SYMPATHECTOMY FOR OBLITERATIVE ARTERIAL DISEASE; INDICATIONS AND CONTRAINDICATIONS*

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THE PURPOSE OF SYMPATHECTOMY in the treatment of peripheral vascular disease is manifestly to abolish the vasomotor tone in order to improve the circulation and to allow development of collateral blood vessels. The greater the impairment of circulation by vasoconstriction, the better are the results to be expected from sympathetic denervation. In those cases, however, in which vasomotor tone is low, sympathectomy may be of little value. In addition, widespread sympathectomy, may actually produce harm by lowering the peripheral resistance, especially in cases where there is severe arterial obliteration. This paper presents an evaluation of sympathectomy in the treatment of obliterative arterial disease, and a discussion of the indications and contraindications for the use of this form of treatment.

The peripheral circulation serves a dual function. By means of blood flow through the capillaries the nutrient demands of the tissues are met. In addition, the peripheral circulation to the extremities in man serves the purpose of regulating the body temperature. In accordance with the requirements for conservation or dispersal of heat, the circulation to the extremities is reduced or expanded. This dual function of the circulation is mediated by a dual control. With vasomotor nerves intact, the circulation through the distal parts of the extremities can be shown to be influenced reflexly through stimulation or inhibition of the sympathetic nerves. After removal of this vasomotor control by sympathectomy the circulation is dependent upon the metabolic requirements of the tissues.[1]

In view of this dual function and dual control, the presence of a dual anatomic structure is to be expected. That such is the case was shown originally by the researches of Sucquet[2] and Hoyer.[3] They first described the neuromyo-arterial glomus, a vascular arrangement quite distinct from the nutrient capillaries, which, in man, was found chiefly in the distal parts of the extremities. The studies of E. R. Clark[4] on the rabbit ear provided knowledge of the structure and activities of these arteriovenous anastomoses in the experimental animal. Understanding of the physiology of these structures was made possible through the investigations of Grant[5] and Bland.[6] By means of these communications between the terminal arteries and the small veins of the extremities, blood can rapidly be shunted from the arterial to the venous system

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without passing through the capillary network. Grant[5] showed that these communications were under vasomotor control since stimulation of the sympathetic nerves caused them to close, as did the injection of adrenalin. Clark[4] observed that injury to the nerve caused the arterio-venous anastomosis to remain continuously dilated for 10 to 14 days. After that time, the smooth muscle apparently acquired tonicity and the lumen thereafter was maintained at a narrow calibre. This observation may help to explain the evanescence of cutaneous vasodilatation after nerve injury, although it fails to account for the persistent

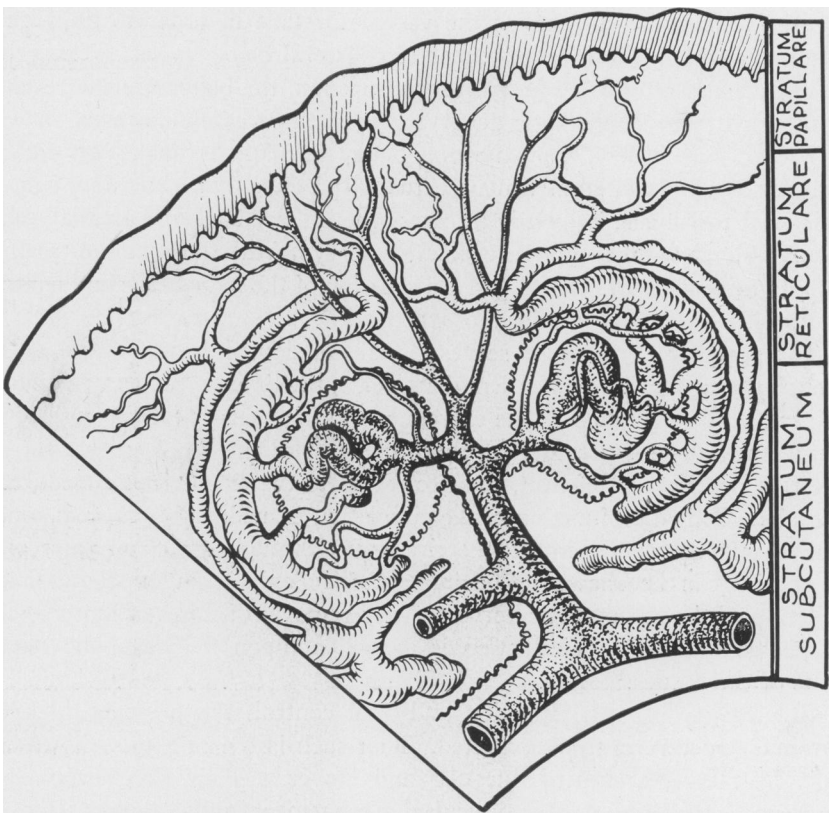

FIG. 1.—Anatomic arrangement of arteriovenous anastomoses as found in the ventral surface of the digit. (Redrawn after Popoff. Arch. Path. 1934.)

and prolonged vasodilatation, especially in the lower extremities, which follows sympathectomy. From observations on experimental animals and man, it seems likely that the increased peripheral skin temperature which follows interruption of sympathetic impulses is mainly due to opening up of these arterio-venous communications.

