DETECTION OF OCCLUSIVE ARTERIAL DISEASE IN THE HAND AND ITS RELEVANCE TO OCCUPATIONAL HAND DISEASE*

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ABSTRACT

Plethysmography is indicated as a test in confirming clinical impressions of occlusive diseases of the hand. Raynaud's phenomenon is discussed in relation to this technique. Three clinical case histories are discussed.

INTRODUCTION

Individuals who develop Raynaud's phenomenon (blanching or blueness of fingers on cold exposure) usually suffer from a *functional* vascular disorder, but they may also have this symptom as a manifestation of occlusive arterial disease of the hand (Figure 1).

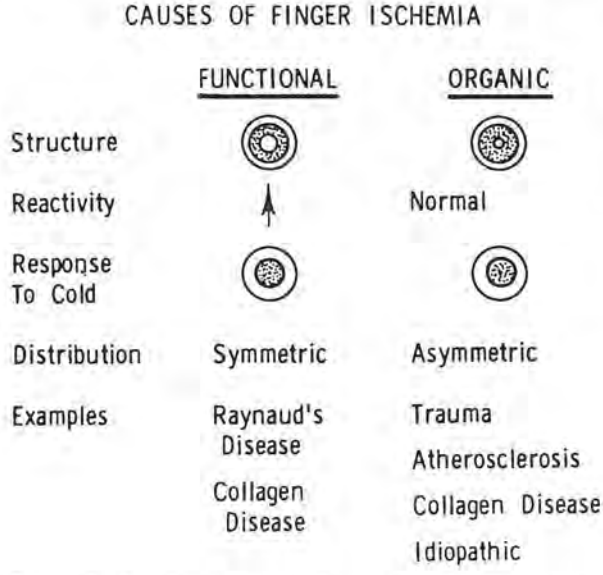

Figure 1. A scheme illustrating the pathophysiological and clinical differences between organic and functional digital ischemia.

This distinction is an important one in medical practice, since among the multiple etiologies for occlusive disease are a number of serious and sometimes fatal conditions.[1-3] In addition, occlusive disease predictably produces more destructive digital ischemia than vasospasm alone and commonly results in severe and occasionally progressive disability. This distinction is also of importance in understanding the mechanisms underlying the appearance of Raynaud's phenomenon in workers exposed to occupational hand-arm vibration. It is essential to know whether the "white fingers" which develop in some such workers are on a functional and, therefore, reversible basis or whether they are the result of traumatic arterial occlusions, which may be permanent.

I must state at the outset that I do not have the answer to this question, but I should like to emphasize that the knowledge and the technology exist to do that job.

In the first place, it is often possible to suspect the presence of occlusive disease in the individual with Raynaud's phenomenon on the basis of clinical findings alone.[4] Clues in the history include: asymmetry of digital involvement, abrupt onset and rapid progression of symptoms, and a story of permanent coolness and color change in the affected digits. Suggestive physical findings include: evidence of permanent digital ischemia (coolness cyanosis, poor capillary fill, and atrophy), fingertip ulcers and infections, and subungual splinter hemorrhages.

Secondly, plethysmography may be used to *confirm* a clinical impression of occlusive disease, and it is also helpful in the evaluation of the patient with intermittent digital ischemia of uncertain etiology.[5,6] Having demonstrated that a quantitative measurement of the digital volume pulse is a reliable indicator of blood flow in both normal and ischemic fingers,[7] we have studied the hands of a variety of patients with Raynaud's phenomenon during the period 1964-1974

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in the Outpatient Department of the University Hospital. The pulse volume in the third finger was recorded during maximal arterial dilatation obtained by combining body heating (to raise oral temperature 0.5°F), direct hand heating, and reactive hyperemia following 5 minutes of hand ischemia.

The presence of occlusive arterial disease was determined by the volume of the pulse in the maximally dilated finger and the contour of the pulse wave as compared with findings in a group of normal subjects. Assessment of collateral circulation in the hand was obtained by alternate manual compression of radial and ulnar arteries at the wrist while recording the pulse from the third finger.

Patients with classical clinical occlusive disease were found to have clearly abnormal plethysmograms, both quantitatively and qualitatively (Figure 2).

