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Evaluation and Treatment of Chronic Digital Ischemia

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y-two patients were evaluated and treated during the past years at the Union Memorial Hospital Hand Center with diagnosis of chronic digital ischemia. These patients with syndrome, manifested by pain, severe cold intolerance and ional tip ulceration, all were failures of conventional con- ative treatment of vasodilators, tobacco abstinence and blocking agents. The evaluation consisted of first ruling large vessel disease by noninvasive techniques or angiog- y. The patients underwent a variety of noninvasive diag- ic tests including Doppler examination, pulse volume re- ings with cold stress, radioisotope scanning of the digital ation and peripheral sympathetic block of the digital es. Treatment included direct microvascular reconstruc- of the distal ulnar or radial artery and palmar arch, in patients, thermal biofeedback, in 22 patients and a new sur- l procedure—digital sympathectomy, in ten patients, in- ing 18 digits. Eight of ten patients with palmar arch re- truction improved with seven of ten having patent vein ts. Thermal biofeedback has been helpful in 20 patients. ing shows that an increase in digital perfusion can be ini- d by all patients. However, only 70% can achieve this ovement. Digital sympathectomy consists of isolating the minal branches of the sympathetic nerves which travel with peripheral nerves, dividing these branches and stripping the entitia of the digital arteries. Eight of nine patients have erienced improvement in digital circulation, as manifested pulse volume recordings after operation and radioiso- studies. Pain is substantially alleviated and the ulcers led. All of these patients responded before operation to the tal nerve block with measured increased in digital per- ion.

HE PATIENT WITH CHRONIC digital ischemia mani- fested by severe cold intolerance and pain, with or hout tip ulceration, has been a problem to physi- ns. The long-term results of sympathectomy per- med in the proximal part of the upper limb have en, in general, discouraging. The conservative treat- nt of vasodilators, tobacco abstinence, and gan- nic blocking agents helps a large number of these ients, but there is a residual group of patients who failures with conventional treatment. This paper pre- nts the evaluation and treatment of 42 such patients who were treated during the past five years at the Union Memorial Hospital Hand Center.

Evaluation

Proximal vessel disease is first ruled out by noninvasive techniques or contrast angiographic examination. No patient in this series had significant proximal disease. All patients were then subjected to a variety of noninvasive tests, including use of the Doppler Ultrasonic Flow Detector to record distal pulses. Alternate compression of each artery at the wrist, the so-called Allen's test, yields useful information about vessel patency. The same test is applied to the fingers for evaluation of individual digital artery flow. The second test involved radioisotope imaging of the distal circulation. In this test, previously reported by Wilgis,[6] we routinely used 20 mCi of Technetium 99 (^{99m}Tc) injected intravenously for a dynamic flow study, with exposures obtained at three second intervals, for approximately 50 seconds. Blood pool and delayed studies are then obtained which depict the perfusion of the digits with radionucleide-tagged cells. Peripheral pulse volume recordings with digital perfusion pressures measured in the resting state and then after cold stress constituted the third test. Cold stress involved immersing the hand in water at 12 C. The peripheral sympathetic nerves were temporarily blocked by injecting 2 cc of 0.5% bupivacaine into the distal palm, which effectively stops the conduction of the digital nerves and their sympathetic contributions to the digital vessels. The patients were again subjected to cold stress and pulse volume recordings.

Treatment

The patients were divided into three groups: 1) those with correctable vascular lesions such as thrombosis of the radial or ulnar artery and palmar arch, with appro-

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priate run off; 2) those patients with essentially vasospastic disease, which could be treated by thermal biofeedback; and 3) those patients with impending tissue loss and severe pain or failed thermal biofeedback, which were treated by peripheral digital artery sympathectomy. All patients were followed through a winter following their treatment with a minimum time of six months.

