

THE CONSERVATIVE TREATMENT OF ARTERIOSCLEROTIC PERIPHERAL VASCULAR DISEASES

PASSIVE VASCULAR EXERCISES (PAVAEX THERAPY)

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SUFFERERS from arteriosclerotic peripheral vascular disease constitute a much neglected group of patients when compared with those suffering from the other forms of peripheral vascular disorders which have received so much attention during the past decade. Arteriosclerosis, with the present interpretation of its meaning, is responsible for the vast majority of disturbances of the peripheral arterial circulation, and, during the past two years, it has been assigned as the etiological factor in 76 per cent. of the patients admitted to our vascular disease clinic. The economic loss which results from the disabilities brought about by this degenerative process is very large when we consider the total cost to charitable organizations and to the State when, following amputation of the extremity, its sufferers have ceased to be objects of interest to the medical profession. Fortunately, this neglected group of patients has, within the past two or three years, attracted the interest of an increasing number of internists as well as surgeons, and many are now devoting much time to the study and treatment of arteriosclerotic peripheral vascular disease.

As a result of these recent studies have come observations which tend to shake faith in the old idea of hopelessness with which this chronic degenerative process has been stigmatized for so many years. Among these studies have been the important observations of Allen and Smithwick¹¹ and others who, by their extensive experiences, have been forced to the conclusion that in some instances the symptomless extremity may exhibit definite evidences of a much more advanced arteriosclerosis than the corresponding painful extremity which exhibits signs of beginning gangrene of the toes. Also, very advanced peripheral arteriosclerosis may be found among patients who have never shown any signs or symptoms of a disturbance of the arterial circulation. There are records of patients who have survived one or more periods of threatened or beginning gangrene of the toes without a major amputation and who have later become practically free from symptoms referable to that extremity.

The arteriographical studies of extremities amputated because of arteriosclerotic gangrene reveal the greatest variation in the size and number of patent arteries and arterioles. Why should not the extremity which exhibits

an apparently adequate arterial bed survive as long as the amputated extremity which, by arteriography, shows practically no patent arterial bed? Extreme caution must be exercised in drawing conclusions as to the adequacy of an arterial bed from röntgenologically visualized arteries of the dead or living extremity. Certainly, for the present at least, there are no definite standards by which we can determine from the visualization of the arterial bed alone that an extremity must be amputated or is even doomed to an amputation. The only criterion is whether or not the tissues, through visualized or non-visualized arteries, are receiving or can be made to receive the nourishment required for their normal metabolic processes. The high incidence of arteriosclerotic gangrene during the winter months has become an obvious challenge of our therapeutic ability. These and many other equally important observations are rapidly changing the general attitude from one of waiting for the time of amputation to one of actually combating the deficiency of the arterial circulation before the trophic changes have begun to make their appearance.

The growing conservative attitude toward this degenerative process has, within the past few years, found expression in the more active education of our patients in a wider and more meticulous use of all of the measures dealing with the local hygiene of the feet, general health, optimum position for the resting extremities, Buerger-Allen exercises, *etc.*, which have been emphasized repeatedly and which have undoubtedly been of tremendous value in tiding many patients through the threatening stages of peripheral arteriosclerosis until an adequate collateral circulation could develop.

To these measures, which go a long way toward encouraging the development of a collateral circulation, we have, within the past two years, added the method of passive vascular exercises (Pavaex) as a means of actively promoting the development of an adequate collateral arterial circulation. This method, as many of you already know, consists of the rhythmic alternation of negative and positive pressures about the affected extremity or extremities.