Popoff[7] called attention to the significance of these arterio-venous anastomoses in peripheral vascular diseases after careful anatomic studies with reconstruction from serial sections. The anatomic arrangements are shown in Figure

1, which has been redrawn from Popoff's paper. He stressed the fact that when arterial blood passes directly into the veins without going through the capillary network, serious deprivation of the tissues may result. In addition, in thrombo-angiitis obliterans he described abnormal arterio-venous communications which might lead to a rapid dumping of the arterial blood into the veins. Figure 2 represents a schematic drawing of the A-V anastomoses taken from Popoff's original work. Microscopic changes in the veins led him to conclude that "Arterialization of the veins is evidently the result of adaptation of the veins to abnormal strain created by an uncontrollable flow of blood through the artero-venous anastomosis." In one patient he even went so far as to compare the oxygen saturation of blood obtained from a vein on the dorsum of the

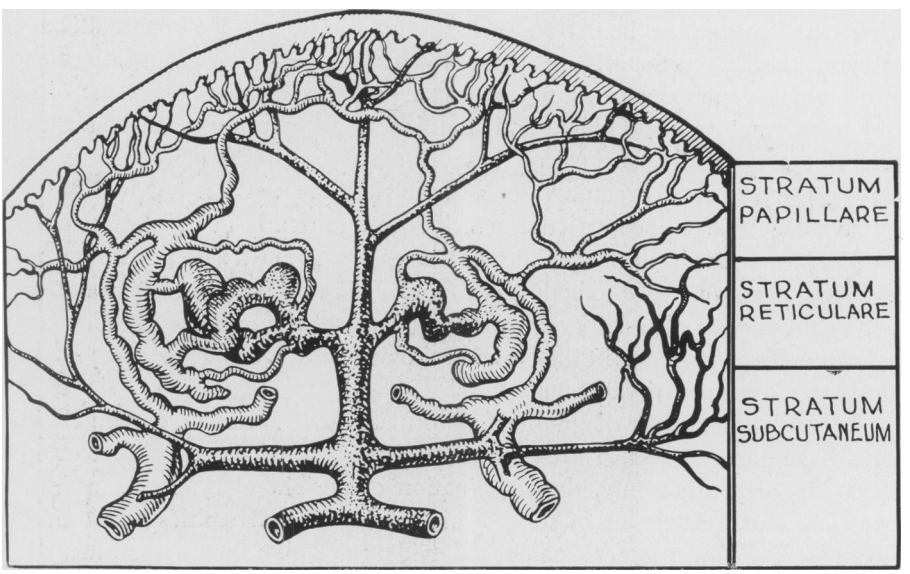

FIG. 2.—Diagram demonstrating two types of anomalous arteriovenous anastomoses found in thromboangiitis obliterans: the lateral type and the terminal type of anastomoses. (Redrawn after Popoff. Arch. Path. 1934.)

foot with that of blood simultaneously obtained from a forearm vein. As he expected in view of his anatomic studies, he found that the oxygen saturation of the blood from the veins of the foot was considerably higher than that of the blood obtained from the arm, suggesting that the blood in its passage from the arteries to the veins had not traversed the capillary loop. This observation was confirmed and extended by Harpuder, Stein, and Byer,[8] in a series of cases. Some of the highest oxygen values which they found were in cases in which the disease was the most advanced. They concluded that "shunt circulation, for practical purposes, is a loss as far as tissue metabolism is concerned." To Atlas[9] goes the credit for having suggested that the disastrous results occasionally encountered after sympathectomy in advanced arterial obliterative

disease were due to opening up of these small arterio-venous communications.

The chief indication for sympathectomy is abnormal vasoconstriction or vasospasm. In extreme cases such as the digital syncope of Raynaud's phenomenon, the diagnosis of this condition is simple, but it is far more difficult to arrive at a sound basis for making this diagnosis in the less severe cases.