Results

Of the ten patients with direct microvascular reconstruction of wrist or palmar vessels, eight were improved and had no further complaints. Seven of these eight patients had patent vein grafts as evidenced by the Allen test with Doppler examination and/or pulse volume recordings. All patients who underwent microvascular reconstruction had evidence of thrombosis of the radial or ulnar artery at wrist level or distant for at least one year prior to surgery. Six of these patients had had a diagnosis of peripheral thrombosis made five years prior to this study, and had been treated conservatively. Chronic ischemic complaints of pain and whiteness in the ulnar two digits necessitated further treatment. The operative approach to this group of patients consisted of exploration of the affected artery, resection of the involved segment and replacement with an interpositional reversed vein graft taken from the dorsum of the forearm. In three patients, a branched vein graft was necessary due to branching of the distal arterial tree.

Thermal biofeedback was used in 22 patients, and was helpful in 20. Testing with pulse volume recordings and cold stress showed that all patients could initiate an increase in digital perfusion using this technique; however, only 70% could sustain this improvement. This particular modality of treatment was most helpful in the patient in whom anxiety and stress played an important part of the initiation of the vasospastic episode. The patients could usually obtain a temperature rise as much as 4.5 C with each biofeedback session.

Digital sympathectomy requires isolation of the terminal branches of the sympathetic nerves which travel with the peripheral nerves, dividing these terminal branches and stripping adventitia from the common digital and proper digital arteries. This procedure is done with the aid of the operating microscope. In this study, we performed 18 digital sympathectomies in ten patients. All of these patients responded before operation to the digital block, with measured increased digital perfusion. Of these ten patients, nine gained improved digital flow both clinically and manifested by pulse volume recordings after operation and radioisotope studies. Wound healing with pain relief occurred in all patients with digital ulcers in whom sympathectomy was performed. All but one of patients have had significant improvement of intolerance which has lasted through an winter's cold exposure. The longest follow-up group of patients is four years.

Discussion

Many authors have recommended reconstruction the distal arterial tree of the upper extremity, including radial and ulnar arteries in the acute thrombotic tion. In the patient with chronic vascular obstruction which has been present for more than one year, the erative technique is somewhat different in that the eased segment must be resected from the first bra proximally to the branching of the palmar arch distally. Sometimes the digital artery to the ulnar aspect of little finger is resected to get to the main branching the common digital artery to the ring and little finger. Mozersky[3] showed by dynamic studies that either radial or ulnar artery predominately perfused the hand in 98% of the patients. The radial artery was dominant in 12% of his subjects. It is our impression that the reason patients thrombose a distal artery and some years later develop pain and signs of digital ischemia is because that vessel provided dominant circulation to the hand prior to the occlusion. Postthrombotic circulation is not enough to accommodate the needs of the hand and chronic digital ischemia is the net result. Therefore, these patients will respond to reconstruction. However, if the patient does not injure his dominant artery, he will not develop chronic digital ischemia in the absence of damage to the dominant vessel. Our operative approach is standard excision of the damaged segment and interpositional vein graft replacement. Microscopic techniques are used, and following vein graft anastomoses, when the tourniquet is released, the noninjured artery is occluded by finger pressure so that the entire circulation to the hand must be delivered through the interposition vein graft. This pressure is maintained for approximately 20 minutes, so that the circulatory dynamics will be given a chance to stabilize.

Thermal biofeedback is essentially the process of gaining voluntary control over automatically, reflexly regulated body functions such as circulation.[1,2] The term "biofeedback" was conceived as a term to describe the process of feeding back physiologic information to the patient. The technique involves monitoring a selected physiologic activity, such as circulation, with an instrument which senses by electrodes or transducers, signals of physiologic information about such body functions as heart rate, blood pressure or temperature. The signals obtained are then amplified and

