.

TABLE I.

Temperature of Corresponding Points on Two Sides of Body Before and Shortly After Right Cervical and Lumbar Ramisectomy.

Position	April 10 *		April 11 †		April 13 ‡	
	Right	Left	Right	Left	Right	Left
Cheek	32.4	31.4	31.9	29.6	34.4	31.6
Chest	34.1	34.4	34.1	33.1	35.1	33.1
Upper arm	32.4	32.1	33.1	31.7	31.4	29.6
Olecranon	34.2	34.2	34.8	33.6	33.4	32.9
Finger-tips 1	29.0	29.5	31.8	31.1	27.3	27.2
Finger-tips 2	27.3	27.6	32.0	30.4	27.5	27.6
Finger-tips 3	26.4	26.3	31.6	30.0	26.3	26.5
Finger-tips 4	26.5	26.0	31.8	29.6	26.0	27.3
Finger-tips 5	26.3	26.6	31.6	29.5	27.2	28.0
Palm	32.9	32.8	33.6	33.4	29.1	31.4
Dorsum hand	30.6	29.8	32.4	32.0	29.0	29.7
Knee	34.2	33.9	33.3	31.3	33.5	31.2
Instep	31.2	31.8	33.5	30.7	33.5	29.3
Inner malleolus	32.3	32.8	34.7	32.4	34.3	30.6
Outer malleolus	32.1	31.8	33.8	31.7	33.7	29.4
Dorsum foot	—	—	34.5	30.4	34.4	28.9
Great toe	30.8	30.3	34.5	29.6	34.7	27.9

* April 10, 1927, 24 hours before operation.
† Two hours after operation.
‡ Corresponding determinations were also made on April 20 and 26, with substantially the same results

*Cutaneous Temperature.**—Prior to operation the temperatures of corresponding points on the two upper and the two lower extremities were approximately equal. Within two hours after operation there was a slight difference in the temperature of the two hands and a marked difference in the two feet. Illustrative values from a large number of consistent readings before and shortly after operation are given in Table I.

The following observations on skin temperature made a year after operation may be given as recorded in her clinical history.

TABLE II.

Showing Approximate Equality in Temperature (in Degree Centigrade) of Corresponding Points on Two Sides of Body After Patient Had Been Covered for One Hour (March 30, 1928).

Position	Right	Left	Difference †
Forehead	33.5	33.8	0.3 L
Temple	34.2	34.8	0.6 L
Cheek	35.3	35.5	0.2 L
Clavicle	34.9	34.6	0.3 R
Chest	35.3	35.5	0.2 L
Upper arm (dorsum)	34.0	34.0	0.0
Olecranon	35.4	35.5	0.1 L
Vena cubiti	34.5	34.6	0.1 L
Lower arm (dorsum)	34.4	34.6	0.2 L
Finger-tips 1	32.2	32.1	0.1 R
Finger-tips 2	31.8	30.8	1.0 R
Finger-tips 3	30.8	30.2	0.6 R
Finger-tips 4	30.7	30.1	0.6 R
Finger-tips 5	31.9	30.2	1.7 R
Thenar	33.7	33.7	0.0
Hypothenar	34.9	34.8	0.1 L
Palm	35.0	34.8	0.2 R
Dorsum of hand	33.6	33.4	0.2 R
Knuckles 1	33.4	33.8	0.4 L
Knuckles 2	32.9	32.7	0.2 R
Knuckles 3	32.5	33.0	0.5 L
Knee	33.5	33.4	0.1 R
Calf	35.4	34.9	0.5 R
Inner malleolus	34.2	33.7	0.5 R
Outer malleolus	34.4	34.3	0.1 R
Dorsum of foot	33.5	32.8	0.6 R
Instep	34.1	33.9	0.2 R
Toes 1	34.3	33.8	0.5 R
Toes 2	34.4	33.8	0.6 R
Toes 3	34.2	33.6	1.6 R
Toes 4	33.5	32.7	0.8 R
Toes 5	32.5	32.6	0.1 L

March 30, 1928. Patient came to hospital this afternoon at 1:30 and was immediately put to bed, clad in a hospital nightgown, in the galvanometer room. The room

* All determinations were made with the thermocouple recently introduced by F. G. Benedict (1928) for study of skin temperatures. Readings can be made within six seconds of the time the metal junction is placed on a given area of skin. The apparatus was loaned to the hospital by the Carnegie Nutrition Laboratory, and I wish to record my indebtedness to Doctor Benedict for his personal supervision of the early observation and for his generous criticism of results.

