Extended Periarterial Sympathectomy: Evaluation of Long-term Outcomes

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Collier S. Pace¹ and Wyndell H. Merritt¹

Abstract

Background: Periarterial sympathectomy is a proposed surgical treatment for patients with refractory Raynaud syndrome; however, there is debate regarding the indications and extent of dissection. Due to the segmental arterial sympathetic innervation, we favor an *extended* sympathectomy in concert with vein graft reconstruction of occluded vessels when necessary. The purpose of this study is to examine outcomes of extended periarterial sympathectomy in our patients. **Methods:** A retrospective chart review was performed on 46 patients who underwent 58 periarterial sympathectomies (12 bilateral) since 1981. The data collected include demographics, comorbidities, previous therapy, operative details, and surgical outcomes. In addition, we contacted available patients for a phone survey. **Results:** Of 58 cases, 68.9% were female, 29.3% were current smokers, and 58.6% had known connective tissue disease. Thirty-three vein graft reconstructions were performed with a long-term patency of 77.4%. Sustained improvement of ischemic pain was reported in 94.8% of cases, and 78% of patients with ulcers completely healed. For the most symptomatic fingertip, mean Semmes-Weinstein monofilament measurements improved from 4.15 preoperatively to 3.29 postoperatively ($P \leq .05$). Mean follow-up was 3.97 years. Of 10 patients contacted by telephone, all reported a decrease in frequency and severity of Raynaud attacks, while 9 reported a long-term decrease in pain an average of 11.6 years after surgery. **Conclusions:** Extended periarterial sympathectomy is an effective and safe procedure for patients with refractory Raynaud syndrome. Our data demonstrate long-term improvement in ischemic pain and sensibility, along with a high rate of ulcer healing and patient satisfaction.

Keywords: periarterial sympathectomy, hand ischemia, Raynaud's, adventectomy

Introduction

Distal periarterial sympathectomy was initially proposed as a surgical treatment option for refractory Raynaud syndrome in the 1980s.¹⁰ The procedure is indicated when conservative and pharmacologic therapy fails, and when performed distally, it appears to be a more reliable and effective treatment option than proximal cervicothoracic sympathectomy, although some still prefer the latter.^{2,6,28} However, periarterial sympathectomy remains controversial, with no agreement regarding indications, extent of dissection, the best way to measure success, and the long-term results. Some believe the procedure should be performed early to reduce years of debilitating Raynaud symptoms and potentially prevent vascular disease progression,¹⁹ whereas others regard it as a salvage procedure worthwhile only for palliation.^{18,22,33} The extent of dissection widely varies, from stripping only a few millimeters of the common or proper digital vessels,¹⁰ or only treating the most symptomatic digit,^{7,8,11,21,36} to others recommending an extensive procedure to all proper and common digital vessels, the superficial arch, dorsal radial artery, and ulnar artery extending into the forearm,^{20,27} with many additional reports in between.^{8,12,15}

Although numerous authors have published positive results with peripheral sympathectomy, comparing outcomes between these studies is challenging due to marked variations in patient selection, reported outcome measures, and no consensus regarding surgical technique.^{3,9-11,16,18,20,22,25,27,32,35} There are no randomized trials evaluating periarterial sympathectomy, and no high-level evidence to support one variation of the procedure over another. At present, when a patient presents with intractable ischemic pain from Raynaud syndrome, often with distal soft tissue ischemia, we must rely on commonsense principles, knowledge of anatomy, and clinical experience to develop a treatment plan.

Analysis of the anatomy of the sympathetic nervous system, animal research, and our clinical experience have guided

¹Virginia Commonwealth University, Richmond, USA

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Corresponding Author:

Collier S. Pace, Resident Physician, Division of Plastic and Reconstructive Surgery, Virginia Commonwealth University, 1200 E Broad Street, Richmond, VA 23298, USA.
Email: collier.pace@gmail.com

Figure 1. Schematic of the extended periarterial sympathectomy. Red areas are stripped of adventitia. Blue represents vein graft reconstruction of occluded ulnar artery.