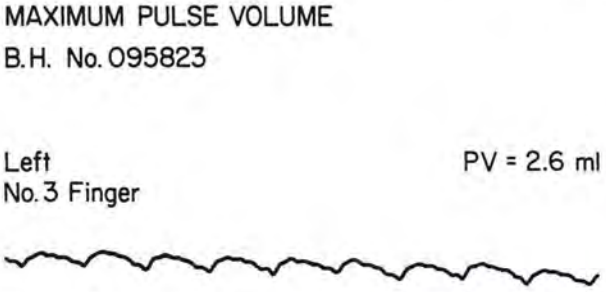

Figure 2. Plethysmogram from the middle finger of a patient with severe occlusive disease. Pulsations recorded under conditions ensuring maximal dilatation. PV = pulse volume in ml/5 ml finger volume/mm Hg brachial pulse pressure x 10^{-5}. Maximum pulse volume in normal fingers is not less than 10 ml (7).

Early in the course of these studies, however, borderline results in patients with a variety of clinical pictures began to appear. The need to obtain data about the anatomic factors that influence finger plethysmography was apparent. A study in a group of patients with scleroderma under care of the staff of the Simpson Memorial Institute* at the University of Michigan Medical Center made this possible. Digital arteriography† and plethysmography were correlated in 31 patients with scleroderma.[8] Although advanced structural disease was found in the arteries of more than 80% of the patients by arteriography, more than one-half of the plethysmograms were either normal or only slightly abnormal (Figure 3). Discrepancies were noted under specific circumstances, however: a. where there was involvement of only one proper digital artery (Figure 4); b. where digital collateral circulation was good, for any reason; c. when the vascular disease was mildly stenotic rather than occlusive; and d. when the vascular disease did not involve the third finger. In general, plethysmography tended toward normalcy when the arteries were able to deliver a substantial amount of blood to the distal

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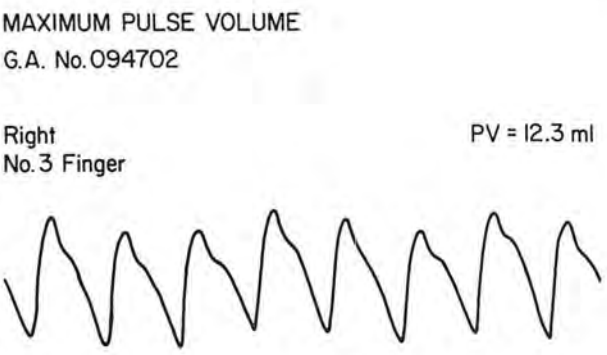

Figure 3. Plethysmogram from a patient with Raynaud's phenomenon and occlusive disease limited to one proper digital artery in the finger studied. Volume is low normal, but dicrotic limb appears straightened. A "borderline" study.

Figure 4. Hand arteriogram from a patient with scleroderma and a completely normal plethysmogram. The radial proper digital artery of the middle finger is obstructed.

two phalanges of the middle finger.

It is clear then that a third finger maximum pulse within the range of normality does not exclude the presence of occlusive arterial disease of the hand. A normal or even mildly diminished pulse (Figure 5) does imply, however, that serious impairment of dig-

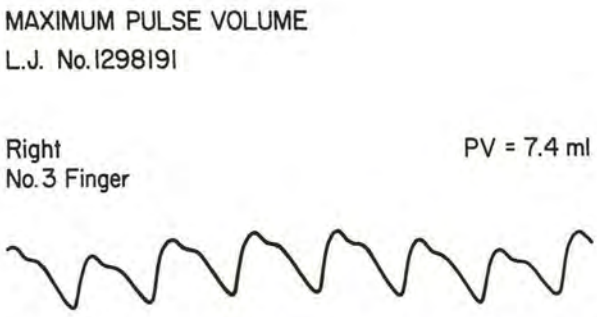

Figure 5. Mildly abnormal plethysmogram from a patient with occlusive disease in digital arteries, but extensive collateral circulation and no finger atrophy.

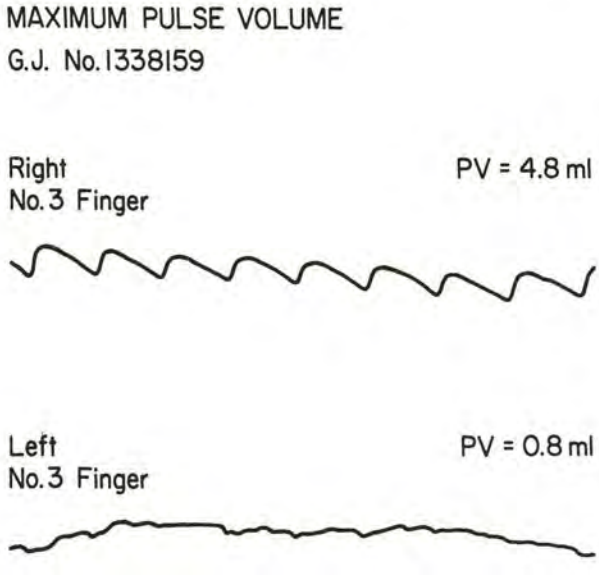

Figure 6. Very small, to almost absent, digital pulsations in a patient with multiple occlusions of hand arteries and advanced clinical disease (recurrent infections and ulcerations of fingertips).