ed in the instrument to activate a display which pors changes in the physiologic activity. Most of the truments have been designed so that the individual dergoing biofeedback training can "see or hear: anges in his selective biologic activity. This modality be demonstrated by using an ordinary thermometer rchased from a drug store. The thermometer is taped the pulp of the middle finger and after five minutes quiet sitting, preferably with the eyes closed, the mperature of the finger is noticed. The individual then peats a few autosuggestion phrases to himself such as y hand feels warm" and/or "I feel calm and reed." Most people will tend to show a rise in finger mperature after 10–20 minutes, some increasing ir finger temperature three to five or even 10 C. ith repeated practice, everyone of our patients was le to learn to increase finger temperature voluntarily. dditionally, we noticed that the patients with pulse lume recordings demonstrated an increase in pulse lume and digital perfusion following biofeedback acity. While this is easily achieved in the controlled enronment, only 70% of the patients could use this techque at home. This has been most helpful in those paents in whom there was an emotional contribution to e vasospastic ischemia episodes. Inasmuch as this chnique is beneficial and, so far, without complicaons, we routinely recommend that patients with cold tolerance and vasospasm undergo biofeedback aining.

Digital sympathectomy was first described by Flatt,[1] ho devised a very distal sympathectomy for use in dis- circulatory problems. Pick,[4] in his anatomy textook, points out that the brachial plexus does not reeive its rami communicantes exclusively from the rvicothoracic sympathetic trunk. Another set aters from the sinovertebral nerve, carotid plexus and e nerve of Kuntz. Intermediary sympathetic ganglia aced in spinal nerve roots or rami communicantes byss the sympathetic trunk. These pathways, escially the intermediary ganglia, remain untouched ting cervicothoracic sympathectomy and later y an important role in residual sympathetic activity. e distal sympathetic fibers travel along the peripheral rves. The distal third of the radial artery is innerled by one filament from the superficial branch to e radial nerve and by eight additional twigs from the teral cutaneous nerve of the forearm. The distal third the ulnar artery receives three direct branches from e ulnar nerve and a branch from the medial cutanes nerve of the forearm. This branch usually travels the volar surface of the ulnar artery and can be ualized at wrist level. The deep palmar arch receives o branches from the deep branch of the ulnar nerve d one from the median nerve. Within the hand, the superficial palmar arch receives approximately 12 branches from the common digital nerves.

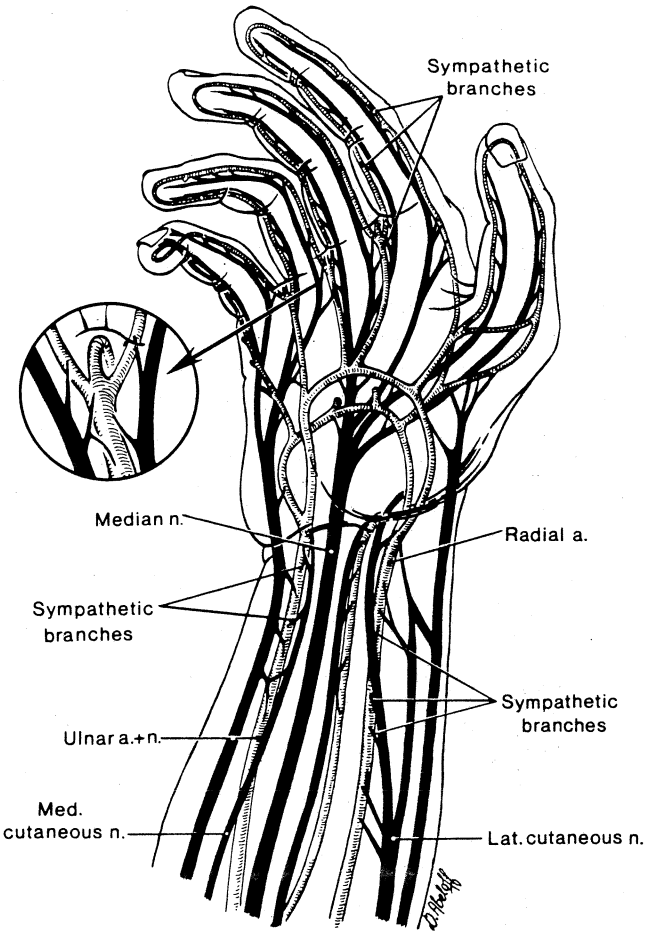

FIG. 1. The distal sympathetics.