Figure 2. Intraoperative photograph of vein graft reconstruction of ulnar artery. This is anastomosed distally end-to-side into the superficial arch.

us to use *extended periarterial sympathectomy* in these challenging patients. We strip the adventitia of the proper and common digital arteries, the superficial arch and the ulnar artery extending into the mid-forearm in continuity, along with the dorsal radial artery. If there is a proximal arterial occlusion of the ulnar or radial artery, we perform a forearm vein graft reconstruction when feasible, most commonly done from the proximal ulnar artery to the superficial arch in an end-to-side fashion, and a sympathectomy of the occluded segment (Figures 1 and 2). Patients who receive a vein graft reconstruction are kept on clopidogrel postoperatively. The senior author has

previously reported additional details of the surgical procedure, including specific recommendations for instrumentation and postoperative management.²⁰ In this article, we report our long-term results with extended periarterial sympathectomy.

Methods

After institutional review board approval, we retrospectively reviewed patients who underwent extended periarterial sympathectomy by the senior author, who has performed the procedure since 1981. Patient records were reviewed from the senior author's private practice. This series consisted of 46 patients, 12 of whom underwent bilateral procedures, yielding a total of 58 cases. Individual data analysis included demographic information, patient comorbidities, previous therapy, details of the surgical procedure, patient outcomes (improvement in ischemic pain, ulcer healing, and Semmes-Weinstein monofilament measurements), and complications. Improvement in ischemic pain was considered when the patients stated during follow-up that their pain had improved, and this persisted throughout their follow-up period. Ulcer healing was achieved if the patients healed all ulcers that were present preoperatively, and these remained healed throughout their follow-up period. Preoperative and postoperative Semmes-Weinstein monofilament measurements were compared with a 2-tailed, paired Student *t* test for those patients whose afflicted digit did not require amputation. Dates of initial presentation, any surgical procedures, and most recent follow-up were also recorded.

In addition, attempts were made to contact patients for a phone interview, and 10 patients were asked a series of questions regarding ulcer healing, pain improvement, satisfaction with the surgery, subsequent surgical procedures, and the severity and frequency of their Raynaud attacks. These responses were recorded and analyzed.

The workup and surgical decision-making is individualized for each patient. Every patient receives a detailed focused neurovascular assessment in the office that includes handheld Doppler examination of the proximal radial and ulnar arteries, the superficial arch, common volar vessels, and proper digital arteries when audible. Baseline Semmes-Weinstein monofilament measurements and digital temperature recordings are always obtained for reference regardless of the planned treatment. Cold recovery testing can be done if the diagnosis of Raynaud syndrome is in question; however, we do not perform this test when ischemic ulceration is present or if the diagnosis can be made clinically to avoid unnecessary provocation of vasospasm. Digital pressures are not measured and no vascular consult requested unless there is a more proximal occlusion. Depending on the history and clinical findings, a hematology consult is occasionally requested to rule out an occult hypercoagulable state, which is sometimes confused with Raynaud's. All patients are started with conservative measures such as trigger

avoidance, nitroglycerin patches, aspirin, and a calcium channel blocker; however, most of these modalities have already been implemented before the patient's initial referral (see Merritt¹⁹ for further details regarding conservative therapy). When conservative measures fail, the patient is a candidate for extended periarterial sympathectomy or botulinum toxin injection. In our practice, the practical barrier for use of botulinum toxin is cost. This is usually not covered by insurance and therefore is not used as frequently as we would like in our practice. When botulinum toxin is not available, is attempted and fails, or the patient chooses surgery, extended periarterial sympathectomy is pursued. We now obtain magnetic resonance angiogram (MRA) studies for every patient preoperatively (although earlier in the series standard angiography was usually obtained) to clarify the vascular anatomy and plan for vascular reconstruction when indicated.