ital blood flow is absent. Conversely, clinical experience has demonstrated that those patients with severely decreased digital pulsations (Figure 6) frequently have advanced occlusive disease (Figure 7) and signs of inadequate digital nutrition such as finger tip ulcers and infections.

Alternate compression of the radial and ulnar arteries while recording the pulse from the middle finger can also provide information of diagnostic value. In a group of normal adults, manual occlusion of either vessel diminished pulse volume in the third finger more than 50% of the time, but obliteration of the pulse was unusual. Complete obliteration was observed in approximately 10% of normal hands during radial compression and somewhat less than 5% of normal hands during ulnar compression. This finding is surprising in view of the well-established

Figure 7. Hand arteriogram in a patient with severe occlusive disease in digital vessels. The middle finger is essentially avascular due to obstruction of the proximal portion of both proper digital arteries.

anatomic importance of the ulnar artery in the circulation to the ulnar three fingers.[9] This result may have been influenced by technical factors. Perhaps the ulnar artery is not as easily compressed as the radial; it certainly is more difficult to locate at the wrist. Otherwise it would appear that, although the radial artery is not commonly the dominant source of blood for the middle finger, when it is, it is less likely to receive adequate back-up from the ulnar artery.

The fact remains that manual compression of individual wrist arteries rarely eliminates the volume pulse in the middle finger. If this phenomenon is observed during studies on a hand because of a history compatible with ischemia, the phenomenon is suggestive of the presence of occlusive arterial disease even if the maximum pulse is quantitatively normal. In diseased hands, we have observed this to occur more frequently during manual occlusion of the radial rather than of the ulnar artery. Angiographic correlation has revealed that obliteration of the middle finger pulse during radial occlusion occurs most commonly when vascular disease has resulted in block

of either: 1. the ulnar artery, or 2. the superficial volar arch, or 3. the ulnar proper digital artery of the third finger (Figure 8).

Figure 8. Hand arteriogram demonstrating the radial proper digital as the sole source of blood for the middle finger. Manual occlusion of the radial artery obliterated pulsation in the middle finger.

Plethysmographic studies on patients with occlusive arterial disease of the hand of varying etiologies have not revealed characteristic patterns associated with specific medical disorders. However, there is evidence that some differentiation is possible with digital arteriography.[10] Certainly, a fairly typical pattern of involvement is seen in scleroderma, and findings compatible with the pathologic changes expected in Buerger's disease and embolic occlusion have been observed in patients with clinical pictures suggestive of those conditions. Unfortunately, little information is available about the plethysmographic or angiographic findings in patients with circulatory disorders of the hand related to occupation. The following three cases were studied at the University Hospital in Ann Arbor, Michigan, during the past decade.

CASE HISTORIES

Case No. 1. W. W., a 35-year-old truck driver, was seen initially in the summer of 1964. He complained of coldness of the distal one-half of the third and fourth fingers of his right hand that had developed after his hand had been injured by a heavy timber falling across it. Although the trauma had been painful, there was no open wound and no fracture. Plethysmographic studies revealed a markedly decreased maximum pulse in the right third finger (Figure 9)

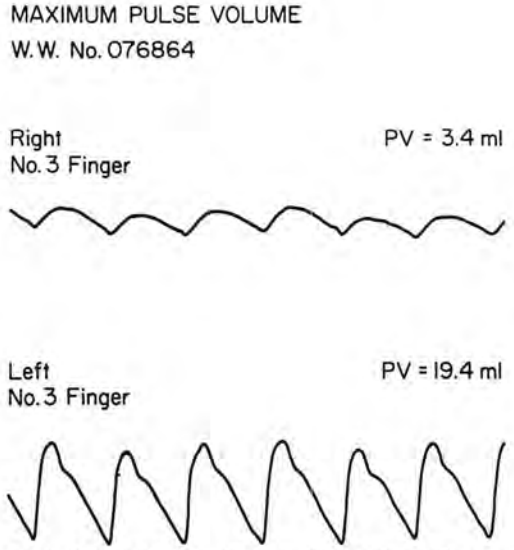

Figure 9. Diminished pulsation in the long finger of the right hand of a patient with an obstructed ulnar artery and superficial volar arch. The normal pulse from the left hand is shown for comparison.

that was completely obliterated by radial compression (Figure 10); and angiography revealed complete occlusion of the superficial volar arch with deficient vascularity in the third and fourth digits (Figure 11). He was last seen in 1967 at which time his only complaint was occasional blanching of the affected fingers on cold exposure.