Brown[10] was the first to approach the problem of placing vasomotor tone in man on a quantitative basis. He compared the rise in skin temperature of the digits with the rise in mouth temperature after the administration of typhoid vaccine. The change in the surface temperature of the digits gave an index of vasodilatation. Morton and Scott[11] used anesthesia, general, spinal or local, to abolish vasomotor tone. They designated the average maximum vasodilator response of undiseased arteries as "the normal vasodilatation level." White[12] was the first to use paravertebral injection of procaine to block the sympathetic nerves to the extremities as a test to evaluate the potential benefit of sympathetic ganglionectomy. The vasodilatation with rise in skin temperature which occurs upon heating the unaffected extremities or portions of the body was employed by Gibbon and Landis[13] to differentiate vasospastic from occlusive arterial disease. All of these vasodilatation tests are useful in estimating the degree of organic vascular occlusion, but they do not indicate the relative degree of vasoconstriction which is intermittently or constantly affecting the blood supply to the peripheral tissues. Vasoconstriction is the normal physiologic response of the body to cooling. It occurs both in normal patients and in those with diseased or injured blood vessels. The vasodilatation tests indicate only to what extent the peripheral blood vessels can dilate; they do not measure the degree of vasoconstriction.

In order to make the diagnosis of abnormal vasoconstriction, certain clinical signs have been utilized. In the selection of patients with intermittent claudication for sympathectomy, the combination of peripheral cyanosis, increased sweating, and constriction of superficial veins of the extremities was used by Freeman and Montgomery[14] as clinical evidence of high vasomotor tone. Experience with sympathectomy in obliterative arterial disease during the past five years leads us to re-emphasize the significance of these clinical signs of abnormal vasoconstriction. Possibly less attention is paid now than formerly to the prominence of the veins on the dorsum of the foot, since we have repeatedly observed patients whose veins were prominent, but in whom other signs indicated a high degree of vasomotor tone. Constricted veins, however, are still looked upon as good evidence of abnormal vasoconstriction. One further observation which is probably of significance is delayed blanching of the extremity on elevation. This delay in the drainage of blood from the foot may well be due to venous constriction and probably indicates concommitant arterial constriction, which sympathectomy is designed to relieve.

The vasodilatation test, as commonly performed, may not allow sufficient time for the blood vessels to dilate to their maximum capacity. This fact is suggested by the frequency with which it is noted that the rise in surface temperature following lumbar ganglionectomy exceeds the highest level obtained

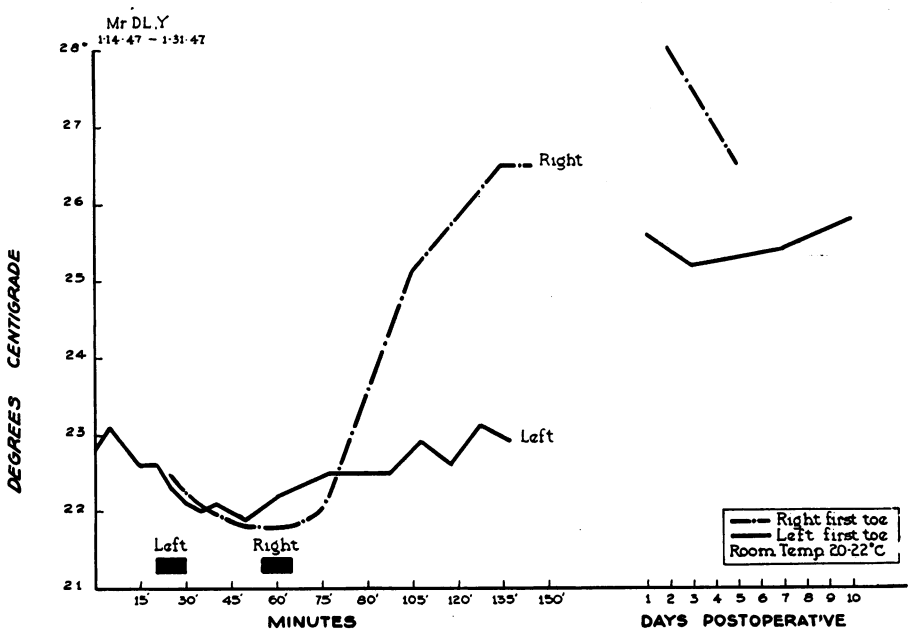

FIG. 3.—Skin temperature increase following lumbar sympathetic blocks and lumbar sympathectomies in a patient with thromboangiitis obliterans.