Results

Of the 58 cases we reviewed, 68.9% of the patients were female, and the mean patient age was 53 years (range: 30-87). In all, 43.8% of patients reported smoking at some point in the past, with 29.3% of patients currently smoking at the time of their operation. Of the 17 patients smoking at the time of surgery, 13 continued to smoke postoperatively. All patients had been given some form of pharmacologic therapy prior to referral to our clinic, the most common of which was calcium channel blockers (86.2%), and several had Botox injections. The most common etiology for Raynaud syndrome was connective tissue disease (scleroderma, mixed connective tissue disease, or lupus) in 58.6% of cases. Other etiologies include Raynaud syndrome with no clear diagnosis of connective tissue disease (22.4%), Buerger disease (10.3%), hypothernar hammer syndrome (5.2%), atherosclerosis (1.7%), and ulnar artery aneurysm (1.7%). It should be noted that 2 of the 3 patients with the presumed diagnosis of hypothernar hammer syndrome were eventually diagnosed with connective tissue disease years later. Fifty of 58 cases (86.2%) had some degree of fingertip ulceration or frank gangrene at the time of presentation (Table 1). Mean follow-up time was 3.97 years (range: 4 months to 23 years).

More than half (51.7%) of our patients had radial or ulnar artery occlusion diagnosed on preoperative imaging. MRA was the most common form of imaging; however, arteriograms were performed on some of the earlier patients, and in those who could not obtain insurance approval for MRA. Vein graft reconstructions were performed on 31 patients, with 4 patients having reconstructions of both the radial and ulnar arteries in the same extremity. In some patients, vascular reconstruction was not possible due to poor distal targets. All vein grafts were taken from the ipsilateral forearm, most frequently the cephalic vein. There

Table 1. Results.

	n	%
Comorbidities		
History of smoking	23	43.8
Current smoking	17	29.3
Diabetes mellitus	7	12.1
End-stage renal disease	4	6.9
Etiology		
Scleroderma	22	37.9
Raynaud syndrome	13	22.4
Mixed connective tissue disease	8	13.8
Buerger disease	6	10.3
Systemic lupus erythematosus	4	6.9
Hypothernar hammer syndrome	3	5.2
Atherosclerosis	1	1.7
Ulnar artery aneurysm	1	1.7
Vascular status		
Finger tip ulceration	50	86.2
Radial or ulnar artery occlusion	30	51.7
Vein graft reconstructions	31	53.4
Vein graft patency rate through most recent follow-up	24 (of 31)	77.4
Outcomes		
Postoperative improvement in pain	55	94.8
Complete ulcer healing	39 (of 50)	78
Complications		
Delayed wound healing of palm incision	18	31
Need for subsequent amputation	11	19
Vein graft occlusion	7 (of 31)	22.6
Infection	2	3.4
Flexion contracture	2	3.4

were 7 vein graft occlusions documented either by hand-held Doppler or MRA throughout the follow-up period yielding a long-term patency rate of 77.4%. Interestingly, 6 of the 7 occlusions occurred in patients who continued to smoke after surgery.

After extended periarterial sympathectomy, with vein graft reconstruction when warranted, 94.8% of patients reported a sustained decrease in pain. Of the 50 patients presenting with fingertip ulcerations, 39 (78%) completely healed all ulcers and did not require further debridement or amputation. The remaining 11 patients (22%) required amputation or stump revision subsequent to sympathectomy, although sometimes this was anticipated because of preoperative dry gangrenous changes that were left present in hopes of better perfusion prior to amputation. Of the patients who did not require any amputation, 38 had preoperative and postoperative Semmes-Weinstein monofilament measurements available in the most symptomatic digit. We report a statistically significant sustained improvement in sensation from a mean of 4.15 preoperatively, compared with 3.29 postoperatively ($P < .05$; Figure 3).

Figure 3. Paired comparison of Semmes-Weinstein monofilament measurements preoperatively and postoperatively.

The most frequent complication was delayed wound healing of the palmar incision, occurring in 31% of patients, which led us to modify the palmar incision from one large flap to 2 separate incisions, 1 horizontal incision placed over the common volar bifurcations, and a vertical incision extending from the mid-forearm to a small bridge just proximal to the horizontal incision (Figure 4). Only 1 of these patients required reoperation for Z-plasty contracture release, with the remainder healing by secondary intention. Nineteen patients (27% of the series) required reoperation, with 11 requiring subsequent amputation or stump revision. Other reasons for reoperation include revision of vein graft reconstruction in patients who occluded and were symptomatic, and more distal sympathectomy of the proper digital vessels when a single digit became symptomatic at some

Figure 4. "T" incision to avoid palmar skin ischemia.

point during the follow-up after extended periarterial sympathectomy. Two patients developed flexion contracture (3.4%), with 1 requiring surgical release, and 2 patients developed an infection (3.4%), neither of which required surgical intervention.