Case No. 2. C. R., a 28-year-old factory worker, was seen in 1972 complaining of coldness and numbness in the right second and third fingers of 2 years' duration. These symptoms were aggravated by exercise and cold exposure. Industrial history revealed that the patient used his right hand in pounding on car molding. No trophic changes were noted on examination of his hand. Arteriography revealed

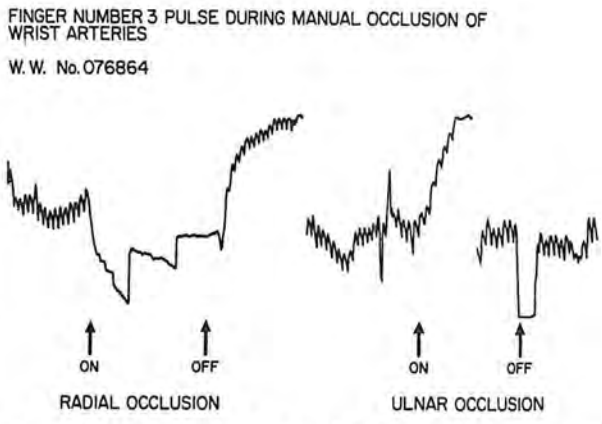

Figure 10. Pulsation of the middle finger of the hand of a patient with an obstructed ulnar artery and superficial volar arch. Manual occlusion of the radial artery obliterates the pulse.

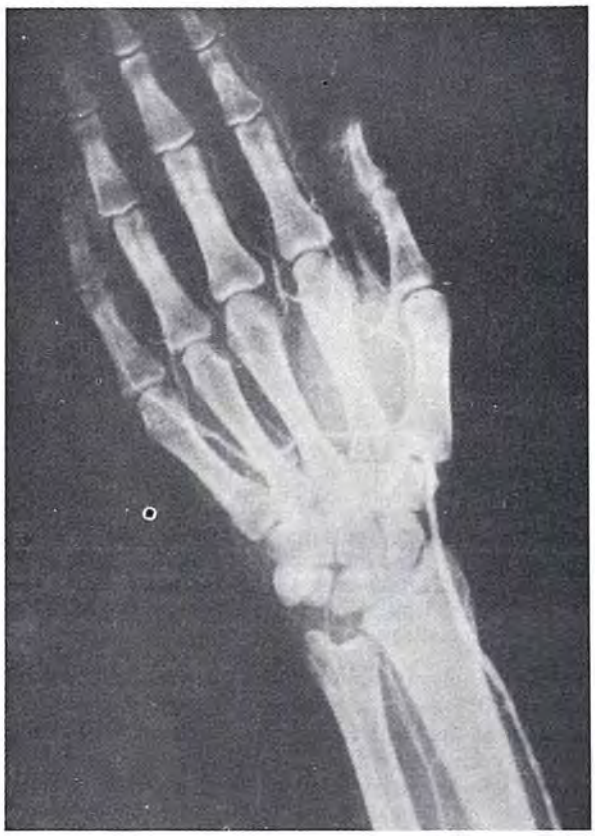

Figure 11. Arteriogram of the right hand in the patient whose plethysmograms are illustrated in Figures 9 and 10.

multiple occlusions in the proper digital arteries supplying the second, third, and fourth fingers, and aneurysmal dilatation of the ulnar artery in the hypothenar region (Figure 12). Plethysmography was not performed.

Case No. 3. C. F., a 43-year-old maintenance worker, was seen in 1966 with a 2-year history that included throbbing pain and cyanosis in the tips of all fingers on cold exposure, and chronic burning discomfort in the distal phalanges of the thumbs and index fingers associated with peeling of the skin of 5 months' duration. The patient reported using a pneumatic hammer and power saw regularly in his work before symptoms developed, but he dated the onset of his disability to a period of cold exposure associated with water immersion. The most striking finding on physical examination was that the index finger of both hands was cooler than the other fingers. Plethysmography was indicative of moderately severe occlusive disease in both index fingers. Arteriography of the right hand revealed segmental stenoses or occlusions involving at least one artery of each digit, but with diminished terminal vascularity only in thumb and index fingers. In addition, the ulnar artery was occluded at the wrist.