The physiological effect of diminished atmospheric pressure upon the body or extremity and the marked increase in the arterial circulation which could be brought about in this way was described in detail over 100 years ago and has, at intervals, been rediscovered and redescribed since that time—most recently by Landis and Gibbon^{16, 19} and by ourselves.^{17, 18, 20} Sir James Murray,^{1, 4} of Dublin, was, perhaps, the first to apply this principle to the treatment of disease. As early as 1812 he subjected animals as well as patients to various degrees of rarefied and compressed air. It was not until 1832, however, that he began to publish the results of his experimental and practical studies. In 1835, he described the effects of diminished atmospheric pressure upon man in the following words: "The effects of a rare atmosphere are pointed out by those who have ascended very elevated situations; but in such cases the air inhaled was as light as that around the body. On the contrary, it is natural to expect different results if you place a man in a rarefied atmosphere, who is at the same time breathing air of the usual density and pressure. Abstraction of a ton and half

a ton of weight from the surface of the body permits the cutaneous vessels easily to fill, and favours their distention as it were by suction, while, at the same time, the lungs receive a column of the usual expansive force supporting the interior trunk and organs, pressing and propelling blood out from the center to the circumference. In this consists the novelty and value (if any) of the principle I propose."

Since that time there have been many variations in the methods of applying negative or positive environmental pressure to modify the circulation of blood in the various parts of the human body. In 1833, Victor Junod^{2, 3} published his thesis for doctorate from the University of Paris in which he described the use of negative pressure in the treatment of various diseases under the title of hæmospasia and aërotherapeia. In 1835, W. Reid Clanny,⁵ of Sunderland, England, working independently of Murray and Junod, published a description of the apparatus which he had devised for removing the pressure of the atmosphere from the body or limbs. It was not until 1887, however, that negative and positive pressures were used alternately to modify the arterial circulation in the extremities. It was Edgar Bluck,⁶ of South Hamstead, England, who first applied the rhythmic alternation of these pressures as he described it: "to bring about an influx and efflux of the blood in the part or parts affected."

It is quite apparent from the chart (Fig. 1), which shows in a chronological order the development of this form of therapy during the past 122 years, that the idea is a very old one and still more important is that the beneficial effects of changes in the environmental pressure were well established many years ago. We have attempted to revive interest in this form of therapy and suggest means by which it can be used as a practical form of therapy for that large group of patients who are suffering from pain and disability because of organic disease of the peripheral arteries.

The first record of the application of diminished atmospheric pressure as a treatment for organic peripheral arterial disease was published in 1917 by Sinkowitz and Gottlieb.¹⁰ They applied the Bier's⁷ suction hyperæmia treatment to four patients with thrombo-angiitis obliterans with very good results. In 1930, Braeucker¹² applied the same method of treatment to nineteen patients with true Raynaud's disease with equally good results.

In 1932, Herrmann²⁰ designed and built apparatus which would automatically bring about the rhythmic alternation of the environmental pressure of an extremity from any desired amount of negative pressure to any desired amount of positive pressure and at any selected rate of alternation. Because of the fact that this apparatus was essentially causing passive exercise of the vascular system, he called the method of treatment *Pavaex* (*passive vascular exercises*).

In order to conform to the generally accepted principle of dilating or stretching muscular tissue, it appeared quite necessary to cause the pressure to change gradually rather than suddenly. Our original Pavaex unit was so constructed that the change of pressure was brought about slowly, the complete cycle of the variation from atmospheric pressure to seventy millimetres of mercury *negative* pressure than to seventy millimetres of mercury *positive* pressure and

finally back again to atmospheric pressure, took about thirty seconds. After much experimentation we came to the conclusion that four complete cycles of alternating pressure from about eighty millimetres of mercury *negative* pressure to twenty or forty millimetres of mercury *positive* pressure will bring about the greatest increase in the arterial circulation with the least damage to the tissues of the extremity. In one complete cycle of fifteen sec-

