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STUDY ON ARTERIOSCLEROTICS UNDERGOING AMPUTATIONS

INCLUDING PRE- AND POSTOPERATIVE PERIODS

by
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PREFACE

The subject of this study was suggested by my teacher and present principal, Professor K. E. Kallio, M.D., Head of the Clinic for Orthopaedics and Traumatology of the Central University Hospital, Helsinki. He has unsparingly given his advice and positive criticism at all stages of this work and I am very happy to have this opportunity to express my deep gratitude for his encouragement.

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Helsinki, 1967.

E. Vankka

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I INTRODUCTION

A. General

Fairly little scientific attention was paid prior to the second world war to extremity amputees in Finland, or in any of the Scandinavian countries for that matter (see Kallio 1943). As a result of the wars in which Finland was involved (1939—1940 and 1941—1944) our country acquired about 5000 new extremity amputees (Solonen 1965), and of them about 3800 were leg amputees (Bakalim 1966). Kallio (1943) has been a pioneer in their investigation in Finland, and a lively pursuit of this subject followed, e.g. through the contributions of Hagelstam (1946), Langenskiöld (1946), Kallio (1947, 1948, 1949a, b, c, 1950, 1951, 1959), Solonen (1956, 1958a, b, c, 1959, 1961, 1965), Bakalim (1964, 1965) and Lindqvist (1966).

On the other hand, those subjected to amputation on account of arteriosclerosis have not received as much attention. Lindholm (1964a, b) is the only one who has previously studied them in this country.

In spite of the fact that amputation surgery is as old as surgery itself, amputations undertaken on account of arteriosclerotic gangrene were anything but common a hundred years ago. For instance, according to Buel (rev. by Dale and Jacobs 1962) gangrene was not responsible for even one of the 91 amputations performed in the New York Hospital during the period 1839—1848.

But with the increasing life span of the population, gangrenes caused by arteriosclerosis have continuously increased in number. This has been observed e.g. in Finland (Lindholm 1964b) and in Sweden (Hansson 1964) during the past 20—30 years, and the same trend of development seems to persist. For instance, with unchanged indications for amputation the annual number of amputations in the town of Malmö, Sweden, is expected to increase by 50 % from the 1955 figure by the year 1970, according to Alffram and Holmquist (1961), and in Gothenburg, Sweden, an increase by 75 % from 1962 to 1970 will occur, according to Hansson (1964).

It would seem, too, that in Finland the number of persons subjected to amputation on account of arteriosclerotic gangrene is also continuously increasing. This suggests that it is most appropriate to study the problems encountered in patients suffering from gangrene.

It is thus to be understood that the fairly general occurrence of arteriosclerotic gangrene and of amputation necessitated by it, is a rather recent phenomenon. Obviously, therefore, questions rating closer investigation are still to be found in this particular field. For instance, rather little attention has been paid in studies concerning amputees to the gradual development of the underlying chronic disease, arteriosclerosis, or to the extent it reaches at different phases in the history of the amputee — from the appearance of the first symptoms of occlusion to the fatal termination. Accordingly, this is one of the aspects for which elucidation is sought in the present work. At the same time it is desired to study the effect of sympathectomy as an expedient obviating amputation. Another object is to ascertain what results have been gained with amputation, bearing in mind that the patients concerned are suffering from arteriosclerosis, and in whom gangrene, too, is only one of the manifestations of this disease.

B. Definition of arteriosclerosis; the classification of vascular diseases

Lobstein (1829, rev. by Pickering 1963) was the first to use the term "arteriosclerosis" to describe any cicatricial macroscopic hardening of the artery (sclerosis), its thickening and changes in its walls, independent of their aetiology. Even the diligent research of recent decades has not produced any aetiological definition of arteriosclerosis. There has consequently been no choice other than artificial classification and descriptive definitions.

Marchand (1904, rev. by Pickering 1963) first distinguished atherosclerosis from arteriosclerosis. The definition of atherosclerosis has caused dispute. The definition given in the Technical Report of the World Health Organisation (Ser. No. 143, 1958) is: "Atherosclerosis is a variable combination of changes of the intima of arteries (as distinguished from arterioles) consisting of the focal accumulation of lipids, complex carbohydrates, blood and blood products, fibrous tissue and calcium deposits, and associated with medical changes." In the opinion of some authori-

ties thrombotic changes are also associated with atherosclerosis. For instance, Allen et al. (1962) propose the addition: "and often complicated by partial or complete thrombotic occlusion of the lumen".