Patients with a reconstructed radial or ulnar artery occlusion showed comparable rates of ulcer healing (80.7%) and pain improvement (90%) when compared with the overall cohort. However, we found that 100% of patients who presented with patent vasculature reported a decrease in pain after extended sympathectomy. Therefore, all 3 patients in our series who did not report sustained improvement in postoperative ischemic pain presented with proximal vascular occlusion. The reoperation rate was higher in patients who presented with occluded vessels (40%) likely due to the 3 patients who had revisions of occluded vein grafts. The rates of amputation subsequent to sympathectomy were 20% and 18.5% for patients with occluded and patent vessels, respectively, although several of these were anticipated preoperatively.

We were able to reach 10 patients, 3 of whom underwent bilateral procedures. All 10 patients reported that they remained ulcer free throughout their follow-up period and that the severity and frequency of their Raynaud syndrome attacks had significantly decreased. Nine of the 10 patients reported a significant decrease in pain after the surgery that had continued throughout the follow-up period. All but 1 patient stated they would undergo the surgery again, after having experienced the recovery process and long-term benefits. Seven of these patients had a diagnosis of connective tissue disease, with the other 3 patients having hypothenar hammer syndrome, Buerger disease, and one with Raynaud syndrome having no identifiable diagnosed cause. Interestingly, the Buerger disease patient was still smoking, and doing quite well. The mean time from surgery to phone interview was 11.6 years (range: 1-23 years).

Discussion

The concept of periarterial sympathectomy was first suggested by Leriche and then accomplished by Jaboulay in 1899 in a segment of the femoral artery.¹ However, in 1921, Leriche showed that the early vasodilatation effect was later lost.¹⁷ Anatomists of the day pointed out that there is little evidence of long centripetal sympathetic nerves running along the arteries, but rather there are multiple segmental sympathetic branches innervating the vasculature. This would rule out any long-term benefit except at the vascular segment stripped, and thus, it seemed more rational to consider proximal sympathectomy at the spinal cord level. Barcroft and Walker⁵ demonstrated an early 6-fold increase in circulation with proximal cervicothoracic sympathectomy, but this also had a disappointing long-term result, as reported by Flatt and others.¹⁰ Pick pointed out that the brachial plexus does not receive its rami communicans exclusively from the cervical sympathetic trunk, but there are accessory

pathways, such as the sinovertebral nerve, carotid plexus, nerve of Kuntz, and the intermediary sympathetic ganglia in the spinal nerve roots, which led to recurrent symptoms.³¹ Distal periarterial sympathectomy was then described by Flatt in 1980¹⁰ for patients with refractory vasospastic disease of the hand because of these discouraging results. He proposed that distal periarterial sympathectomy would be more effective and did so by stripping 3 to 4 mm of adventitia from the proper digital arteries at their bifurcation from the common volar artery, theorizing sympathetic response would be ablated on the finger's distal vessels. He found temperature improvement of 1° to 3° and positive subjective results in 8 patients followed 1 to 17 years. The etiology of the patients' disease included frostbite, trauma and connective tissue disease.

Unfortunately, now 36 years after Flatt's original manuscript, questions still remain regarding the pathophysiology of Raynaud syndrome and the proper surgical treatment of vasospastic disease. The hand's cutaneous circulation seems controlled through several complex mechanisms, including the action of sympathetic neurotransmitters on alpha-adrenergic receptors. Vasospasm associated with Raynaud syndrome may be due to central dysregulation of this neurotransmitter system,¹⁴ or it may be a heightened response to normal sympathetic activity because of an upregulation of adrenergic receptors.³⁴