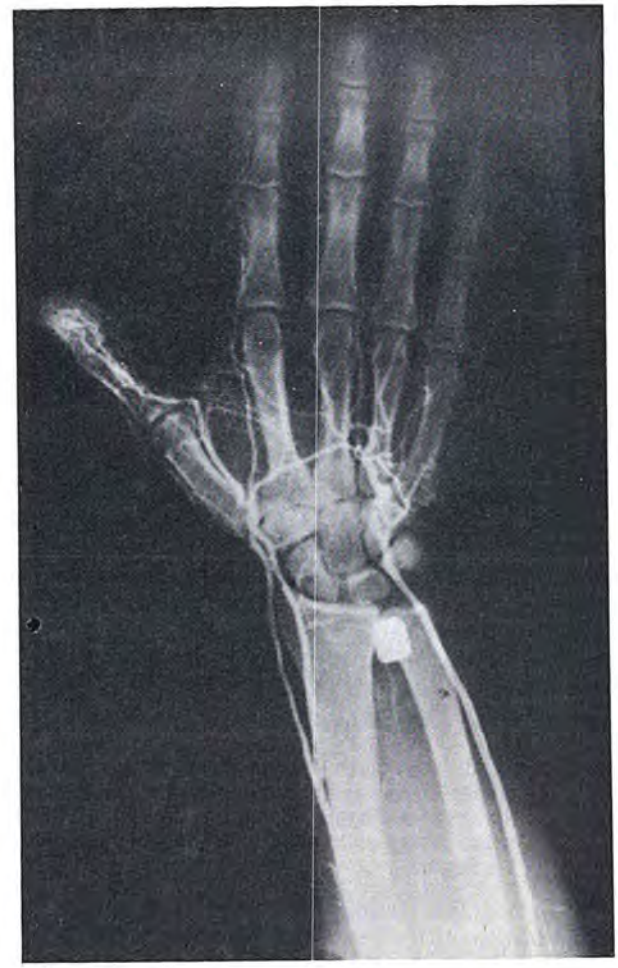

Figure 12. Arteriogram of the right hand in patient C.R.

Each of these patients with ischemic fingers, apparently related to occupational trauma of completely different origins, was found to have occlusive arterial disease in the hand. How frequently this condition underlies vascular symptoms in workers who develop "white fingers" as a result of occupational hand-arm vibration is unknown; but that is a question which certainly can be answered by a properly-designed investigation. The technology is available to get the job done.

ACKNOWLEDGMENTS

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QUESTIONS, ANSWERS, COMMENTARY

Question (D. Wasserman, NIOSH): Do you use your measurement technique with more than one finger simultaneously?

Answer: Yes, if it is possible to do it. It's hard to do it on more than two fingers at once. It gets a little awkward. You certainly can do it on two. I've never done it on more than three at once.

Question (D. Wasserman): Can you tell me why there is symmetry in the fingers afflicted with Raynaud's phenomenon?

Answer: If it is a functional problem (and we don't know the cause of the functional disorder, i.e., Raynaud's disease), then it seems to be a sort of generalized increase in reactivity of the vascular smooth muscle in the hands. And if indeed it is a generalized problem, then it is not surprising that you would observe it in a symmetric way. But I wouldn't like you to believe that always it appears as it did in just the same two fingers on the same hand. Sometimes you will have one finger and then another finger. But when I say symmetric, perhaps it is a little misleading. I probably should have said it would appear to be bilateral. The bilaterality of symptoms in patients with Raynaud's disease is not necessarily just the second or third fingers on each hand. I wouldn't be that doctrinaire about it.

Question (W. Taylor, University of Dundee): I think you would add also that it's in early life that you get Raynaud's and that you often get feet and other areas involved, as well. But I would like our engineering friends to know that the lack of medical progress lies in this area because here we have a functional disease known since 1864 and we have no idea what or why these fingers blanch!

Question (A. M. Ehrly): I'm not surprised at your making a correlation between the arteriography and the plethysmography, both are different matters to demonstrate the so-called secondary Raynaud's syndrome. We have done the correlation between oscillography and angiography, and I must say we have found a good correlation between these two types of diagnostic tools. So, I would like to ask have you done oscillographic measurements in addition to your plethysmography?