† R.= right higher than left: L.= left higher than right.

temperature at that time was 26° (Centigrade), and she was well covered and directed to keep her arms and legs under the bed clothes for an hour. She was watched through a window, and coöperated admirably. Skin temperatures were made by means of the Benedict thermocouple, as were previous determinations, and full precautions were taken to insure accurate readings of standard temperatures and equal exposure of all corresponding points which were recorded on patient's body. Readings were always made from

TABLE III.

Showing Difference in Temperature of Corresponding Points on Two Sides of Body After Alcohol Rub and Exposure to Room Temperature (25°) for Ten Minutes.

Position	Right	Left	Difference
Forehead	33.4	34.5	1.1 R
Temple	33.7	34.1	0.4 L
Cheek	34.6	35.1	0.5 L
Clavicle	34.1	34.3	0.2 L
Chest	35.3	34.8	0.5 R
Upper arm	32.0	31.0	1.0 R
Vena cubiti	33.7	34.0	0.3 L
Olecranon	34.0	34.3	0.3 L
Finger-tips 1	32.9	32.2	0.7 R
Finger-tips 2	31.7	28.3	3.4 R
Finger-tips 3	29.0	28.3	0.7 R
Finger-tips 4	29.5	29.8	0.3 L
Finger-tips 5	30.3	29.9	0.4 R
Thenar	32.8	33.1	0.3 L
Hypothenar	32.9	33.3	0.4 L
Palm	33.8	34.8	0.1 L
Dorsum of hand	32.5	32.8	0.3 L
Knuckles 1	32.2	33.4	1.2 L
Knuckles 2	32.8	32.2	0.6 R
Knuckles 3	32.7	32.2	0.5 R
Knee	30.8	30.2	0.6 R
Shin	32.5	31.9	0.6 R
Calf	34.4	33.6	0.8 R
Inner malleolus	31.1	31.0	0.1 R
Outer malleolus	31.4	30.2	1.2 R
Dorsum of foot	32.8	30.4	2.4 R
Instep	33.5	32.2	1.3 R
Toes 1	33.8	33.0	0.8 R
Toes 2	31.9	30.0	1.9 R
Toes 3	31.8	29.0	2.8 R
Toes 4	31.9	28.6	3.3 R
Toes 5	33.3	28.3	5.0 R

right to left; that is, a point selected for measurement on the right cheek was immediately followed within twenty seconds by readings from a corresponding point on the left cheek.

Observation 1.—After patient had been well covered for an hour, readings were taken at corresponding points on the two sides of her body, as indicated in the above table. Each point was uncovered just before the reading was made, and it was observed that a fall of as much as .5° C. might occur within one minute after a given point was exposed. In reading the successive finger-tips, those of the fifth finger, being last read, were colder than those of the first since they had been exposed for a somewhat longer time; but each corresponding finger on the two sides had been exposed for approximately

the same length of time when the reading was made. Because of the tenderness of patient's fingers and toes, it was found impracticable to obtain such readings from beneath the bed clothes. The absolute values obtained for a given point are indicated in Table II, the actual figures having been calculated after the observations were made.

The determinations in Table II were made between 2:35 and 3:00 P.M. It is perhaps worthy of note that points on face, body and upper arm are almost exactly equal, while the finger-tips on the right are on an average .8 of a degree warmer than those on the left. Similarly the temperatures of the right foot are slightly greater than those of the left, even though patient had been covered for an hour.

Observation 2.—In order to determine which side was most affected by artificially induced heat loss, patient's arms and legs were given an alcohol rub for five minutes and she was then permitted to lie exposed to room temperature for ten minutes (room temperature 25° C.), and then the following series of observations were taken. It is worthy of note that when these observations were commenced the left lower extremity was slightly cyanotic, while the right continued pink.