Schettler (1961) comes rather close to Lobstein's original conception in saying: "Für uns ist die Arteriosklerose der Sammelbegriff chronischer arterieller Umbauvorgänge, die zu Verhärtung, Elastizitätsverlust und Lichtungseinengung der Arterien führen können und damit Funktionsstörungen der versorgten Organe bewirken." (To us, arteriosclerosis is the collective notion of chronic arterial rebuilding processes which may result in hardening, loss of elasticity and reduced lumen of the arteries and thus cause functional derangement of the organs supplied.)

Atherosclerotic changes in the late or complication stage of the abdominal aorta and of the medium-large arteries of the extremities are referred to as arteriosclerosis obliterans. According to Allen et al. (1962) this is a diagnostic term having as synonyms: atherosclerosis obliterans, "occlusive peripheral arteriosclerosis", "arterielle Verschlusskrankheiten (occlusive arterial diseases)", and endarteritis obliterans.

Several suggestions have been made for the classification of vascular diseases (Wright et al. 1941, Ratschow 1959, Allen et al. 1962, Pickering 1963, etc.). However, the pure forms stated in the classifications are rare. Mostly various combinations of them are concerned (Linzbach 1958).

From the clinical point of view, the height of occlusion is significant because the localization of arterial lesions not only determines the symptoms but is also of consequence as regards prognosis and therapy (Leriche 1953, Krautwald and Völpel 1959, Ratschow 1959, Allen et al. 1962). A classification that has proved rather serviceable is the topographic division of chronic arterial occlusion diseases, according to Ratschow, on the strength of the localization of obstructions: the peripheral, lower leg, pelvic and shoulder region, and carotid types of occlusion. In the lower extremities in particular, however, mixed types are often encountered when several occlusions occur at various heights (Heine et al. 1965).

C. Genesis of obliteration symptoms

Before arteriosclerosis becomes clinically manifest in the form of obliteration symptoms, slowly increasing changes have been in progress in the intima often for as long as 20—30 years: fatty streaks and fibrous plaques. From the fifth decade onwards, the effect of thrombosis begins

to produce symptoms of obliteration and ischaemic changes of the organ or tissue supplied by the affected artery, leading to cardiac infarction, apoplexy, and/or the occurrence of gangrene in a lower extremity (Allen et al. 1962, Sandler and Bourne 1963).

The disease may remain completely dormant even in the case of fairly severe arteriosclerotic patho-anatomical changes unless it is accompanied by obliterative thrombosis (Scheidegger 1965). This is because more than 50 % of the lumen of the artery has to be occluded (Schoop 1964), even up to 90 % (Wylie and McGuinness 1953) or still more (Brice et al. 1964), until the blood flow is reduced to such an extent that symptoms appear.

The widespread nature of thrombosis is not always dependent on the severity of the atheroma formations (Schoop 1964). Its clinical significance arises from the fact that occlusion proceeds rapidly, frequently leading to complete occlusion and, when vital organs (brain, heart) are concerned, to death (Mittelmeier 1959). Just as the commonest complication of atherosclerosis of the coronary arteries is thrombosis, the commonest cause necessitating amputation of lower extremities in arteriosclerotic patients is likewise the occurrence of a thrombus (Edwards and McAdams 1953). For instance, Wessler and Schlesinger (1953) observed a fresh, completely occluding thrombus in about 50 % of 66 patients subjected to amputation on account of arteriosclerosis; in 25 % the thrombus was multiple.

Factors, other than the degree of obliteration, influencing the clinical picture are: the extent, number and rate of development of obliterations, the distance of the proximal limit from the aorta, the efficiency of collateral circulation, and general circulatory conditions (Munk 1939, Mittelmeier 1959, Ratschow 1959, Allen et al. 1962). Munk (1939) said very pertinently that the development of arteriosclerosis into a manifest disease depends on how, where and when it occurs.

D. Factors promoting development of arteriosclerosis

It has become increasingly general to accept a polyaethiology as an explanation of arteriosclerotic changes. A number of causes have been observed which have been found to aggravate the arteriosclerotic changes.