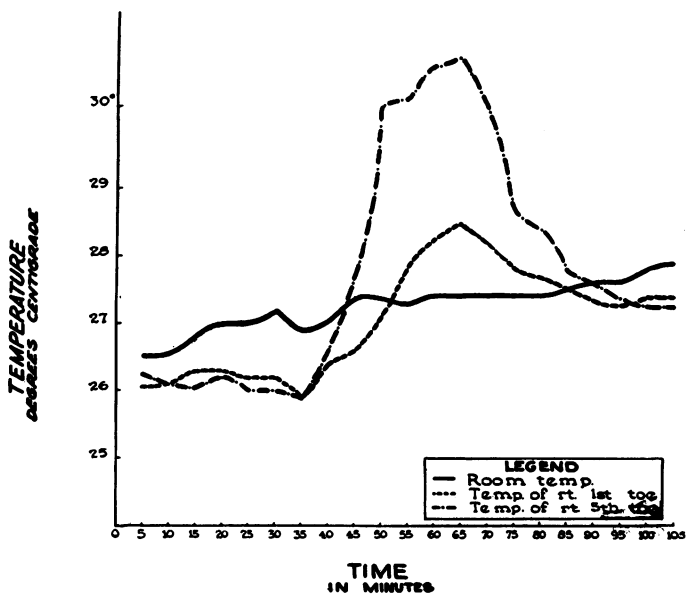

FIG. 4.—Skin temperature changes following right lumbar sympathetic block in patient with erythrocyanosis frigida.

during the vasodilatation test. Figure 3 shows the skin temperature increase following lumbar blocks in a patient with severe thromboangiitis obliterans. It can be seen that in the days following lumbar sympathectomies, the surface temperatures consistently exceeded those observed at the height of the vasodilatation tests. Subsequent studies on this patient have confirmed the value of the operations. We have come to place great reliance upon the subjective improvement, noted by the patient after temporary removal of vasomotor control by blocking the sympathetic ganglia with procaine, as an indication for sympathectomy. The indications for sympathectomy and the results obtained in a small group of patients with obliterative arterial disease are shown in Table I.

Failure of the skin temperature to increase to normal levels through vasodilatation after release of vasomotor tone does not necessarily indicate that the vasomotor tone is low. The arterial obstruction may be of such severity that it is impossible, even with the opening up of collateral channels, to deliver sufficient blood flow to the distal parts of the extremity to raise the surface temperature to normal levels. On the other hand, vasoconstriction may further reduce the circulation to the tissues. Previously, many patients were excluded from the benefits of sympathectomy, because of the failure of the surface temperature to reach normal high levels following temporary interruption of vasomotor control. In the case illustrated in Figure 4, the patient had suffered from erythrocyanosis frigida of both lower and upper extremities for many years. She developed a painful ulceration beneath the nail of her right great toe, which failed to heal in four months. Immersion of the forearms in hot water (Landis-Gibbon test) failed to produce any rise in the temperature of the toes. Blocking of the posterior tibial nerve with 2 per cent procaine resulted in a rise in skin temperature of only 2 degrees centigrade. With lumbar sympathetic block, as shown in Figure 4, the skin temperature increase was more pronounced and there was great improvement in the color of the extremity, as well as relief from pain. Bilateral lumbar sympathectomy subsequently performed, resulted in complete relief of her symptoms.

The quantity of blood which can be delivered to the peripheral tissues in a given period of time depends not only upon the diameter of the arteries supplying the part, but also upon the peripheral resistance. Lowering of the peripheral resistance in any section of the vascular bed proximal to the nutrient capillaries, especially those in the distal portions of the extremities, necessarily reduces the effective pressure. The effect upon the height of oscillations measured at the ankle of lowering the peripheral resistance by opening up of blood vessels in the working calf muscles has been previously reported. This resistance was shown to be a significant factor in the distribution of blood to the peripheral tissues. It was suggested at that time that extensive sympathectomy might be contraindicated in the presence of advanced obliterative arterial disease, since the peripheral resistance might be so lowered in the proximal portion of the limb as to curtail the flow of blood in the more distal parts of the extremity. Atlas[9] has shown that in three patients lumbar sympathectomy allowed a rise in the surface temperature of 2 to 5 degrees centigrade above