Raynaud disease (or *primary Raynaud's*) refers to characteristic symptoms of pain and cold intolerance, with a typical pattern of digit color change, often induced by cold temperature or stress. It is not associated with any underlying disease and is frequently considered an inherited characteristic. *Raynaud phenomenon* (or *secondary Raynaud's*) is, by definition, associated with an underlying disease process, with characteristic symptoms thought to be a secondary result. These patients more frequently have pathologic vascular changes, such as intimal hyperplasia, fibrosis, adventitial sclerosis, perivascular inflammation, and thrombosis. It is debated whether these changes are due to the primary disease process or whether repeated severe ischemic Raynaud attacks cause a secondary "reperfusion injury" that is responsible for the gradual changes in the vasculature.^{14,19} In practice, classifying these patients can be difficult because while they often initially present with "Raynaud disease," years later some form of connective tissue disease is diagnosed. The senior author and others³⁰ therefore suggest these designations be abandoned, and we use Raynaud syndrome to refer to all patients in this article. Regrettably, the precise mechanism causing Raynaud attacks and the etiology of vascular pathologic changes remain a conundrum.

Although Maurice Raynaud described this syndrome in the 1860s, many questions remain unanswered regarding the best treatment in patients with refractory symptoms. The diagnostic criteria are not universally agreed upon, and the pathophysiology is still unclear. Multiple different treatment modalities exist, with a wide range of speculation about the mechanisms of action. For patients who do not

respond to conservative therapy, distal periarterial sympathectomy has emerged as the most effective surgical option. In our series, which appears to be the largest in the literature, we show durable improvement in ischemic pain, high rates of ulcer healing, and long-term patient satisfaction with extended periarterial sympathectomy in patients who have failed medical treatment.

Our sympathectomy technique involves more extensive dissection than any other variation reported. The senior author arrived at this relatively aggressive technique through analysis of the anatomy of the autonomic nervous system, reports from basic science research, and clinical experience. Pick's descriptions of the sympathetic nervous system anatomy show diffuse and segmental innervation of the blood vessels in the hand, wrist, and forearm.²⁹ The innervation is particularly intense at sites of vessel bifurcation, such as the superficial vascular arch and common volar bifurcations. In addition, the nerve of Henle branch from the ulnar nerve provides intense sympathetic contribution to the ulnar artery in the forearm along with contributions from the medial antebrachial cutaneous nerve well proximal to the wrist.⁴ Pick²⁹ noted that the greatest intensity of sympathetic contribution to the radial artery was from the lateral antebrachial cutaneous and superficial radial sensory nerves into the snuffbox area of the dorsal radial artery where we usually find occlusion beneath the extensor pollicis longus. When studying the anatomic depictions of the sympathetic nerves, one can easily imagine how a limited sympathectomy with skip areas could readily be bypassed by the alternative sympathetic pathways that are left intact. In fact, persistence of untreated alternative sympathetic pathways has been a primary explanation for the inconsistent results obtained with proximal cervicothoracic sympathectomy² and failure of the early efforts at periarterial sympathectomy of proximal extremity vessels. We therefore strive to ablate as many of the distal sympathetic contributions as is feasible to maximize sympathetic denervation, sometimes stripping the proper digital artery to the proximal interphalangeal joint (PIP) level in the most symptomatic digit.²⁰

Several animal studies support the efficacy of distal periarterial sympathectomy. Morgan has shown that sympathetic nerves are confined to the adventitia and that removing the adventitia would ablate the sympathetic innervation.²³ He later showed no sympathetic reinnervation after a year in a rabbit ear model.²⁴ Kaarela et al demonstrated that while periarterial sympathectomy removes the sympathetic innervation at the site where adventitia has been stripped, adrenergic responsiveness to sympathetic stimulation distal and proximal to the site of adventectomy is relatively preserved with distal response only somewhat inhibited.¹³ This suggests the need for extensive periarterial sympathectomy to provide a significant decrease in adrenergic stimulation.