In the following, the effect which some such predisposive factors, such as age, diabetes, sex, and blood pressure, exert on the development of arteriosclerosis will be considered.

Age

Age in itself cannot be considered a cause of arteriosclerosis, but it is a time factor in accordance with which the number of arteriosclerotic patients, the degree of severity of the disease and its fatal complications increase (Schinz and Reich 1955, Bredt 1961).

Roberts et al. (1959) in an autopsy material of 500 patients observed an increase of arteriosclerotic lesions with age, both as regards extent and degree of severity. There were variations in these respects in different parts of the vascular system, however. In the lower part of the abdominal aorta, changes were encountered in subjects of all ages. Segmental occlusion of the aorta and of the iliac and femoral arteries was found to occur in the fifth or sixth decade in most instances. The rate of sclerosis is slower in the intestinal region: up to the age of 70, comparatively few changes occur in the splenic, mesenteric, coeliac and renal arteries.

Arteriosclerotic obliterations causing lower extremity amputation are rare in persons younger than 50 years. For instance, in Hansson's (1964) series all but one of 236 patients subjected to amputation on account of arteriosclerosis were over 50 years, and 59 % were older than 70. In the series of 284 amputations at the lower leg or thigh of Dale and Capps Jr. (1959), those performed because of arteriosclerosis numbered 259. The age group above 50 and that above 70 years accounted for 92 % and 46 % of the series respectively.

Diabetes

On the strength of autopsies and clinical studies, the incidence of arteriosclerosis has been found to be distinctly higher in diabetics than in non-diabetics (Dry and Hines 1941, Roberts et al. 1959, Schettler 1961). The longer the diabetic affection, the higher is the probability that arteriosclerotic circulatory disturbance ensues. According to Scherf and Boyd (1955), 90 % of the diabetics whose disease has persisted for ten years display signs of arteriosclerosis.

According to Lempke et al. (1963), amputation ensues on an average three years earlier in arteriosclerotics with diabetes than in non-diabetic ones, and according to Schumacker (1951) even as much as seven years earlier. Diabetes increases the amputation frequency (Bell 1950, Claugus et al. 1958, Lempke 1963), and diabetics undergo bilateral

amputation in a higher proportion than non-diabetics (Joslin 1944, Silbert and Haimovici 1950). Sclerosis of the coronary and cerebral arteries is affected by diabetes, too, though not as strongly as that in the lower extremities (Clawson and Bell 1949, Roberts et al. 1959).

Sex

Differences in the development of arteriosclerosis have been noted between the sexes. In men, arteriosclerosis begins to develop earlier and with greater intensity than in women; the difference is most distinct in respect of the coronary arteries and those of the lower extremities (Barr et al. 1955, Walker et al. 1956, Lew 1957, Roberts et al. 1959). Women are fairly free of arteriosclerosis up to their menopause, whereupon, after reduction of their oestrogen secretion, the arteriosclerosis grows worse to such an extent that changes are encountered in equal degree in both sexes between the ages of 70—80 years (Barr et al. 1955, Roberts et al. 1959).

The occurrence of arteriosclerosis of the lower extremities in men and women in different age groups is illustrated by the following proportions: for persons between 50 and 70 years, Hines and Barker (1940) found a men/women ratio of 6:1 and Ratschow (1959), 3:1. At ages below 60 years this ratio is 11:1 according to Hines and Barker. The series assembled of persons amputated on account of arteriosclerosis show a predominance of males in agreement with the preceding. For instance, the series of McKenzie (1953) of amputees older than 65 years had a male component of 66 %. In that of Dale and Jacobs (1962) the contribution of men was 65 % and in Lindholm's (1964b) series, 59 %.

This sex-dependent difference becomes quite small with increasing age or is, in fact, inverted. Series consisting mainly of geriatric patients have been reported to include men at 55 % (Alffram and Holmquist 1961) and at 40 % (Lindholm 1964a). Persons with coronary affection, too, show a distinct difference between the sexes. For instance, Oliver and Boyd (1954) found for the proportion of men and women in the age group of 50—59 years a ratio of 5:1, while in the group of 60—69 years the share of women had already increased so that the ratio was 2:1.