TABLE I

INDICATIONS AND RESULTS OF SYMPATHECTOMY IN OBLITERATIVE ARTERIAL DISEASE

Case No.	Patient	Age	Diagnosis	Condition of Extremity	Lowest Palpable Artery	Indications for Sympathectomy	Operation	Results	Late Improvement
1	P.A. Male U.C.H. 124118	48	T.A.O. 10 mos.	1. Spontaneous amputation of distal phalanx of 6 fingers and sclerodactylia of all fingers. 2. Tips of fingers show painful ulcers. 3. Numbness and tingling of toes.	1. Arteriogram shows rt. radial blocked and blocks of digital arteries. 2. Ankle pulses present bilaterally.	1. Cold, clammy extremities. 2. Improvement in arteriogram after lumbar sympathetic block.	1. Bilateral upper thoracic sympathectomy. 2. Bilateral lumbar sympathectomy. (L-1, 2, 3, 4.)	1. Stumps of fingers healed completely. 2. Pain, numbness and tingling of feet have ceased.	++
2	O.L.Y. Male U.C.H. 136430	49	T.A.O. 7 wks.	1. Cold, aching feet bilaterally. 2. Weakness and dragging left foot. 3. Intermittent claudication, lf. foot, 1 block. 4. Spotty ischemic neuritis.	1. Lf. popliteal. 2. Rt. dorsalis pedis (rt. post. tibial absent). 3. Rt. ulnar obliterated.	1. Cold, clammy extremities. 2. Moderate venous constriction. 3. No improvement in claudication with lumbar sympathetic block, but color improved.	1. Bilateral lumbar sympathectomy. (L-4 only.)	1. Coldness and aching pain gone. 2. Improvement in strength, lf. foot. 3. Claudication time improved x 20. 4. Spotty ischemic neuritis decreased greatly and finally disappeared.	+++
3	O.M. Female U.C.H. 131147	47	Raynaud's with considerable local arterial obliteration 10 yrs.	1. Erythrocyanosis frigida, upper and lower extremities. 2. Extreme cyanosis rt. large toe with ulceration.	1. Ankle pulses present bilaterally.	1. Cold, clammy cyanotic extremities. 2. Venous constriction with delayed blanching time. 3. Improvement with lumbar sympathetic block (good color, warmth and relief of pain).	1. Bilateral lumbar sympathectomy. (L-2, 3, 4.)	1. Improvement in color, warmth and pain 2. Ulcer healed.	+++
4	W.S. Male Franklin 2321	52	Arteriosclerosis obliterans. 9 mos.	1. No excoriation, some rubor. 2. Colder rt. extremity. 3. Numbness of toes 3, 4, 5 on rt. 4. Intermittent claudication, rt., 1 block.	1. Rt. femoral. 2. Lf. posterior tibial.	1. Cold, clammy rt. foot. 2. Delayed blanching time. 3. Claudication improved after lumbar sympathetic block on 2 occations.	Rt. lumbar sympathectomy. (L-1, 2, 3.)	1. Rt. foot warmer. 2. Claudication time improved x 4. 3. Numbness in toes disappeared.	++
5	F.Z. Female Franklin 1998	44	T.A.O. 15 yrs.	1. Lf. foot colder than rt. 2. No ulcers.	1. Lf.: No femoral. 2. Rt.: All ankle pulses present. Radial and ulnar pulses diminished.	1. Mottled, cyanotic skin. 2. Delayed blanching time. 3. Hands moist. 4. Temporary improvement following lumbar sympathetic block.	Rt. upper thoracic sympathectomy. Lf. lumbar sympathectomy.	1. Claudication greatly improved in lf. leg and foot. 2. Claudication time improved x 5. 3. Rt. hand warmer with good circulation.	+¬

TABLE I—*Continued*

INDICATIONS AND RESULTS OF SYMPATHECTOMY IN OBLITERATIVE ARTERIAL DISEASE

Case No.	Patient	Age	Diagnosis	Condition of Extremity	Lowest Palpable Artery	Indications for Sympathectomy	Operation	Results	Late Improvement
6	E.K. Male Franklin 1946	26	T.A.O. 3 yrs.	1. One sq. cm. area of gangrene, rt. index finger. 2. Stasis of index with elevation and delayed filling with dependency.	1. Lf. ulnar weak.	1. Raynaud's phenomena at onset. 2. Cold, clammy extremities.	1. Rt. upper thoracic sympathectomy.	1. Increased warmth rt. arm and hand. 2. Healing of ulcer.	+
7	J.L. Male S.F.H. 38132	34	T.A.O. 10 yrs.	1. Lf. 4th and 5th toes missing with draining ulcers at site. 2. Rt. foot cyanotic.	1. Rt. leg: Pulses all present but diminished. 2. Lf. leg: Popliteal.	1. Cold, moist cyanotic feet.	1. Bilateral lumbar sympathectomy (L-2, 3, 4).	1. Ulcerated areas healed rapidly. 2. Foot and leg warmer. 3. Exercise tolerance increased x 10.	++
8	A.G.G. Female S.F.H. 40320	14	Post-traumatic spasm of brachial artery with thrombosis.	1. Pulses absent lf. upper extremity. 2. Lf. forearm and hand cyanotic, cold and anesthetic. 3. Induration of lf. forearm muscles.	1. Lf. axillary.	1. Cold, cyanotic hand. 2. Volkmann's contracture. 3. Improvement with stellate sympathetic block.	1. Left thoracic sympathectomy.	1. Return of pulses. 2. Hand still cold and anesthetic. 3. Volkmann's contracture.	±
9	H.L. Male Franklin 4172	65	Arteriosclerosis obliterans 1 yr.	1. Feet cold and moist. 2. Intermittent claudication, lf., 2 blocks.	1. No pulses below femorals.	1. Cold, clammy feet. 2. Venous constriction with delayed blanching time. 3. Improvement in color and temperature with lf. lumbar sympathetic block.	1. Left lumbar sympathectomy (L-1, 2, 3, 4).	1. Left foot warm and dry.	+
10	D.P. Male Franklin 4123	68	Arteriosclerosis obliterans 1 yr.	1. Feet cold and moist. 2. Intermittent claudication, rt., 1 block.	1. Femoral.	1. Cold, clammy feet. 2. Delayed blanching time. 3. Improvement in color and temperature with rt. lumbar sympathetic block.	1. Right lumbar sympathectomy (L-1, 2, 3, 4).	1. Right foot warm and dry.	+

the control level, but was followed by the rapid development of gangrene, necessitating amputation of the leg in each case. He attributed this disaster to the opening up of the arteriovenous communications which, although it permitted the surface temperature to rise, actually resulted in still further reduction in the nutrient capillary flow.