Answer: No, we haven't done oscillographic measurements. In circumstances where there's a good single repaired circulation (if you have a good artery on one side of the finger and a not good one on the other side), it doesn't surprise me that one observes functionally a fairly good picture. I would be surprised if oscillography were any more sensitive to do that job than the type of method we are using here. Perhaps it is, but we'd have to do them side by side to get the answer. The main feeling I have, and I try to emphasize it here, is that I think when plethysmography is normal, from the clinical point of view, that does not mean that there couldn't be occlusive disease in that digit. It means that, if there is occlusive disease, it's not functionally very bad. But, from the point of the epidemiologic studies, that wouldn't be very helpful. On the other hand, I think you have to know the accuracy of the methods you are using. All I can say is that this particular method is quantitative. My experiences with oscillography in other parts of the body, in the legs for instance, were such that oscillography was no better or no worse than many plethysmographic techniques.

Question (A. M. Ehrly): An additional comment. You've distinguished between functional and organic stenosis and such; it would seem, in a lot of patients, that there can be both elements in one patient? That means you can see angiographically that a patient has stenosis occlusions and that he has also hyperactive arteries of the fingers. So, perhaps we have white fingers when you cool them. I think we cannot only divide into functional and organic, we must know that there are in-between patients who have organic stenosis and functional hypersensitivity.

Answer: I think that's a good point, and I wouldn't debate that. The main feeling I have is that, for instance, plethysmography is one way to tell whether people have occlusive disease. It doesn't tell you all those who have occlusive disease, but plethysmography certainly can detect occlusive disease, so at least it's an objective measure.

Question (M. Hoza Dresser Industries): Quite a number of years ago I ran chipping hammers for several years, and I have (according to Mayo Clinic and my doctor in Houston, Texas) an affliction termed "fibrous dysplasia." They tell me this in medical terminology, and I still have difficulty totally understanding this. It appears that I have a type of bone growth. When the bone breaks, the bone does not mend properly; rather there is a great deal of cartilage formation in the break area. They told me not to hit anything for fear of additional splinter-

type breakage. Do you believe my problem is related to my past use of chipping hammers?

Answer: I frankly doubt that there's any relationship between the problem that you have and the exposure to the tool that you worked with.

Question (H. Von Gierke, Aerospace Medical Research Laboratory): Have you tried plethysmography using different lengths of the cup? Could you identify in what part of the finger the stenosis exists?

Answer: No, I haven't. We have a cup over the terminal two digits. You could use one over the terminal digit, and then measure flow. If you have occlusive disease, it involves the digital arteries, usually in a good part of their length. I think it would be unusual, then, to have just the very tip involved, and be able to pick that up and not be able to demonstrate it if you put the cup over the distal two phalanges rather than the terminal one. There is another methodology that can do that—so-called segmental plethysmography where you wrap a sensing device around a piece of the finger. Personally, I doubt that it would be very helpful in differentiating different kinds of problems.

Question (H. Von Gierke): Yes, but by your method you average over a fairly long time period.

Answer: That's correct.

Question (H. Von Gierke): Then, actually if each occlusion should be just short of the tip or at the upper part of the finger, your volume flow in the lower show up as increased pulsations, and that then could mask part of the phenomenon.

Answer: I don't deny that, but from the angiographic point of view and with these patients, I don't remember seeing any example of what you refer to. Frankly, I doubt that it occurs very often.

Question (G. Gruber, Southwest Research Institute): I'd like to ask you a question and then make a comment. I sense that you are looking for a diagnostic tool to assess the severity of occlusive arterial diseases when you showed us the direct relationship between blood flow and pulse volume. Perhaps the pulse volume measurements are easier to make; thus, it is your choice of measurement technique to assess abnormalities of occlusive arterial diseases. However, did I not detect from your talk diagnostic information relating to the slope of the line that you have for normal patients versus the abnormal patients? There was nothing there?

Answer: Yes, you are correct. There was nothing there; that was the point. There really was no separation.

Question (G. Gruber): One other comment—and I'm going to take you somewhat out of hand-tool vibration to whole-body vibration. I thought about the epidemiological study that I'm conducting on bus and truck drivers. Of course, these people are exposed to flow vibrations, seat vibrations, as well as hand vibrations (although the steering wheel is probably not presenting as severe vibration intensities as some of the hand tools that you are dealing with). We have discovered in long-distance bus drivers a more than usual, in fact a rather frequent, occurrence of circulatory disorders of the lower extremities, the scrotum, and rectal areas. We've shown that varicose veins in lower extremities were also rather frequent among bus drivers. We also detected more than a normal amount of hemorrhoids, all indicating dilitational factors. We had hypothesized that not just occlusional blockage of the vessels can occur, but also dilitational factors, perhaps related to the whole body resonance as the pressure (the fluctuating pressure) oscillations develop in the general trunk area. The oscillations have a malfunctioning effect on some of the valves that, of course, are key elements in the blood supply. I just wanted you to comment on the part of the finger could be increased, or it could way these things have, perhaps, of showing up again —a different environment, a different occupational group—and perhaps, also indicating the same sort of physical mechanisms.