Blood pressure

Numerous studies have demonstrated that chronic arterial hypertony promotes the development of arteriosclerosis (Nordman 1929, Kathke

1955, Könn 1956, Liebegott 1959, etc.). Hypertonia is in fact, in addition to diabetes, the most significant disease contributing to arteriosclerosis. Apart from its general effect, increased arteriosclerosis of the coronary arteries is most notable among the changes observable in different organs (Bäurle 1951, Spandling 1956, Roberts et al. 1959, Schettler 1961, etc.).

In the pulmonary circulation, too, hypertonia exerts an arteriosclerosis-increasing effect on the pulmonary arteries (Merkel 1947, Könn 1956). Wilkins et al. (1959) observed arteriosclerotic changes at autopsy in the cerebral and renal arteries in obese hypertonics, in addition to the coronary arteries, to a greater extent than in non-hypertonics of the same age. Chronic hypertonia has no distinct effect on obliterative peripheral arteriosclerosis of the lower extremities (Juergens et al. 1960), nor is hypertonia present in any higher proportion of those subjected to amputation of lower extremities on account of arteriosclerosis than in non-amputated persons of the same age (Spandling 1956, Juergens et al. 1960).

II OBJECTS OF THE PRESENT STUDY

The principal purpose of this study was to follow in patients subjected to amputation on account of arteriosclerosis the gradual development of their fundamental disease, from the first symptoms of obliteration through the sympathectomy and amputation stages up to death.

Closely associated with this topic is the question of how such a least-desirable measure as amputation might be avoided. Sympathectomy is discussed as a prophylactic expedient.

When, however, amputation must be performed, it is important to know how it should be done in order that the best possible result can be achieved in the light of associated diseases, operative mortality, technical success of the operation and rehabilitation. Attention is also paid to these factors. Attempts have been made to find answers to the following questions:

(1) What was the kind of gradual development of arteriosclerosis revealed by the clinical symptoms of obliteration present prior to amputation?

(2) How extensive were the arteriosclerotic changes at the time of amputation?

(3) What was the extent of arteriosclerotic changes revealed by autopsies and death certificates?

(4) What was the contribution of sympathectomy as a therapy precluding amputation?

(5) What was the effect of the height of obliteration in the lower extremities, and of other potential factors, on the healing of the stump after amputation?

(6) What is the post-amputation prognosis as regards the use of a prosthesis, life expectancy and cause of death?

III MATERIAL AND METHODS

A. Material

The clinical series involved in the present study consists of 184 lower extremity amputees who were subjected to amputation at the lower leg or at the thigh during the period 1950—1963.

Amputation was performed on 97 patients between 1950 and 1963 in the Clinic for Orthopaedics and Traumatology, Central University Hospital, Helsinki, and on 87 patients in the former Hospital of the Finnish Red Cross between 1950 and 1959.

The series constitutes a selected material. All told, 296 amputations below or above the knee were carried out in the two hospitals in question during the above-mentioned period. Of them, those 184 patients were included in the present series in whom the cause necessitating amputation was gangrene or a severe ischaemic condition due to arteriosclerosis. The series from both hospitals have been combined and treated as one single series.

Of the 184 patients, 138 (75 %) were hospitalized other than for the purpose of amputation on account of either obliteration symptoms due to arteriosclerosis or diabetes. Thanks to this, when the results of examination at the time of amputation, and data concerning sympathectomy operations were gathered, information was available from 98 case reports from internal medicine hospitals and 72 from surgical hospitals, in addition to 216 case reports covering amputations. This amounts to a total of 386 case reports with associated laboratory and X-ray examinations.

For all 127 patients established as dead at the time of follow-up study, information concerning the causes of death entered in the death certificates has been obtained from the Central Office of Vital Statistics of Finland.

Autopsies were performed on 32 patients. Autopsy records concerning all these patients have been available.

Of the 57 surviving patients, 38 (67 %) were subjected to follow-up study. The shortest and longest periods between amputation and follow-up study were 13 months and nearly 14 years, the average interval being four years. Of the 38 patients, 30 presented themselves for follow-up examination, while the examination of the other eight was performed at the homes for old people or invalids where they were being cared for. Nine of the 19 patients not included in the follow-up study lived at a considerable distance. Of the other ten, whose homes were in the vicinity of Helsinki, seven failed to present themselves for examination, while three could not be contacted.