At approximately the same time that Atlas reported his experiences, one of us had noted some curious phenomena in four cases, the significance of which was not then appreciated. The first patient was suffering from thromboangiitis obliterations and had sustained an occlusion of the left iliac artery. Immediately following lumbar ganglionectomy the hypesthesia of the left foot, presumably of an ischemic nature, became much more extensive. At the time it was thought that the drop in blood pressure during spinal anesthesia and the use of the head-down position to combat this complication accounted for the manifest increase in vascular insufficiency. Some months later, however, he developed extensive gangrene of the dorsum of the foot, as shown in Figure 5, and amputation of the leg was performed. The fact that he continued to smoke and presumably had further episodes of arterial obliteration served to explain the development of gangrene, although the distribution of the necrosis on the dorsum of the foot while the toes were still viable was curious. Atlas described a similar distribution of gangrene in his cases.

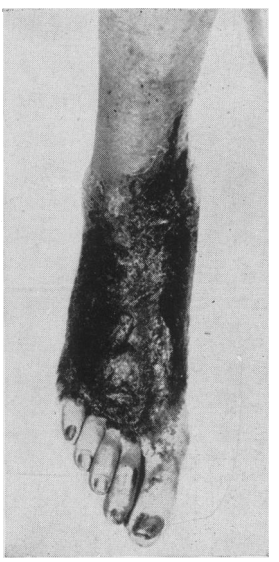

FIG. 5. — Necrosis of tissues on dorsum of foot in patient with advanced thromboangiitis obliterans after lumbar sympathectomy.

The second patient was suffering from severe ischemic neuritis after an acute arteriosclerotic occlusion of the left popliteral artery. When she obtained relief from pain with lumbar block, the sympathetic ganglia were excised. The spontaneous pain which she had suffered constantly for 10 months was immediately relieved. However, oscillations at the ankle, which before sympathectomy were barely perceptible, instead of being improved, actually disappeared. The records obtained on this patient are shown in Figure 6. Necrosis of the tissues on the dorsum of the foot developed as can be seen in Figure 7, necessitating amputation of the leg three months later. The data on these four cases are given in Table II. None of these patients gave clinical evidence of increased vasomotor tone, but in each one there was temporary relief of severe rest pain following lumbar block. It is interesting to note that each of these patients had sustained an acute occlusion of a major artery, as the result of thrombosis. The terrific pain and hypersensitivity which they developed in the months following the acute occlusions might well have been due to ischemic neuritis or to some type of causalgia. In each case the relief of pain by lumbar block might better have been attributed to interruption of the sympathetic

impulses, which is recognized to be effective in treatment of causalgia, rather than to any improvement in the supply of blood to the peripheral tissues.

Atlas[9] has enumerated as specific contraindications to sympathectomy, 1. Severe extensive arterial occlusion; 2. Rapid blanching on elevation; and 3. Atrophy of skin and subcutaneous tissues. From our present understanding, we would now classify the cases described above as belonging to the low vascular tone group in which specific indications for sympathectomy were not present. Moreover, they presented signs which we now regard as specific contraindications to sympathectomy.