The digital arteries themselves receive from three to 12 twigs from the proper digital nerves (Fig. 1). In considering the patient with distal arterial problems, most of these patients exhibit ischemia in the fingers from the level of the midpalm to the tips. It seems reasonable that if there are sympathetic nerves which are present in the distal peripheral nerves and the objective is relief of symptoms in the digits, then the sympathetic interruption should be performed as far distal as possible. Blocking of the distal sympathetics before operation allows one to predict the effect of the digital sympathectomy. In our patients, only those who had a positive response from the peripheral blockade with bupivacaine were subjected to the operative procedure. In 17 of 18 digits, the operative procedure was beneficial. So far, we have had no recurrence of symptoms following the operative treatment in these patients, inspite of being exposed to the cold for a winter season. The operative approach varies with the number of symptomatic digits. A zig-zag transverse palmar in-

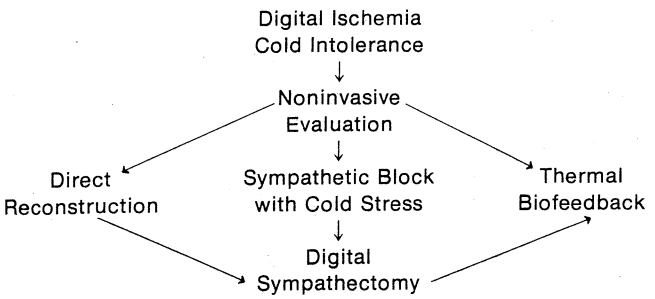

FIG. 2. Methods of evaluating chronic digital ischemia to see if there is a surgically correctable arterial lesion.

cision exposes the palmar arch and the common digital arteries permitting one to effectively treat all four digits. In the isolated digital ischemic condition, we have elected to proceed farther distally in the finger to the level of the proximal interphalangeal joint so that all possible connections between the digital nerve and the digital arteries are divided. The neurovascular structures are exposed and with the aid of the operative microscope, all connections between the nerve and vessel are divided by sharp dissection. Then, using two jeweler's forceps and some sharp dissection, the loose adventitia around the common digital and proper digital arteries is removed in a circumferential fashion. This effectively removes all of the terminal sympathetic branches from the vessel. We routinely do this for a distance of 2 cm. It must be emphasized that the vessel is not to be damaged, and the media and intima must be left untouched or thrombosis will occur. Many times there is not an immediate response due to the strong humeral component of sympathetic activity which may still be present in the digit. However, one begins to see a response several hours after operation, and by the following day, the finger is usually warm and there is a temperature difference of as much as 6 C between the operated and nonoperated digits. In our patients, the ulcers usually healed within two weeks and the pain was alleviated almost immediately. Part of the pain relief may have been due to the temporary neuropraxia of the digital nerve secondary to manipulation. All working patients have returned to work and there have been no complications of the operative procedure.

In summary (Fig. 2) the patients with chronic digital ischemia must first be evaluated to see if there is a surgically correctable arterial lesion. The evaluation consists of a series of noninvasive studies including diagnostic testing with cold stress and sympathetic blockade of the peripheral nerves. If vascular reconstruction is not indicated, then two methods of treatment can be employed: thermal biofeedback of surgical distal digital sympathectomy. The results have been encouraging and, although we realize that many operative and therapeutic approaches have been presented for this problem, this is an attempt to deal with the problem at a distal, and hence, more effective level.

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DISCUSSION

DR. JERE W. LORD, JR. (New York, New York): My comments are directed to two points in the paper. First, the location of the trouble in some patients with digital ischemia is in the subclavian artery as it comes under the scalenus anticus muscle and over the first rib. Anomalies in this region may cause atherosclerotic plaques which ulcerate, with ensuing microemboli to the digital arteries. One of the other discussers will illustrate this well.