Distribution by age, sex and height of amputation

In the present report, the age at amputation is understood to be the patient's age at the time when the first or only amputation at a height above the ankle was performed. Unless otherwise stated, reference to the patient's age in the following will mean his age at the time of amputation.

With regard to the height of amputation, distinction is made between amputations at the lower leg and those at the thigh. No other kinds of amputation occur in the present series, except for one exarticulation of the knee, which has been placed with the lower leg amputations. In that instance, too, later reamputation at the thigh was performed.

The primary amputation is understood to be the first amputation performed at a height above the ankle. Any amputations performed after the primary amputation on the same extremity are referred to as reamputations.

Fig. 1 shows the distribution of the amputees by age and sex. In addition, the figure indicates the contribution of diabetics to each ten-year age group and their percentages of the entire male and female series. The men number 111 (60 % of the entire series) and the women, 73 (40 %). The older age groups contain a greater number of women than men, while a predominance of men is noted in the younger groups. The largest male age group is that between 60—70 years, comprising 50 patients or nearly one-half (45 %) of all the men. The largest female ten-year age group is that between 70—80 years, consisting of 33 patients, or 45 % of all women.

The mean age at amputation is found to be 66.2 years for the men and 72.4 years for the women. The difference in age (6.2 years) is statistically

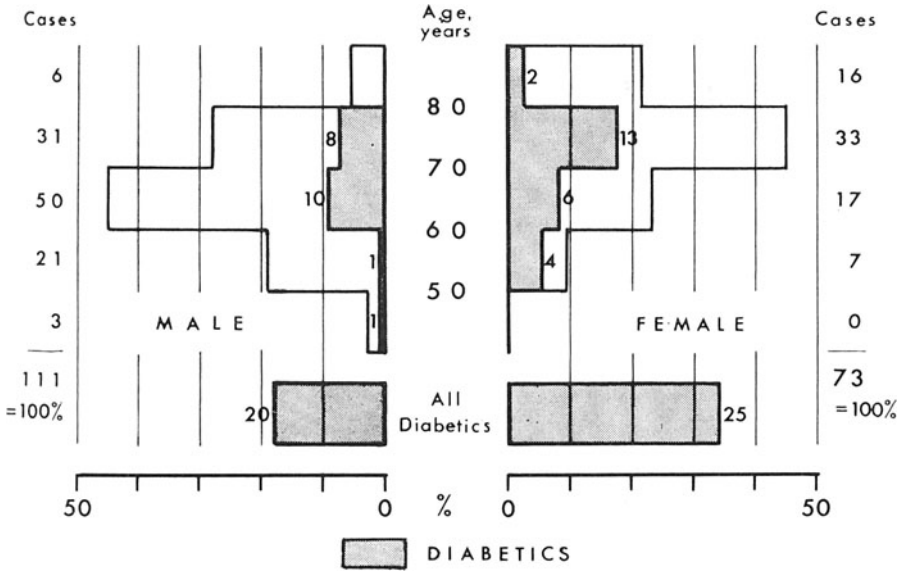

Fig. 1. Age distribution of the male patients (111) and female patients (73) of the series for different ten-year age groups, in per cent. The shaded portions indicate the contributions of diabetics, and the separate shaded bars the percentages of diabetics in the male and female subseries regardless of age.

highly significant ($P < 0.001$) according to Student's t test. The mean age in the entire (male and female) series is 68.7 years. Only three men were subjected to amputation at an age under 50 years. Altogether 153 patients (83 %) were older than 60 and nearly one-half of the patients in the series (47 %) were over 70 years at the time of amputation. The oldest patient was 92 years old and the youngest 47. Both were male.

The diabetics in the entire series number 45 (24 %). Of the women, 25 (34 %) had diabetes and of the men, 20 (18 %); the difference between these percentages is statistically almost significant ($P < 0.05$) according to the χ^2 test. The mean ages of the diabetics and non-diabetics were 68.2 and 68.8 years, respectively. The corresponding figures for the men alone are: 66.9 and 66.2 years; for the women: 69.7 and 73.8 years. No statistically significant differences were established between the diabetic and non-diabetic groups in respect of age at amputation. The average period of treatment for diabetes prior to amputation was 3.1 years, and the mean age at which diabetes was established was 62.2 years. The treatment for diabetes consisted of insulin in 21 cases (47 %), which was used at 20—112 I.U. per day (average: 56 I.U. per day). Ten

patients received peroral tablet treatment, and the other 14 managed on diet.