TYPES OF ALTERNATION OF THE ENVIRONMENTAL PRESSURE USED TO IMPROVE THE CIRCULATION IN AN EXTREMITY. HISTORICAL REVIEW

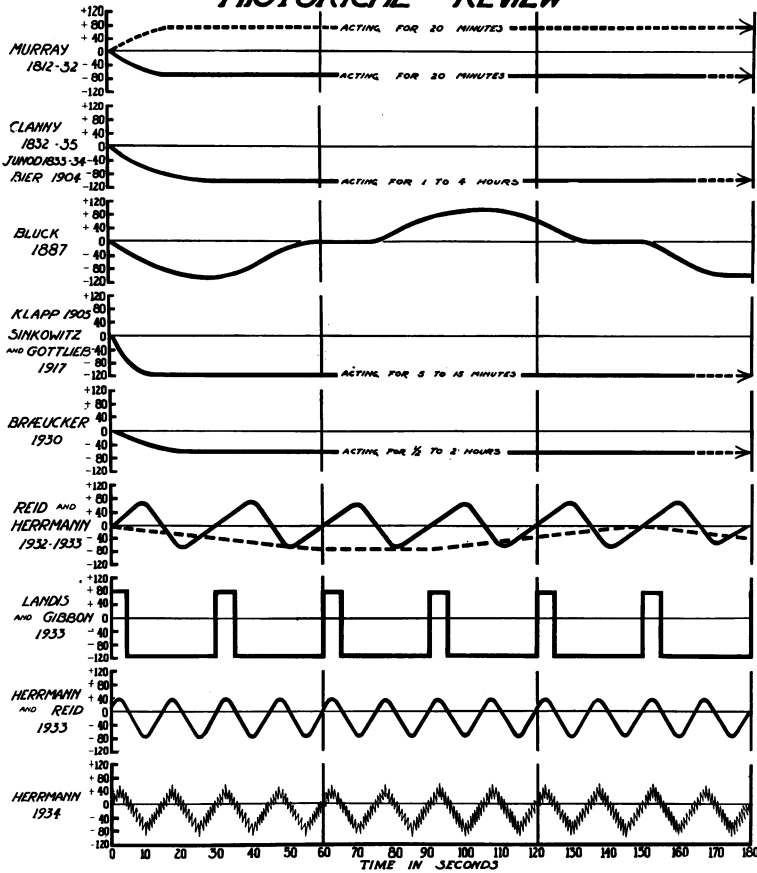


FIG. 1.—Chart showing, in their chronological order, the more important methods of applying negative and positive pressure to the body or extremities.

onds about five seconds are used for the positive pressure phase and about ten seconds are used for the negative pressure phase. Until about four months ago we were limiting each treatment to thirty minutes but recently DeTakats²³ has pointed out to us that much more benefit can be brought about by increasing the time of the individual treatments to one or two hours or even more. There seems to be no limit to the length of time the treatment can be carried

out without discomfort or untoward effects. The frequency or length of the treatments should depend entirely upon the urgency of the condition to be treated, as for instance, acute arterial occlusion either by operation, trauma, thrombosis or embolism must be considered as surgical emergencies and treated intensively until adequate circulation has been permanently established. For patients who are hospitalized the number of hours of actual treatment vary from four to eight each day, while the less urgent and ambulatory patients receive from three to seven hours of treatment each week.

In the method advocated by Landis and Gibbon¹⁹ considerably greater degrees of positive and negative pressure are being used and the alternation is so arranged that only five seconds are allowed for the eighty millimetres