On other occasions, stenosis with and without poststenotic aneurysmal formation may cause peripheral ischemia, enhanced by vasospastic overload. Angiographic study of the subclavian artery, supplemented by delineation of the small arteries of the wrist and hand, are cornerstones in the correct management of some patients.

The second point I would like to comment upon is the value of upper thoracic sympathectomy in selected patients with severe vasospastic disorders and digital ischemia, and also in some patients with localized occlusion of the proximal arterial tree not amenable to vascular reconstruction.

In 1944, or thereabout, at New York Hospital Drs. Bronson Ray and A. D. Console did some superb studies in humans and demonstrated that some sympathetic fibers in a few patients were carried through the somatic nerves as Dr. Wilgis pointed out. In other patients all the fibers went through the upper sympathetic chain.

Further, I feel strongly that the supraclavicular approach, the so-called Atkins and Telford approach, in vasospastic patients is a risky one. The anterolateral transthoracic approach of Palumbo, or the transaxillary one of Goetz, or the posterior approach of White and Smithwick, should be employed. I'd like to cite one case which presents some horrors of that phenomenon.

F.M., a 42-year-old white woman, a nonsmoker with marked hirsutism, entered the hospital on December 9, 1953, with a two-week history of pain, blueness, and coldness of the fingers of the right hand. The radial, ulnar, and proximal digital arteries pulsated well. Conservative therapy was of no avail, and a stellate ganglion block brought temporary complete relief for a short time. It was then decided an upper thoracic sympathectomy should be performed, and this was performed by a skilled neurosurgeon, using the supra-

vicular approach. The immediate postoperative effect was ex-ent, but on the second postoperative day the hand became cold ending to the elbow and pulses disappeared beyond the axillary ery. Exploration that night of the supraclavicular incision re-ed only some ecchymosis in the adventitia of the subclavian ar-, which pulsated well.

Exploration of the proximal brachial and axillary arteries showed found spasm, with a feeble pulse, which responded some-t to a periarterial sympathectomy locally and intra-arterial in-ion of Priscoline; the extremity was warm to the wrist and the d improved in color, but, unfortunately, this regressed, and after period of several weeks mummified and had to be amputated proxi-l to the wrist. (slide) This shows the amputated, gangrenous hand.

The patient recovered from this, and ten years later she developed ilar symptoms in the left hand, and on this occasion, in addition the spasm, she had a thrombosed ulnar artery. At this time, I rformed a left transthoracic sympathectomy through the lumbo approach, and over the next five years the hand remained good condition. The patient died of a myocardial infarction at the e of 57 years.

If we are going to continue to do sympathectomies in the future, am sure there are some surgeons who will continue to use the praclavicular approach of Telford and do it successfully. How-ver, for those who have not done many, I would suggest that they done either through the anterolateral transthoracic approach or rough the posterior or the transaxillary one.

In conclusion, I'd like to say of Dr. Wilgis' paper that it may make need for proximal sympathectomy obsolete. If so, we should look r an excellent hand surgeon to do this kind of work.

I'd like to ask one question. Dr. Wilgis in his paper and in his stract states that they all went through one winter successfully. know several have been operated upon three to four years ago and wonder if they continue to have no signs of regeneration of the gital sympathetic nerves?

DR. MICHAEL E. JABALEY (Jackson, Mississippi): In the spec-um of peripheral vascular disease, patients with digital ischemia ake up a relatively small per cent. Nevertheless, the unrelenting in and ulceration, when present, make them especially memorable those of us who treat them. And we have all gone through the any of searching for emboli and thromboses and, finding none, ave only been able to offer weight reduction, abstinence from to-cco, and drugs. Occasionally, we have advised cervical sympa-ectomy, not necessarily out of any conviction that it might help, but satisfy the patient's request that we do something.

In his presentation, Dr. Wilgis has proposed that the concept of mpathectomy may be correct, but that the approach that we have eviously advised may be incorrect. He has shown us by dissec-on and by clinical results that there may be sympathetic connec-ons between peripheral nerves and blood vessels well out into the tremity, and that if these are divided, vasospasm may be relieved d clinical improvement may result. It stands to reason that if this is , then the more distally the sympathectomy is performed, the more kely it is to be effective at the fingertips.