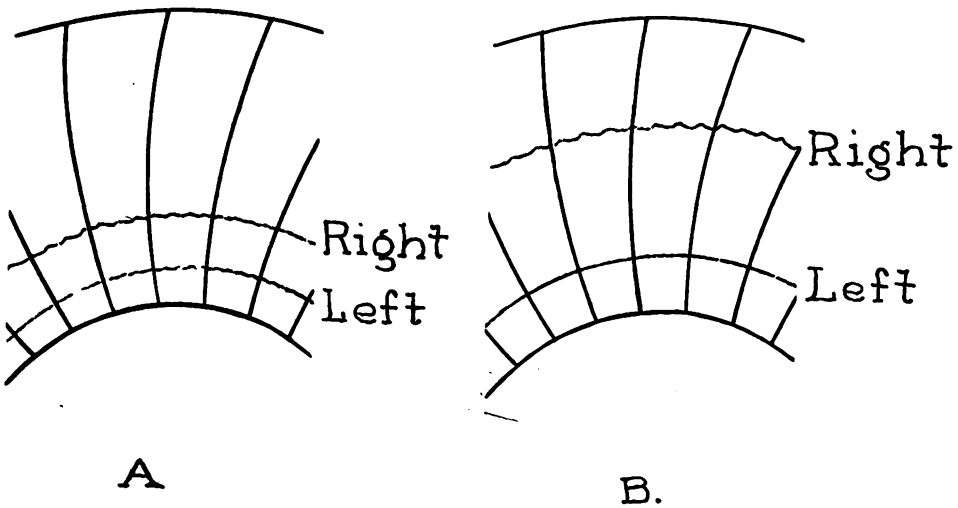

FIG. 6.—Simultaneous arteriograms in a patient with thromboangiitis obliterans after left lumbar sympathectomy.

The gangrene following sympathectomy in patients with severe obliterative arterial disease may be likened to the gangrene which so frequently follows proximal ligation of the major artery in the presence of an arterio-venous fistula. Direct measurements of intra-arterial pressure[15] have shown that occlusion of the major artery proximal to an arterio-venous fistula results in a precipitous drop of pressure due to the greatly expanded vascular bed available on the venous side. Arterial blood brought down by collateral pathways escapes easily into the venous side of the circulation. In obliterative vascular disease the major arteries are already blocked. Destruction of vasomotor control over the arterio-venous anastomoses by sympathectomy may abruptly deflect into the venous system the nutrient collateral flow to the capillaries. Clark[4] has shown that, with both the capillaries and the arterio-venous anastomoses open, there is blood available to flow through both pathways, although the relative size of the arterio-venous shunts allows far greater diversion of blood to the veins directly than through the capillaries. It is interesting to speculate on what would be the case were the volume flow of blood to be reduced by compression of the afferent arteries while the arterio-venous anastomoses were open.

TABLE II*

CONTRAINDICATIONS AND RESULTS OF SYMPATHECTOMY IN ADVANCED OBLITERATIVE ARTERIAL DISEASE

Case No.	Patient	Age	Diagnosis	Condition of Extremity	Lowest Palpable Artery	Reason for Sympathectomy	Operation	Result	Contraindications to Sympathectomy
1	L.B. Male H.U.P. 43202	45	T.A.O. Sudden occlusion lf. iliac artery.	Numb foot with constant burning pain.	None on lf.	1. 4° C. rise in skin temp. after nerve block.	Lf. lumbar symp. L-1, 2, 3, 4.	Immediate increase in anesthesia. Necrosis dorsum of foot. Amp. of leg 18 mos. later.	1. Absent oscillations at ankle. 2. Pain due to "ischemic neuritis." 3. Continued smoking.
2	E.L. Female Grad. Hosp. 149471 H.U.P. 47754	54	Arteriosclerosis. Sudden onset blanching and coldness lf. foot	Tender, thrombosed popliteal artery. Foot warm, hypersensitive.	Femoral	Relief of pain by lumbar block.	Lf. lumbar symp. L-1, 2, 3, 4.	Immediate relief of pain. Necrosis dorsum of foot. Amp. of leg 3 mos. later.	1. Atrophy of soft tissues. 2. Pain due to "ischemic neuritis." 3. Rapid blanching on elevation.
3	M.B. Female H.U.P. 45979	59	Diabetes. Arteriosclerosis. Sudden occlusion lf. femoral artery.	Foot warm but hypersensitive.	Femoral	Relief of pain by lumbar block. Temporary relief from periarterial sympathectomy.	Periarterial symp. femoral artery. Alcohol injection. L-1, 2, 3.	Ecchymosis dorsum of foot. Amp. of leg 12 mos. later.	1. Absent oscillations at ankle. 2. Pain due to ' ischemic neuritis." 3. Rapid blanching on elevation 15 sec.
4	M.B. Male P.H. 58148	58	T.A.O. Post-traumatic causalgia.	Fracture 1-2 metacarpals. Ulceration 3rd toe. Foot warm, hypersensitive.	Femoral	Previous femoral periarterial sympathectomy with temporary improvement. Relief of pain by lumbar block.	Lf. lumbar symp. L-1, 2, 3.	Immediate increase in ecchymosis dorsum of foot. Amp. of leg 2 mos. later.	1. Atrophy of soft tissues. 2. Pain due to "Causalgia." 3. Rapid blanching on elevation.

* We desire to express our appreciation to the following hospitals for permission to use the records from their surgical services: Hospital of the University of Pennsylvania, Graduate Hospital of the University of Pennsylvania and the Pennsylvania Hospital.