In the senior author's early experience, limited sympathectomy did not produce consistent durable results in our patients. Some of the first few patients with limited sympathectomy

who did not have previous ulnar artery stripping proximal to the wrist returned with recurrent symptoms and ulnar artery occlusion. In our subset of patients who received extended periarterial sympathectomy and had a patent ulnar artery preoperatively, only 1 went on to occlude the ulnar artery in follow-up, suggesting a preventive effect on future occlusion. This is important in scleroderma patients, who may have as high as 50% incidence of ulnar artery occlusion.³¹ Furthermore, when palmar sympathectomy has been done and subsequent ulnar artery occlusion occurs, reoperation for vein graft reconstruction of the superficial arch becomes exceedingly difficult. It seems preferable to strip the ulnar artery prophylactically before it occludes, which requires more than a limited incision at the wrist.

Although the anatomy and animal research make compelling arguments for an extended operation, there are too many questions regarding the disease process itself to comprehend true reasons why extended periarterial sympathectomy works. We speculate that removal of sympathetic innervation allowing vessel dilation, and reconstruction of occluded vessels when indicated, improves tissue oxygenation and nutrition, which leads to symptom improvement and ulcer healing. However, a competing theory¹³ is that removal of constricting sclerotic adventitia may allow the vessels to dilate irrespective of sympathetic innervation to allow increased blood flow. The physiology behind symptom improvement after this operation remains to be clarified.

We have not found it useful to differentiate patients with "Raynaud disease" and "Raynaud syndrome," because many with no diagnosis of connective tissue disease will eventually have one years later. Patients with scleroderma demonstrate Raynaud symptoms an average of 11.5 years prior to serologic diagnosis.³⁰ While early reports suggested that periarterial sympathectomy was less effective in patients with scleroderma,³⁵ this is in contrast to our success in these patients. Other authors also report symptomatic improvement in 83% to 92% of scleroderma patients following periarterial sympathectomy.^{22,32} We believe that these patients can experience significant long-term relief of symptoms from extended periarterial sympathectomy and that by reducing the frequency and severity of Raynaud attacks, surgery may prevent progression of vascular disease in the hand, such as ulnar artery occlusion.

Another important factor that differentiates patient populations in vasospastic studies is the status of the proximal vasculature. Comparison of periarterial sympathectomy in patients with arteriosclerotic disease with those having connective tissue disease shows the latter group responds more favorably.¹¹ Anytime there is question of proximal vessel patency, imaging should be performed. Some published studies include only patients with patent vessels,³⁶ whereas others do not report inflow status.^{3,8} There are reports, however, that show a high rate of symptom improvement (83%) even in patients with occluded vessels that cannot be reconstructed, although these cases had a

Video 1. Incision planning and operative dissection for extended periarterial sympathectomy (video available in the online version of the article).

fairly high incidence of ulcer recurrence.³² We have found that almost all of our patients who present with vascular occlusion can be reconstructed with a forearm vein graft done end-to-side from the proximal ulnar artery to the superficial arch. These patients have done well long-term in our experience, with high rates of symptom improvement and ulcer healing, although they do have a higher reoperation rate. It is worth noting that of the 7 patients who occluded their vein grafts in our series, some remained asymptomatic while 3 noticed symptom recurrence and required a revision of their vascular reconstruction. The reasons for this are not clear.

A major factor limiting comparison between studies is the extent of sympathectomy performed. There is some degree of variation in technique between almost every report published on this operation, and some papers use different techniques within the same study.^{11,25} Several authors describe a high incidence of symptom improvement and ulcer healing with limited sympathectomy confined only to the proper and common digital vessels.^{8,18,36} However, the mean follow-up time in these studies was less than half of our series, and the proximal vasculature of the patients was either patent or not reported. As stated previously, limited sympathectomy has not proven to provide durable results in our patient population because of late proximal vascular occlusion.

While we demonstrate clinical success with surgical sympathectomy in our series, chemical sympathectomy using botulinum toxin injection has emerged as an alternative treatment for this patient population. Neumeister provides a comprehensive summary of the use of botulinum toxin for the ischemic hand, citing retrospective literature that shows good outcomes using this modality.²⁶ When we use this therapy in our practice prior to sympathectomy, it frequently offers patients some benefit initially, but after a few months, their symptoms recur. We suspect this may be

due to the advanced vascular sclerosis and occlusion that is present in the majority of our patients. However, the rationale and data supporting botulinum toxin are noteworthy. As a result, the senior author now drips 50 units of botulinum toxin over the vessels at the time of sympathectomy, and injects 50 units into the contralateral hand if symptoms are present (see Video 1, available in the online version of the article). Future analysis of these patients may offer further insight into the role of botulinum toxin in this setting.