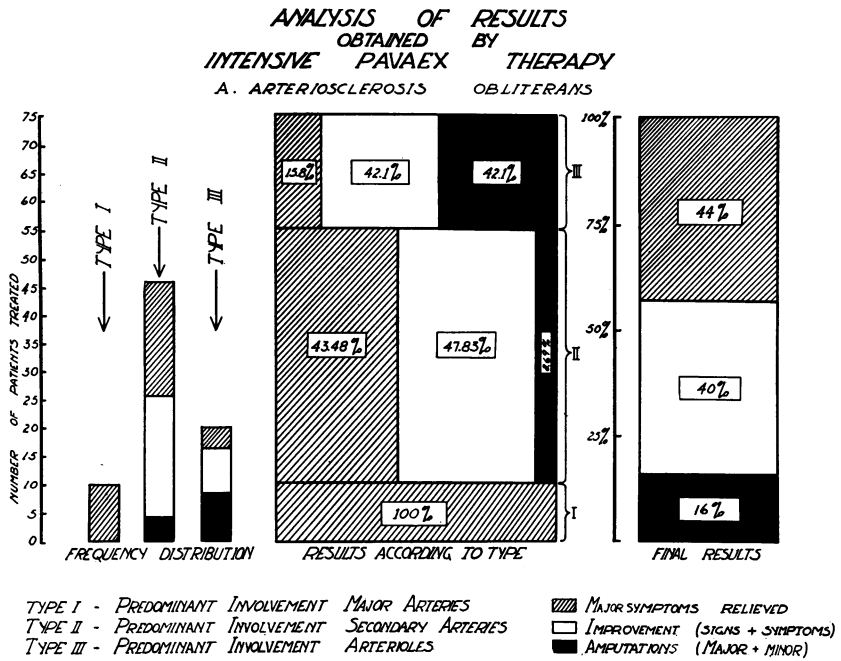


FIG. 2.—Chart showing the analysis of results obtained by intensive Pavaex therapy in a series of seventy-five unselected patients with arteriosclerosis obliterans.

of mercury positive pressure to act upon the extremity and twenty-five seconds are allowed for the negative pressure of 120 millimetres of mercury to be maintained about the extremity which is being treated. This method may prove to be most efficient in those cases of extensive arteriolar obliteration which require greater pressures to bring about an exchange of blood in the distal parts of the extremity. Much experimental work is still necessary before one can say with certainty which of the two methods will give the better results. It is highly probable that each of these methods will have its definite field of application in the treatment of the obliterative arterial diseases of the extremities. Herrmann²² has now constructed apparatus which will not only bring about the rhythmic exchange of environmental pressures slowly but

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will, at the same time, create 80 to 100 short oscillations each minute during both the negative and the positive phase of the cycle. (Fig. 1.). It is believed that this addition to the cycle which we now use will increase the dilating efficiency of the negative pressure as well as increase the possible canalizing effect of the positive pressure, especially in those cases where venous and lymphatic obstructions are being treated.

In applying the negative and positive pressures slowly to the extremities of patients with organic arterial diseases, we found that pressures over 100 millimetres of mercury occasionally caused petechial hæmorrhages and not infrequently secondary arterial thrombosis. We found, after a large series of determinations, that approximately eighty millimetres of mercury *negative* pressure and twenty millimetres of mercury *positive* pressure were the optimum pressures for patients with extensive organic changes in the arteries of