From our own dissections in the peripheral nerves, we have found ore or less the same thing, and for that reason I really agree with erything that Dr. Wilgis has said. I would like to show you a uple of cases that I have previously discussed with him.

(slide) The presentation in these patients, of course, may often e dramatic, and the spotchy discoloration that one sees in the digits ry often is associated with unrelenting pain.

(slide) This is a 23-year-old man who had been seen by a whole alanx of physicians and surgeons over a four-month period be-use of pain, impending, and finally, ulceration in the digital tip. the date he was operated upon, he was found to have throm-ses of the digital arteries at this level. In those patients where the tery has been explored and no runoffs found, thereby mitigating ainst any reconstruction, we have excised that segment, (and in process performed a digital sympathectomy), as Dr. Wilgis has plied.

It has now been three weeks since his surgery, and the ulceration still present. The pain is less, but we have found that even though we may relieve pain and improve blood supply to these tips, they still may not heal ulceration if it is present. This particular patient required a cross-finger flap before the digit healed.

It has now been a year since treatment, and I have just recently seen him. He's had no further symptoms in this finger but he has developed pain in an adjacent finger since that time.

(slide) Here is a patient undergoing compression of his radial artery (Allen test), which is the only artery carrying flow to the hand. He's just elevated the hand and made a fist, and he's just opened it. I think you can see the blanching that's present everywhere.

(slide) When the pressure on the artery is released, all the other digits blush and recover the pink color, but the little finger remains white. It is also numb, and has been for the past several hours. This man had no other sign of vascular disease.

(slide) Both sides of this digit were explored. On the ulnar side of the little finger we found a fibrotic cord replacing a 1.5 cm segment of the digital artery, suggesting that it had thrombosed some time previously, and had been in that state for a long time. On the radial side of the little finger, we again found a thrombosis, but this time a fresh one, whose age suggested that it probably was the cause of his acute symptoms.

(slide) The artery was explored. There was distal runoff present. A thrombectomy was performed. The vessel was closed. His symptoms abated, but we have been unable to follow him.

I would like to ask Dr. Wilgis two questions:

First, some may wonder whether those patients you showed might have been aided by a sympathectomy at the cervical level, done in the more or less classical way. Can you tell us if any of the patients you treated had previously had cervical sympathectomies?

And secondly, I enjoyed seeing your dissections, but I wonder if you could tell us whether you or anyone else has any proof to suggest to us that those little nerves that you showed really are sympathetics.

DR. CALVIN B. ERNST (Baltimore, Maryland): I rise only to emphasize Dr. Stallworth's admonition of ruling out proximal large vessel disease which might serve as an embologenic focus for digital ischemia. Pulse volume recordings as well as Doppler blood pressure measurements are helpful but the simple expedient of taking bilateral arm blood pressures serves as well, particularly when there are significant gradients.

(slide) Here we see a stenotic lesion in the proximal left subclavian artery in a 55-year-old woman who presented with left index finger ischemia. To identify this proximal embologenic lesion required two arteriograms, because during the first study the angiographer, upon performing a selective left subclavian injection, passed the angiographic catheter beyond the lesion. Upon restudy, the ulcerative-stenotic lesion was identified. This underscores the need for studying the entire proximal arterial tree to detect such lesions. Parenthetically, brachial artery pressure gradients between right and left upper extremities measured 45 mmHg, a difference which documented proximal stenosis.

Some proximal embologenic lesions may be far more subtle, however, particularly when upper extremity blood pressures are equal. (slide) This arteriogram documents intimal roughening in the left subclavian artery in another individual who also had the blue digit syndrome. (slide) Upon exploring this subclavian artery, an ulcerated plaque was identified.