The readings given in Table III indicate that after equal exposure of the two sides the fingers of the right hand tend to be very slightly warmer and the toes of the right foot very markedly warmer than those of the left. It is interesting that the difference in temperature of the toes is more marked for the outer toes than for the inner; corresponding points on the feet other than the toes show similar difference.

Observation 3.—Patient lay prone and quiet during the first two observations. At 3:45 she was permitted to sit up on the edge of the bed so that her feet hung pendant. Five minutes later an attack of cyanosis was evident in her left foot, and in view of this readings were again taken on the toes of the two feet. In Table IV the results of these observations are given. It will be seen that there was an average of 3° C. difference in the temperature of the two toes at this time, and the color difference was striking. This completed the series of thermal observations, the last being taken at 4:10 P.M.

TABLE IV.

Temperatures of the Toes During an Attack of Ischæmia of Left Foot.

Position	Right	Left	Difference
Toes 1	30.1	26.6	3.5 R
Toes 2	27.7	24.9	2.8 R
Toes 3	28.2	25.1	3.1 R
Toes 4	28.0	25.0	3.0 R
Toes 5	30.8	25.6	5.2 R
"Ball" of foot	31.0	28.4	2.6 R

The other changes in the case which have persisted since operation may now be mentioned.

Horner's Syndrome.—The right pupil has continued about 1–2 mm. smaller than the left throughout the year. A slight difference in size of the two palpebral fissures is still noticeable but enophthalmos on the right has almost entirely vanished. Except at the beginning there has been no obvious difference in the temperature of the two sides of the face, nor has there been any difference in color. On July 27, 1927, the following note was made concerning her fundi. "Careful examination showed clearly-defined disc margins and normal physiological cupping. It is quite evident, however, that there were more small arteries crossing the fundus on the left side than there were crossing the right fundus. One gained the impression that the retinal arteries on the right side were somewhat larger than those on the left." Examination a year after operation showed that this was still true, the difference being still marked, especially as regards the veins.

In passing, we may note that the difference in size of the retinal vessels is a feature of sympathetic paralysis to which Horner (1869) called attention in his original description of the syndrome. The present case is of interest from the anatomical standpoint because only the first dorsal ramus was severed. The symptoms were definitely less marked than in cases of complete sympathetic paralysis. The pupillary constriction was perhaps as much as one would anticipate in a case of complete paralysis, but the enophthalmos was less marked and less persistent and there was no obvious vasomotor change in the face. This suggests that in this instance at least the control of the iris comes chiefly from the first thoracic ramus, and that the vasomotor control of face and conjunctivæ, normally associated with the Horner syndrome, comes from rami lower down.

Sensory Disturbances.—While taking blood pressure (March 30, 1928) it was noted that compression of the right leg was much more painful to the patient than compression of the left. She remarked that since her operation the right leg had continued to be rather "tingly" and somewhat more sensitive and hyperæsthetic to touch than the left. She also remarked upon this when I was testing her knee jerk, the right patella seeming much more tender to her than the left. Such hyperæsthesia may be in some way associated with disturbance of peripheral circulation resulting from ramisectomy.

Another interesting sensory phenomenon is that all operative incisions have remained markedly hyperæsthetic, even though healing occurred *per primam.* The cicatrix of her periarterial incision is still exquisitely tender. This is also true of her cervical incision, but less so of her lumbar. I have no explanation to offer for this rather striking fact.

Reflex Changes.—Recent discussion concerning the relation of the sympathetic system to functional activity of skeletal muscle renders the reflex changes observed in this case interesting and important. Twenty-three minutes after the lumbar rami were severed (when the first examination of her reflexes could be made) there was an obvious difference in the character and briskness of the patient's knee jerks which, immediately before operation, had been, as far as we could determine, identical. The depression of the knee jerk on the operated side, though it became less marked with the lapse of time, persisted for a year after the operation, and it is still noticeable. When the patient lies prone and the resting tension of quadriceps is tested by moving the patella laterally, it is obvious that the quadriceps on the operated side is under considerably less resting tension than on the normal side. This difference was evident even during sleep. The difference in the physiological condition of the muscles on the two sides was brought out very strikingly in the following way. When the patient was placed on a table so that her legs hung pendant, the right knee jerk, though less brisk than the left, was followed by seven or eight pendulous swings of the leg before coming to rest, while on the left side the jerks, though more ample, caused the leg to swing only two or three times before coming to complete rest. The relaxation on the left continues to be much slower than on the right. This difference between the two sides has been observed on at least twenty occasions since her operation. Moreover, when, instead of eliciting the knee jerk, the legs were lifted to a horizontal position and released suddenly, the patient's attention being at the time otherwise occupied, the right limb swung ten or twelve times before coming to rest, while the left was quiet after four or five swings. These differences have diminished slightly during the course of the year, but are still marked.