Answer: Well, thank you for those comments. There are a lot of ways to interpret that. For instance, examine it physiologically. Last year at a meeting in Sweden, Professor Taylor and I heard (from Dr. Folkow's group) about the effects of vibration on muscle, certain kind of muscle; they do studies on clams and have found that vibrations make the muscle relax. So there may be something there.

Question (F. Dukes-Dobos, NIOSH): I have several questions. First, I would like to ask whether or not you were able to detect the effect (immediate or long-term) of smoking in terms of either pulsation or the slope of the circulation volume curve?

Answer: It's very simple to demonstrate the effect of smoking acutely and by plethysmographic methods. If you are recording the pulse (just a casual pulse in the finger) within a minute or two of smoking a cigarette, there usually is a marked constriction. The pulse gets much smaller, and this is a very well known pharmacologic mechanism. The nicotine action results in vasoconstriction and some of you who smoke, who shouldn't, may be aware of actual cooling of the digits after smoking a cigarette. Many people notice that subjectively. You can demonstrate that very clearly plethysmographically. I haven't performed any elaborate studies in this area, but it is easy to demonstrate. In fact, I've often thought it might be a good behavior modification tool if you are interested in reinforcing the importance of not smoking; people could watch their pulses get smaller after they smoke a cigarette.

Question (F. Dukes-Dobos): The second question relates to your instructions to your patients. How long before the examination were they not allowed to smoke?

Answer: That wasn't done in any kind of orderly way. If the patient hadn't smoked for overnight, and came in in the morning, you could easily demonstrate this.

Question (F. Dukes-Dobos): The third question relates to a qualitative assessment of your pulse waves from contours. Would you please elaborate on how you qualitatively have assessed these curves?

Answer: The normal pulse rises very rapidly and then there's a dicrotic notch, a dicrotic wave, and then it descends. The abnormal pulse gets abnormal in three ways. Simply speaking, the rate of rise of the pulse may be altered, but that's a more advanced change; more commonly, with early disease, there's a flattening out of this dicrotic limb on the curve. There's a loss of this dicrotic notch, or a tendency for it to disappear; then there is a decrease in the rate of rise in the curve; and finally, just sort of a general flattening of it.

Question (F. Dukes-Dobos): The final question. You were talking about radial and ulnar occlusion. How do you separate the occlusion and what technique did you use?

Answer: The radial artery is on the thumb side of the wrist and the ulnar artery is on the small finger side of the wrist. The researcher then uses his own hand to occlude these vessels. Indeed, it's a crude type of maneuver; it can't be quantitated very well. It's a lot easier to compress the radial artery because you can feel it and you can tell when you've stopped it. In fact, if you are experienced at it, you can keep one finger distal to the point where you are compressing it, and you can actually feel that the pulse is no longer there, if compressed enough. On the ulnar side, that's harder to do; that's why I indicated it's a little bit hard to guarantee that with any given subject you have, in fact, compressed it completely.

Question (W. Taylor): I would like to ask two questions. In the Department of Health and Social Security (U.K.) report, our government did not consider Raynaud's phenomenon as an industrial disease; they said there were no cases of tissue necrosis, of gangrene, connected with this syndrome. I would like to know whether you've seen in your clinical work what we would call pure Raynaud's associated only with vibration.

Answer: The last case that I discussed in my paper might fit in that category. I would have to answer your question in a negative way. I'm not in a particular setting where I might be likely to see that kind of case. I would be amazed that this would not occur, however. From what I've seen, if you have advanced occlusive disease for any reason, you can, in some subjects, develop loss of the proper nutrition to the digit.

Comment (W. Taylor): One of Walton's patients had 26 years' exposure on road rippers. Before surgery, he came to the hospital with his finger tissue already necrotic, which rather upset everybody because no help had been asked before the tissue necrosis. The surgeons then decided the following day to do a sympathectomy; they did a right and a left one in a single operation. Unfortunately, we lost the heart, which was resuscitated, but the patient didn't regain consciousness. Thus, we obtained a full series of post mortem sections.