Finding proximal embologenic vascular lesions requires excluding such foci from the circulation, either by excision of the arterial segment and vein graft interposition, or by extra-anatomic reconstruction, such as axilloaxillary bypass. We have favored axillary-axillary bypass over the past few years, performing the ipsilateral anastomosis end-to-end, distal to the embologenic lesion. This procedure is technically simple and the morbidity and mortality rates are low.

Therefore, careful arteriographic study is necessary in evaluating individuals with digital ischemia because overlooking a proximal embologenic lesion precludes successful management since repetitive embolic events will continue. Local operative procedures on the hand will not succeed under these circumstances in preventing progressive digital ischemia.

Since some proximal arterial lesions are subtle, I would like to know if you have identified any such lesions during follow-up, particularly among those individuals who have not improved.

DR. HARRIS B. SHUMACKER, JR. (Indianapolis, Indiana): If I understood him correctly, I find myself in disagreement with the author's opening statement that proximal sympathectomy in digital lesions of this sort is ordinarily a failure. Perhaps the occasional failures which occur may have something to do with the manner in which the proximal sympathectomy is carried out.

I have a large experience with the original White-Smithwick posterior preganglionic operation. I believe that the number of extremities so denervated for various ischemic lesions approaches 500. There has been no death. Most of the patients have left the hospital in 4 or 5 days; and I consider it a very simple and effective operation and better than a postganglionic procedure.

There are two conditions in which the operation not infrequently yields less than desirable results. One is in idiopathic Raynaud's disease, where there is, I firmly believe, in addition to sympathetic overactivity, a local fault, as Sir Thomas Lewis pointed out long ago. I don't see how operating distally could remove any local arterial fault.

The other is in progressive arteritis of small arteries not treatable by any known medical means; that is, not treated in such a way that the disease process will always cease to progress. Once again, I don't see how the site of the operative procedure carried out can alter the progression of the disease.

I am confident that if a known distal lesion is present, either embolic or intrinsic in the artery itself, and simple proximal preganglionic sympathetic denervation is not effective, one certainly would be justified in immediately resorting to an effort at microvascular reconstruction of the blocked artery or arteries.

I do not mean for my remarks to detract from the remarkable contribution which Dr. Wilgis has made. It is new, thought-provoking, and, in their hands, it has been certainly most successful, and I expect that it will be used with greater frequency in the future.

DR. E. F. SHAW WILGIS (Closing discussion): In an attempt to answer some of your questions, we have not seen regeneration of these small sympathetic branches in the patients that have been done so far.

And to try to answer some of the questions on cervicothoracic sympathectomy, our interest in this particular subject was stimulated by the fact that the first three patients in this study had been failures of the cervicothoracic sympathectomy, and they were done [illegible] years ago, and they all have responded to the more distal approach.

Since this study has been completed a year ago, we have performed approximately 30 more of these operations. Six of these patients had been failures of cervical sympathectomy.

We haven't seen any patients with proximal disease in the few who have not responded to any of the approaches that we have presented. However, in all of the preoperative testing we have effectively ruled out problems in the subclavian and upper thoracic tree.

I'd like to emphasize two points: 1) that we do insist on these patients not smoking. (slide) This simple slide shows the difference between the pulse pressure and pulse wave, and then after one cigarette. We show this slide to all our patients to insist that they give up smoking.

I did have one patient who said, "Well, if this operation works as well, then I can just smoke twice as much," but we were reluctant to do it.

In answer to Dr. Jabaley's question, (slide) and if you remember this slide, it's oriented a little differently now. This is the artery and the sympathetic connection here. We have been doing histochemical studies, as well as histologic studies on these nerves, and Dr. Flatt has shown that this nerve, with electron microscopy, is an unmyelinated fiber, indicating that it may well be a sympathetic.

We have been taking the adventitia from the vessel and the nerves and subjecting this to catecholamine fluorescence studies, and I'll show you one of these. If we can just darken the auditorium completely, this may show up. (slide) But this is a digital artery here, and these little dots along here, and especially right through here, show the catecholamine-rich sympathetic trunk coming into the artery. We're hoping to do this in more extensive fashion.