Immediately after operation the right ankle jerk was less brisk than the left; this difference has also persisted and is quite as striking as the knee jerk. It is difficult, however, to know whether there is less resting tension in the right gastrocnemius muscle than the left, for there is nothing corresponding to the patella with which to measure the resistance to previously imposed lateral deviation.

In the upper extremity the existence of a post-operative brachial neuritis for three or four months after the operation rendered comparative observations upon the biceps and triceps jerks of little value. However, after her motor power had completely recovered, as was evident on July 27, 1927, the right biceps jerks have continued during the year to be less brisk than the left, and this was true also of the response to triceps.

DISCUSSION

The Relation of the Sympathetic Nerves to Muscle Tonus.—Liddell and Sherrington (1924, 1925) have given reasons for believing that the stretch reflex is the mechanism by which the tonus of skeletal muscle is maintained. In another paper the present writer (1928*a*) has offered clinical evidence pointing in the same direction. Since the knee and ankle jerks are fractional manifestations of the stretch reflex, they serve as indices of the tonic condition of the muscle from whose tendon they are elicited.* One may conclude, therefore, from the diminished knee jerk following immediately upon sympathectomy that the tonus of the quadriceps has been notably diminished in this case as a result of the operation. The greater tendency of the right leg to swing when hanging pendant, and the relative flaccidity of the right patella give further evidence of the same thing.

The fact that sympathectomy leads to a diminution in tonus of human beings is important and calls for comment. The same phenomenon has been observed repeatedly in well-controlled observations upon animals, notably by Kuntz and Kerper (1926), and also in man by Kuntz (1927). It is to be noted, however, that tonus *though diminished is not completely absent,* which is true also of spastic cases following ramisectomy (Royle, 1924; Steele, 1927). This in my opinion definitely precludes the theory that the sympathetic system governs muscle tonus. One might suggest that sympathectomy causes an increase in the threshold of the stretch reflex. Reasons have been offered elsewhere for looking upon the muscle spindles as the chief afferent end-organs of the stretch reflex (Fulton, 1926, 1928*a*). But alteration of the innervation of muscle-spindle's intrafusal fibres cannot well be invoked to explain the reflex changes following upon ramisectomy, since Hinsey (1927) and Hines and Tower (1928) have recently proved that the intrafusal fibres receive somatic innervation, and not sympathetic as some have supposed. Consequently some secondary factor such as altered blood supply or, less likely, the interruption of accessory sympathetic fibres which are supposed to supply skeletal muscle fibres, may play a rôle in producing this result. This interpretation, moreover, does not require the postulation of a vague dual mechanism of muscular activity, and it is compatible with the view, well supported experimentally, that the stretch reflex is responsible for the maintenance of muscle tonus.

Circulatory Changes.—It is commonly believed that the circulatory alterations which follow upon sympathectomy gradually become compensated (see Lewis, 1927). In the present case, however, there has been very slight change in the circulatory condition of the right foot during the year; in fact the foot is about the same now as it was two hours after ramisectomy. The clinical condition of her hands was little affected by the operation although there has

* This generalization cannot be applied unrestrictedly, for in the spinal animal knee jerks may be present in a relatively atonic muscle. This is a somewhat special case, discussed at length elsewhere (1926, Chs. XI and XXI), and does not affect the present argument.

been a slight and probably significant elevation of temperature of the right hand. The ischæmic process had evidently progressed so far on that side that removal of the sympathetic fibres was without effect. This is perhaps not surprising in an advanced case of Raynaud's disease, since in such instances the capillary walls become constricted (Lewis, 1927, p. 283) and probably fibrosed beyond repair.