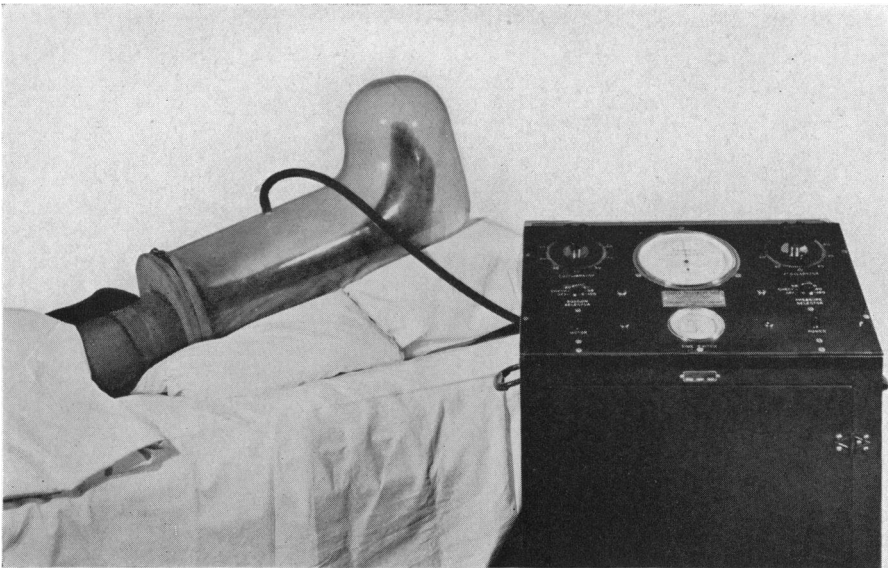


FIG. 3.—The Pavaex treatment unit with the treatment boot of pyrex glass. Note that the foot and leg have been elevated several inches above the level of the patient's heart.

the extremities. The elevation of the extremity several inches above the level of the heart (Fig. 3) has been found to be more satisfactory than the use of large amounts of positive pressure to free the extremity of venous blood. However, certain variations of these pressures have frequently been necessary as, for example, when treating the cyanotic or static type of vascular disturbance which is associated with extensive arteriosclerosis, it has been found advisable to decrease the amount of negative pressure to about sixty millimetres of mercury and to increase the positive pressure to about forty millimetres of mercury. (Fig. 4.)

In the course of over 12,000 Pavaex treatments we have learned, as one might have anticipated, that the most startling results have been obtained among those patients suffering from a more or less sudden occlusion of one

of the major arteries of the extremity, for instance, in the cases of ligation of a major artery, major arterial embolism or rapid arterial thrombosis. It has been our experience that the worry of gangrene in such cases can be eliminated by the early application of this form of therapy.

The usefulness of the Pavaex method of treatment in cases of the arteriosclerotic type of peripheral vascular disturbances seems to depend largely upon the part of the vascular tree which is mostly affected. It was, therefore, necessary that all patients be studied carefully before the treatment was begun. An accurate diagnosis of the type and extent of the arterial disease was made upon each patient by the oscillometric and calorimetric studies before and after vasomotor relaxation and under controlled conditions of

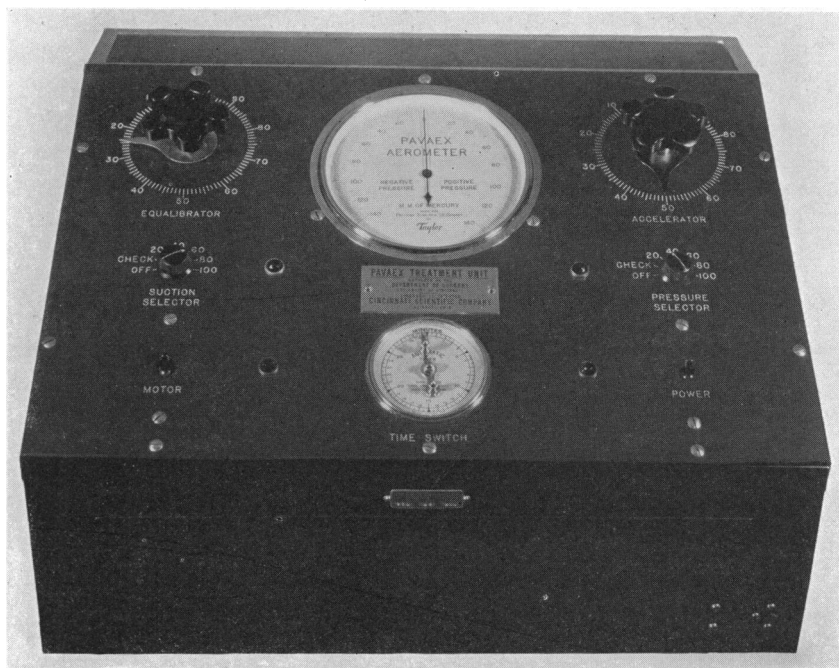


FIG. 4.—Photograph showing the details of the control panel of the Pavaex treatment unit.

temperature and humidity. As a result of these studies we have classified all of our patients with arteriosclerotic peripheral vascular disturbances under one of three main types depending upon the part of the arterial tree which showed the greatest involvement.