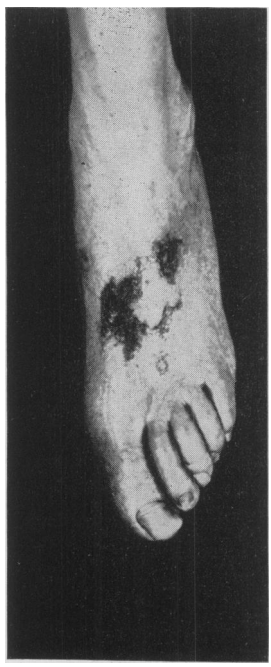

FIG. 7. — Necrosis of tissues on dorsum of foot 3 months after lumbar sympathectomy in patient with arteriosclerotic occlusion of popliteal artery.

The question may be raised as to how sympathectomy produces its admittedly good results if the only effect is the opening up of the arterio-venous communications. In the first place, the best results from sympathectomy are obtained in those patients who have capacity for vasodilatation and especially in those in whom there is a high degree of vasomotor tone. The possibility that the vasomotor tone restricts the blood flow to the tissues is suggested by the objective improvement in muscle blood flow which obtains after release of vasomotor control.[14] It is quite likely that even the major arteries are under vasomotor control. Arteriographic studies on three patients before and after either temporary paralysis of the sympathetic vasoconstrictor nerves or lumbar sympathectomy demonstrated an increase in the volume flow of blood through the major arteries. Figure 8 illustrates the results obtained in a patient with thromboangiitis obliterans after left lumbar sympathectomy. The ankle pulses were present on both sides but after release of vasomotor control on one side the flow of blood through the major arteries was greatly increased.

It is well known that the presence of a fistula between the major artery and vein of a limb is an excellent stimulus for the development of collateral circulation. Arteriographic studies in patients with arterio-venous fistulas demonstrate the profuse development of such collaterals. The fact that quadruple ligation and excision of such fistulas is rarely followed by gangrene indicates their functional importance.

In his microscopic studies of arterio-venous anastomoses, Popoff[7] called attention to the frequency with which the afferent artery became dilated. It is possible that the benefits of sympathectomy may actually be attributed to the permanent opening of multiple small arterio-venous communications. Such arterio-venous fistulas furnish a stimulus for the dilatation of afferent arteries and collateral channels. Atlas[9] has demonstrated that, after a period of time following lumbar sympathectomy, there appears to be an actual hypertrophy of the collateral bed, allowing for an increase in the oscillations compared with those taken immediately after operation.

Although the peripheral circulation has a dual function with dual control and even a dual microscopic structure, the blood supply comes through one system of arteries. Removal of vasomotor tone by sympathectomy, especially in those cases in which this vasomotor tone is increased, may reasonably be expected to improve the circulation to the tissues in spite of the diversion of large quantities of blood through useless channels into the veins. In addition,

sympathectomy may not unreasonably be expected to furnish an adequate stimulus for the development of collateral circulation. In the presence of severe obliterative vascular disease, however, especially in those cases with low vasomotor tone, sympathectomy may be contraindicated because large quantities of

FIG. 8.—Oscillometric records taken at the ankle before and after lumbar sympathectomy in patient with arteriosclerotic occlusion of the popliteal artery.

blood are diverted directly into the veins without passing through the capillary system.

CONCLUSIONS

Sympathectomy is useful in the treatment of obliterative arterial disease, especially in those patients who show evidence of abnormal vasoconstriction. Even though preoperative diagnostic tests fail to show an adequate rise in skin temperature after release of vasomotor control, sympathectomy may bring about a lasting and progressive improvement.

In advanced obliterative arterial disease, however, especially in patients without evidence of abnormal vasoconstriction, sympathectomy may result in gangrene. Although the total circulation may be increased after sympathec-

tomy in these cases, much of the blood is probably shunted directly into the veins through the opening-up of numerous arterio-venous anastomoses. The nutrient capillary flow may actually be reduced.

In the less advanced cases of obliterative arterial disease, sympathectomy may promote the development of collateral circulation through permanent opening of these arterio-venous communications.

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DISCUSSION.—DR. LOUIS G. HERRMANN, Cincinnati: Doctor DeBakey has presented in modern dress another important factor in the maintenance of peripheral blood flow under various conditions. For decades physiologists have tried to impress upon us the importance of the shift of the mass of blood from one part of the body to another when certain physiologic needs are to be satisfied. The sleepiness which comes on after a hearty dinner, the cerebral ischemia which sometimes overtakes a speaker when he reaches the rostrum, the muscle cramps in extremities which come on when one goes swimming immediately after a heavy meal, are all practical examples of the shift of the mass of blood from one part to another as a result of the vasomotor function of the sympathetic nervous system.

Doctor DeBakey and Doctor Ochsner have chosen to call this the lending-borrowing mechanism, but I prefer to describe it by the term "hemometakinesia" which they have coined. I am also of the opinion that such a mechanism is of real importance and I would emphasize that such a shift of the mass of blood should be given serious consider-