The fluctuation in the blood pressure and pulse of the present case is worthy of note. On several occasions the posterior tibial pulse seemed to disappear while being palpated, and its failure ushered in an attack of cyanosis of the foot. Doctor Homans' observation that the radial artery became pulseless during manipulation is also significant. All these facts strongly suggest that the vascular spasm in Raynaud's disease involves the great vessels of the extremities as well as the small. The capillary fibrosis which eventually occurs is probably a secondary result of longstanding ischæmia.

The fact that ramisectomy has led to definite improvement in an extremity which had only lately become involved by the ischæmic process strongly favors the view, well supported on other grounds, that Raynaud's disease is due primarily to instability of the sympathetic vasoconstrictor centres of the extremities. Whether such factors as a constitutional tendency to abnormal agglutination of corpuscles in the peripheral capillaries* (Iwai and Meisai, 1925, 1926) also operate in the production of Raynaud's disease, must be left open. In view of the well-recognized fact that emotional disturbances tend to aggravate the symptoms in cases of Raynaud's disease, it is difficult to believe that the malady is due primarily to a defective melieu of the corpuscles. But the improvement following ramisectomy is not a logical objection to the

* Iwai and Meisai (1925) found that citrated blood of a patient with Raynaud's disease invariably clots if allowed to stand in a water-bath at 0° C. for ten minutes, the clotting taking place no matter how vigorously the receptacle was shaken. On again warming to 31° C. or higher the clot so formed redissolves. The patient's serum acted equally well on the patient's own corpuscles washed with normal saline and on the washed corpuscles of any other normal individual in a dilution of 1–1,000, but if agglutination were allowed to take place and the supernatant serum removed, it was found no longer to have any agglutinating action on the patient's cells or those of a normal control. If erythrocytes, after agglutination with patient's serum, were washed three times with normal saline at a low temperature and then with saline at 33° C., the last washing still showed the agglutinating power of the original serum. To prove that this reaction might take place equally well in a capillary vessel, the blood was run through a fine capillary loop warmed in a water bath. This it did with ease until the tube was cooled when agglutination and plugging of the tube took place, the agglutination being such as to show in the tube areas of closely clumped corpuscles separated by areas of clear serum. On warming, the corpuscles re-dissociated and the flow of blood was restored. The same phenomenon was seen in the capillaries of the patient by focusing a microscope on the patient's cornea and bathing it with saline cooled to 10° C., the agglutination being accompanied by pain. Further to prove the theory that *lowering of the temperature* alone caused the symptoms of the disease, a piece of ice was placed on various parts of the patient long enough to obtain a lowered temperature in each part tested. All regions of the body (*e.g.*, the abdomen) gave the typical picture of cyanosis and pallor so characteristic of the malady as observed in the extremities. This work has since been further confirmed by similar experiments by the same investigators on another case of Raynaud's disease (1926).

hypothesis of the Japanese workers, since increase in diameter of the peripheral vessels following constrictor paralysis would offset an abnormal tendency toward intravascular agglutination. The view of Iwai and Meisai suggests that Raynaud's disease and the Buerger's syndrome have much more in common than has previously been supposed.

Many fresh problems concerning the vasomotor control of the skin have been opened by the publication of Sir Thomas Lewis's monograph (1927) on the cutaneous blood-vessels, and this case has been analyzed as far as possible in the new light of his stimulating investigation. One must, however, await the study of further cases of Raynaud's disease before it will be possible to consider the relation of this malady to the broader problems of the normal cutaneous circulation.

SUMMARY

A case of Raynaud's disease is described in which ischæmic symptoms of the four extremities were equally advanced on the two sides of the body. A right-sided cervical and lumbar ramisectomy was carried out, and immediately after the operation all deep reflexes, which before had been equal, were markedly depressed on the operated side. In the right lower extremity the pulse became more full and the right foot 3° (C.) warmer than the left. There was also a right-sided Horner's syndrome.

The patient has been carefully followed for a year and the altered reflexes, Horner's syndrome and thermal differences have persisted during that period. She has had no further symptoms of ischæmia in her right foot, but her right hand was not obviously benefited by the operation. There has also been a permanent and well-marked diminution of the resting tonus of her right lower extremity since the operation.

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