A series of seventy-five unselected cases of arteriosclerosis obliterans which have received intensive Pavaex therapy has been analyzed and the results obtained in each group are presented in the following tables. Repeated follow-up examinations have been made on the majority of the patients in this series.

Type I. Predominant Involvement of the Major Arterial Pathways of the Extremity.—Of the seventy-five unselected cases of arteriosclerosis obliterans,

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only ten were found to belong to this group. All of the patients of this group came to the hospital because of acute or subacute thrombosis of some major peripheral artery. (Fig. 2.) All of these patients were seen within twelve hours after the onset of the acute pain and intensive treatment was begun very shortly thereafter. After varying amounts of treatment, depending upon the extent of the arterial occlusion, all of these patients reported complete relief of all major symptoms including the severe intermittent claudication which had preceded the onset of the acute occlusion in the majority of the cases. No amputations were necessary.

Type II. Predominant Involvement of the Secondary Arterial Pathways of the Extremity.—Of the seventy-five unselected cases of arteriosclerosis obliterans which were analyzed, forty-six were found to belong to this group. This group is made up largely of patients who were not aware of the fact that they had organic arterial disease until some trivial infection of a toe or



FIG. 5.—Result obtained by intensive Pavaex therapy in a patient (J. K., age fifty-eight years) with extensive peripheral arteriosclerosis obliterans associated with severe diabetes mellitus. This patient lost his right leg eighteen months previously because of gangrene. (A)—Extending gangrene of the left foot. No pulses palpable in the foot. (B)—Three weeks after a Lisfranc's amputation had been performed. At the time of the amputation not a single bleeding vessel was encountered. After forty-two hours of Pavaex therapy the stump was covered with healthy granulation tissue. This amount of treatment was given over a period of ten days. Small pinch grafts of skin were applied and the surface was almost completely epithelialized when photograph B was taken. The stump has remained healed and he bears weight on it without discomfort.

corn developed into a spreading infection in the foot or gangrene of the toe. Thirty of these patients were diabetics. Many of these patients were treated for weeks or months for fallen arches, rheumatism, sprained ankles or metatarsalgia before the real nature of their disturbance was suspected.

Of these forty-six patients who received intensive Pavaex therapy, twenty patients (43.37 per cent.) were completely relieved of all major symptoms. Twenty-two of these patients (47.83 per cent.) were greatly improved and were able to resume their work without further discomfort but were not completely relieved of all of the former pain. Four of these patients (8.69 per cent.) showed definite gangrene of the distal part of their foot at the time of admission to the hospital and before any Pavaex treatments had been given. The gangrene was definitely limited by the intensive Pavaex treatment but various types of amputations through the foot were necessary to remove the gangrenous tissue. We feel that the Pavaex therapy made possible this less

radical type of amputation; nevertheless, in the summary of the results (Fig. 2) we have listed these patients as having had amputations rather than in the group showing improvement. At the time of the amputations the tissues of the affected feet were avascular but the Pavaex treatments soon caused healthy granulation tissue to appear and rapid healing of the stumps was effected by skin grafting. These stumps have proved to be serviceable for weight-bearing and far superior to any artificial foot or limb. (Fig. 5.)

Type III. Predominant Involvement of the Arterioles of the Feet.—Of the seventy-five cases of arteriosclerosis obliterans which were analyzed, nineteen were found to belong to this group. All of these patients showed evidence of generalized vascular sclerosis with relatively little involvement of the major and secondary arteries of the extremities but with evidence of extensive obliteration of the arterioles of the feet and toes. Many of these patients showed the purplish-red discoloration of the feet with more or less mottling and irregular pigmentation of the skin of the entire lower part of the extremity. The disturbance was usually bilateral but more marked on one side. Both feet were always cold and the patients complained of a constant dull aching pain in the entire foot with some radiation of the pain up the leg as high as the knees.