Limitations in this study include the lack of a control group and the use of some subjective outcome measures. While a randomized trial comparing the efficacy of extended periarterial sympathectomy with limited sympathectomy or even continued conservative treatment would yield valuable information, there are ethical impossibilities to that approach. The majority of our patients are sent with advanced Raynaud syndrome, unremitting pain that keeps them awake at night, and frequently have signs of ischemic tissue loss of their digits or frank gangrene. Because they have already failed conservative management, there is ethical concern with randomizing them to a conservative arm of a research study. Faced with a patient who may need amputation, we feel bound to attempt treatment that we feel offers the best chance at a favorable outcome. Although our outcome measure of postoperative pain reduction was the patient's subjective opinion, we did evaluate Semmes-Weinstein monofilament data and contacted available patients to specifically verify their outcome and satisfaction with surgery.

In our experience, extended periarterial sympathectomy with vein graft reconstruction when indicated has provided long-term improvement in symptoms and ulcer healing in our patients. In all, 95% of patients report an improvement in their symptoms, and 78% completely heal preoperative ulcers. These outcomes were maintained throughout a mean of 4 years of follow-up, extending as long as 23 years. While many questions remain regarding the pathophysiology of Raynaud syndrome, extended periarterial sympathectomy is a safe and effective treatment option for patients with refractory symptoms and tissue loss. Further research may clarify the exact mechanism(s) through which periarterial sympathectomy exerts its benefit, and help identify the ideal surgical candidates.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Statement of Informed Consent

All identifying details were withheld, when possible, to protect the privacy of our patients. Informed consent was obtained from all patients who could be contacted to be included in the study.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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References