I would like the engineers to know this. The first thing that came out was that every artery in the whole body was normal other than the digital arteries. They showed the classical picture reported in the early sixties by Ashe (Ohio State Univ.). The next attack was made on the nerves and the Pacinian corpuscles were infiltrated with round cells and showed a certain amount of infiltration and destruction subcutaneously, but beyond the skin level, the nerve trunks were normal. That worries me when we are looking for objective tests, rather than subjective tests.

Question (W. Taylor): Are you sure that we've gotten rid of the sympathetic nerve control when you're testing in a hot room? I want to know whether you did repeat plethysmographs on normal subjects during that 24-hour period? I have a feeling that vascular tone, whatever that may mean, is a big factor in all our work in the field and that we've been unable to control it. I, myself, have been very apprehensive in a hot room when I've had this done, and I just wondered are you sure this is controlled?

Answer: Well, I can't give you absolute assurance with this particular procedure, but I know that if we haven't obliterated all sympathetic tone, it is probably some 90 odd percent gone. The people using these kinds of methods consider them to be fairly traditional approaches to measuring maximum circulation in various areas. One way that you can crudely test this is to see whether you get a difference by directly blocking the nerve, (i.e., injecting the nerve with a blocking agent). The response you get to heat plus reactive hyperemia, or heat alone, and the results with nerve block are very similar. This total body heating to the point of profuse sweating, or rise of body temperature, or both is just about the most potent stimulus we can get and is comparable to blocking a nerve.

Comment (A. M. Ehrly): Just an additional comment to your question. I think we perform a similar procedure. We inject priscol or nitroglycerin, or reserpine before making our tests, especially in doing our arteriography. We can really exclude all functional occlusions.

Question (P. Rentos, NIOSH): You have mentioned a phenomenon relating to constriction of vessels of the hand. You said that, in regard to cold, this was a functional phenomenon that you were observing, but that in the case of vibration, this was of an organic nature. Could you clarify what is meant by organic in this case and what were you suggesting?

Answer: Well, I don't know if I put it exactly that way. I don't know what vibration does. The main issue as far as I'm concerned is whether the vessels are just oversensitive to normal stimuli or whether, in fact, the vessels are narrowed or blocked or both and are incapable of dilating normally, so that they are actually partially occluded or occluded. To me, that is the basic question in this disorder. Is it just that the vessels are nervous and excitable or are they in fact physically changed?

Question (P. Rentos): In both cases, is what you observed reversible? Does the effect become nonexistent as a result of removal from exposure to either cold or vibration?

Answer: If it's a functional problem, and if the person is not exposed to the stimuli that will tend to cause this problem, they will not have the problem; but if it's an organic problem and there's actual structural change in the artery, there is no reason to believe that it is going to get better. It is a permanent type of damage, and I think that's a very important question.

Question (G. Laroche): Two years ago while working at the Mayo Clinic, I checked on a few of those cases of Raynaud's disease that were treated by cervical sympathectomy. The view was, for some years, to do sweat tests before and after the cervical sympathectomies. We found that the sweat test was not useful and that there was really no difference between studies made at rest and after sweating. What then has been your experience with cervical sympathectomies in general after the cessation of disease?

Answer: Practically no experience; this is a clinical question, as far as management goes. Most of the patients who develop Raynaud's phenomenon have a functional disorder. I don't think the problem is usually of a severity that requires any kind of medical intervention; but if it's a far advanced one, I think there are pharmacologic approaches that are probably just as good as sympathectomy. I worry about sympathectomy; I can't answer your question because I don't think I have had one patient that I referred to the thoracic surgeons for sympathectomy in the last 10 years.

Comment (W. Taylor): Could I add just one bit to that? I have details on a very small occupational disease group (namely, six), and the answer would be "No." First, there is a very active period after 2 to 3 weeks, with great improvement, and then the patient slowly reverts back to normal. Furthermore, all our patients, particularly in forestry, are on vessel dilators and the answer there is equally negative.

Question (G. Laroche): I have a second question for Dr. Zweifler. Do you believe that the plethysmographic tracings at rest or with stimulation would give you enough selective objective evidence or objective criteria for their use as a measure of impairment or disability?

Answer: If you measure the maximum pulse under conditions of maximal dilatation and the maximum pulse is clearly abnormal using the criteria that, at least, we've established (or other people can establish their own criteria with the same methodology), then you have definite objective evidence of disability. As I indicated earlier, you cannot make the reverse statement: the patient might have occlusive disease and a normal plethysmogram. And that's the way I would answer your question.

Question (G. Laroche): Would you use it specifically to determine the impairment or the disability?

Answer: Yes, I think it could be helpful in that regard.

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