Of the nineteen patients in this group only three (15.7 per cent.) stated that they had been relieved of their pain with a definite improvement in the color of the feet. Eight of the patients (42.1 per cent.) stated that they were definitely improved although not completely relieved of all the pain. They were, however, able to sleep, which they considered extremely important and attributed it to the reduction in the severity of the pain. Eight of the patients (42.1 per cent.) were apparently not benefited at all by the Pavaex treatments as their pain continued to grow worse and the gangrenous lesions when present continued to progress in spite of the intensive treatment; consequently these eight patients were subjected to mid-thigh amputations. In this latter group of patients the Pavaex treatments frequently caused the pain to increase in severity.

SUMMARY.—Seventy-five unselected patients with arteriosclerosis obliterans who had received intensive Pavaex therapy were analyzed. It was found that thirty-three of these patients (44 per cent.) reported that they had been completely relieved of their major symptoms; thirty of the patients (40 per cent.) reported that they were greatly improved by the treatment; four of the patients (5.34 per cent.) were admitted to the hospital with definite gangrene of the foot and this gangrene was limited and sufficient collateral arterial circulation developed after this treatment to permit an amputation to be performed through the foot followed by prompt healing of the wound; and only eight of the patients of this entire series (10.67 per cent.) actually lost their extremities because an adequate collateral circulation could not be established by the Pavaex method of therapy. We believe that the results obtained in this series of patients justifies the faith which we have placed in this conservative method of treatment of such a serious form of obliterative arterial dis-

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ease of the extremities as arteriosclerosis has proved itself to be in the past.

CONCLUSIONS.—(1) The variability in the clinical manifestations of patients suffering from arteriosclerotic peripheral vascular disease should make us endeavor to tide them through the periods of threatening disaster as well as endeavor to promote actively the development of an adequate or balanced collateral circulation.

(2) The addition of passive vascular exercises (Pavaex therapy) to all those measures of general care advocated by Allen,¹¹ Buerger, Reid¹⁴ and others, will materially aid in bringing comfort to the patient and preventing serious sequelæ from making their appearance in patients with arteriosclerotic peripheral vascular disturbances.

(3) Thus far the benefits of the Pavaex treatments have been least obvious in those patients with extensive obliteration of the arteriolar bed of the feet, and most striking when the pathological changes were primarily limited to the major or secondary arterial pathways, especially when there was a rapid occlusion of the artery by embolism, trauma, surgery or thrombosis.

(4) The active treatment of the obliterative arterial diseases of the extremities is, as a result of recent work, rapidly becoming a truly non-surgical procedure and may soon rightfully become the function of the departments of internal medicine.