1. Arnulf G. Physiological basis of sympathetic surgery for the upper limb in Raynaud's diseases. *J Cardiovasc Surg*. 1976;17:354-357.
2. Baddeley RM. The place of upper dorsal sympathectomy in the treatment of primary Raynaud's disease. *Br J Surg*. 1965;52:426-430.
3. Balogh B, Mayer W, Vesely M, et al. Adventitial stripping of the radial and ulnar arteries in Raynaud's disease. *J Hand Surg Am*. 2002;27(6):1073-1080.
4. Balogh B, Valencak J, Vesely M, et al. The nerve of Henle: an anatomic and immunohistochemical study. *J Hand Surg Am*. 1999;24(5):1103-1108.
5. Barcroft H, Walker AJ. Return to tone in blood-vessels of the upper limb after sympathectomy. *Lancet*. 1949;1:1035-1039.
6. Coveliers HME, Hoexum F, Nederhoed JH, et al. Thoracic sympathectomy for digital ischemia: a summary of evidence. *J Vasc Surg*. 2011;54:273-277.
7. Drake D, Morgan R. Digital sympathectomy for refractory Raynaud's phenomenon in an adolescent. *J Rheumatol*. 1992;19:1286-1288.
8. Egloff DV, Mifsud RP, Verdan C. Superselective digital sympathectomy in Raynaud's phenomenon. *Hand*. 1982;15:110-114.
9. Elgammal T, Blair W. Digital periarterial sympathectomy for ischaemic digital pain and ulcers. *J Hand Surg Br*. 1991;16(4):382-385.
10. Flatt AE. Digital artery sympathectomy. *J Hand Surg Am*. 1980;5:550-556.
11. Hartzell TL, Makhni EC, Sampson C. Long-term results of periarterial sympathectomy. *J Hand Surg Am*. 2009;34(8):1454-1460.
12. Jones NF, Imbrigha JE, Steen VD, et al. Surgery for scleroderma of the hand. *J Hand Surg Am*. 1987;12:391-400.
13. Kaarela O, Raatikainen T, Carlson S, et al. Effect of perivascular sympathectomy on distal adrenergic innervation in the hands of monkeys. *J Hand Surg Br*. 1991;16(4):386-388.
14. Kahaleh B, Matucci-Cerinic M. Raynaud's phenomenon and scleroderma: dysregulated neuroendothelial control of vascular tone. *Arthritis Rheum*. 1995;38:1-4.
15. Koman A, Smith BP, Smith TL, et al. Vascular disorders. In: Wolfe S, Pederson W, Hotchkiss R, Kozin S, eds. *Green's Operative Hand Surgery*. Philadelphia, PA: Elsevier; 2011:2197-2240.
16. Kotsis SV, Chung KC. A systematic review of the outcomes of digital sympathectomy for treatment of chronic digital ischemia. *J Rheumatol*. 2003;30:1788-1792.
17. Leriche R. Causes of failure in periarterial sympathectomy. *Bull Soc De Chir*. 1921;47:1111.
18. McCall TE, Peterson DP, Wong LB. The use of digital artery sympathectomy as a salvage procedure for severe ischemia of Raynaud's disease and phenomenon. *J Hand Surg Am*. 1999;24A:173-177.
19. Merritt WH. Comprehensive management of Raynaud's syndrome. *Clin Plast Surg*. 1997;24:133-159.
20. Merritt WH. Role and rationale for extended periarterial sympathectomy in the management of severe Raynaud syndrome: techniques and results. *Hand Clin*. 2015;31:101-120.
21. Miller LM, Morgan RF. Vasospastic disorders. *Hand Clin*. 1993;9:171-187.
22. Momeni A, Sorice SC, Valenzuela A, et al. Surgical treatment of systemic sclerosis—is it justified to offer peripheral sympathectomy earlier in the disease process? *Microsurgery*. 2015;35:441-446.
23. Morgan RF, Reisman NR, Wilgis ES. Anatomic localization of sympathetic nerves in the hand. *J Hand Surg Am*. 1983;8(3):283-288.
24. Morgan RF, Wilgis ES. Thermal changes in a rabbit ear model after sympathectomy. *J Hand Surg Am*. 1986;11(1):120-124.
25. Murata K, Omokawa S, Kobata Y, et al. Long-term follow-up of periarterial sympathectomy for chronic digital ischaemia. *J Hand Surg Eur*. 2012;37(8):788-793.
26. Neumeister MW. The role of botulinum toxin in vasospastic disorders of the hand. *Hand Clin*. 2015;31:23-27.
27. O'Brien BM, Kumar PAV, Mellow CG, et al. Radical microarteriolysis in the treatment of vasospastic disorders of the hand, especially scleroderma. *J Hand Surg Br*. 1992;17B:447-452.
28. Ojimba TA, Cameron AEP. Drawbacks of endoscopic thoracic sympathectomy. *Br J Surg*. 2004;91(3):264-269.
29. Pick J. *The Autonomic Nervous System: Morphological, Comparative, Clinical, and Surgical Aspects*. Philadelphia, PA: Lippincott; 1970.
30. Priollet T, Vayssairat M, Housset E. How to classify Raynaud's phenomenon. *Am J Med*. 1987;83:491-498.
31. Rodman GP, Myerowitz RL, Jusch GO. Morphological changes in the digital arteries of patients with progressive systemic sclerosis (scleroderma) and Raynaud's phenomenon. *Medicine*. 1980;59:393.
32. Ruch DS, Holden M, Smith BP, et al. Periarterial sympathectomy in scleroderma patients: intermediate-term follow-up. *J Hand Surg Am*. 2002;27(2):258-264.
33. Sampson CE. Periarterial sympathectomy in the treatment of upper extremity peripheral vascular disease. In: Hyam JA, Periera EAC, Green AL, eds. *Surgery of the Autonomic Nervous System*. Oxford, UK: Oxford University Press; 2016:129-141.
34. Troum SJ. Management of vasospastic disorders of the hand. *Clin Plast Surg*. 1997;24:121-32.
35. Wilgis EF. Digital sympathectomy for vascular insufficiency. *Hand Clin*. 1985;1:361-367.
36. Wilgis EF. Evaluation and treatment of chronic digital ischemia. *Ann Surg*. 1981;193:693-698.