BIBLIOGRAPHY

- ¹ Murray, James: Nature and Treatment of Cholera—New Method Proposed. London Med. and Surg. Jour., vol. 1, No. 24, pp. 749-752, July 14, 1832; also London Med. and Surg. Jour., vol. 2, pp. 185-186, September 8, 1832.
- ² Junod, V. T.: Les Avantages de la Méthode Hémospasique. Thesis for Doctorate, Paris, 1833, published in Censeur Médicale, 1833.
- ³ Junod, V. T.: Recherches Physiologiques et Thérapeutiques sur les Effets de la Raréfaction de l'Air, tant sur le Corps que sur les Membres Isolés. Paris, Deville Cavellin, 1834. Reprinted from Rev. Méd. franç. et étrang., vol. 3, 1834.
- ⁴ Murray, James: On the Local and General Influence on the Body of Increased and Diminished Atmospheric Pressure. Lancet, London, vol. 1, p. 909, March 28, 1835.
- ⁵ Clanny, W. R.: Apparatus for Removing the Pressure of the Atmosphere from the Body or Limbs. Invented and Described by W. R. Clanny. Lancet, vol. 1, pp. 804-805, February 10, 1835.
- ⁶ Bluck, Edgar: Improved Means or Appliances for Promoting or Modifying the Circulation of the Blood in a Living Body. Darling and Sons, London, 1888.
- ⁷ Bier, A.: Ueber einige Verbesserungen Hyperämischer Apparate. Münch. med. Wchnschr., vol. 51, p. 241, February 9, 1904.
- ⁸ Klapp, R.: Ueber die Behandlung entzündlicher Erkrankungen Mittelst Saugapparaten. Münch. med. Wchnschr., vol. 52, p. 740, April 18, 1905.
- ⁹ Klapp, R.: Mobilisierung Versteifter und Streckung Kontrakturierter Gelenke durch Saugapparate. Münch. med. Wchnschr., vol. 52, p. 796, April 25, 1905.
- ¹⁰ Sinkowitz, S. J., and Gottlieb, I.: Thrombo-angiitis Obliterans—the Conservative Treatment by Bier's Hyperemia Suction Apparatus. J. A. M. A., vol. 68, No. 13, pp. 961-963, March 31, 1917.
- ¹¹ Allen, A. W., and Smithwick, R. H.: Use of Foreign Protein in the Treatment of Peripheral Vascular Diseases. J. A. M. A., vol. 91, pp. 1161-1168, 1928.

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- ¹² Braeucker, W.: Die Behandlung der Raynaudschen Krankheit. *Der Chirurg*, vol. 3, p. 756, 1931.
- ¹³ Reid, Mont R.: Diagnosis and Treatment of Peripheral Vascular Diseases. *Am. Jour. of Surg.*, vol. 24, p. 11, April, 1934.
- ¹⁴ Reid, Mont R.: The General Care of Peripheral Vascular Diseases. *ANNALS OF SURGERY*, pp. 733-743, October, 1932.
- ¹⁵ Reid, Mont R.: A General Consideration of Blood Supply in the Practice of Medicine and Surgery. *Jour. Southern Med. Assn.*, vol. 26, No. 2, pp. 107-115, February, 1933, Birmingham, Ala.
- ¹⁶ Landis, E. M., and Gibbon, J. H., Jr.: Effects of Alternate Suction and Pressure on Circulation in the Lower Extremities. *Proceedings of the Society for Experimental Biology and Medicine*, vol. 30, pp. 593-595, 1933.
- ¹⁷ Reid, M. R., and Herrmann, Louis G.: Treatment of Obliterative Vascular Diseases by Means of an Intermittent Negative Pressure Environment. *Jour. of Med.*, vol. 14, p. 200, June, 1933.
- ¹⁸ Herrmann, Louis G.: Syphilitic Peripheral Vascular Diseases—Treatment by Means of an Intermittent Negative Pressure Environment. *Am. Jour. of Syph.*, vol. 17, p. 305, July, 1933.
- ¹⁹ Landis, E. M., and Gibbon, J. H., Jr.: The Effects of Alternate Suction and Pressure on Blood Flow to the Lower Extremities. *Jour. Clin. Invest.*, vol. 12, p. 925, September, 1933.
- ²⁰ Herrmann, Louis G., and Reid, Mont R.: The Pavaex (Passive Vascular Exercise) Treatment of Obliterative Arterial Diseases of the Extremities. *Jour. of Med.*, vol. 14, p. 524, December, 1933.
- ²¹ Herrmann, Louis G., and Reid, Mont R.: Passive Vascular Exercises—Treatment of Peripheral Obliterative Arterial Diseases by Rhythmic Alternation of Environmental Pressures. *Arch. Surg.* (In press.)
- ²² Herrmann, Louis G.: The Pavaex (Passive Vascular Exercise) Treatment and Its Effect upon the Peripheral Arterial Circulation. *Jour. of Med.* (In press.)
- ²³ DeTakats, Géza: Personal Communication.