From Fig. 2 the numbers of final lower leg and upper leg stumps and their distribution by sex and age can be seen. Moreover, the diabetics' stumps have been indicated for all ages in aggregate.

The 219 stumps itemized in Fig. 2, which belonged to 184 patients, came about as follows. Primary lower leg amputation was performed on 24 extremities. Nine of them (38 %) had to be re-amputated later, in two instances at the lower leg and in seven at the thigh. The end result was 17 lower leg stumps and seven upper leg stumps. Correspondingly, primary amputation at the thigh was performed on 195 extremities, of which nine (5 %) had to be subjected to later reamputation. The total is thus 219 primary amputations and 18 reamputations (8 %).

The 219 final stumps comprise 17 lower leg stumps (8 %) and 202 upper leg stumps (92 %). As regards their distribution among the 184 patients, the number of unilateral amputees is 149 (81 %); 13 lower leg amputees and 136 upper leg amputees. This leaves 35 bilateral amputees (19 %), consisting of 31 with bilateral upper leg stumps and four with one lower leg and one upper leg stumps, and totalling 70 stumps. 171 amputees (92 %) had a unilateral or bilateral upper leg stump and 13 (8 %) had a unilateral lower leg stump.

The mean age of the unilateral lower leg amputees is found to be 64.8 years and that of the unilateral upper leg amputees is 69.8 years, means which do not differ on a statistically significant level. The mean age at amputation of the bilateral amputees is 65.8 years against 69.4 years for the unilateral amputees; the difference is statistically almost significant ($P < 0.05$). The time intervening between the amputations on the first amputated leg and on the other in the bilateral cases was 1.1 years on the average.

Comparison of the diabetics and non-diabetics reveals that of the diabetics, 5 have unilateral lower leg stumps (11 %) against 12 (9 %) among the non-diabetics. The diabetics with bilateral stumps number 8 (18 %), and the non-diabetics, 27 (19 %). The mean age of the bilateral diabetic amputees is 66.9 years and the average interval between amputations was 1.0 years; the corresponding figures for the non-diabetics are 65.3 years and 1.2 years. The are no statistically significant differences.

On comparison of the male and female series the observation can be made that both have unilateral lower leg stumps in equal proportion: the women number 5 (7 %) and the men 8 (7 %). Unilateral upper

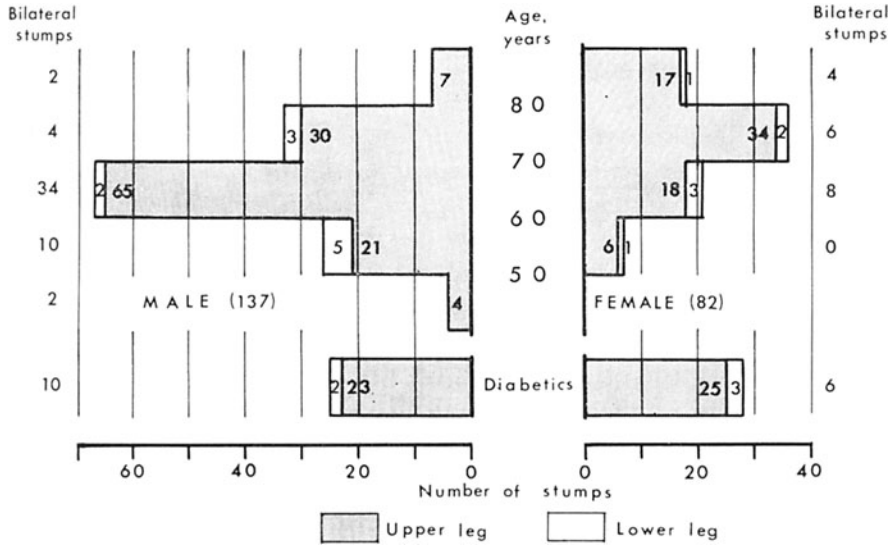

Fig. 2. Distribution of the male and female patients' upper leg and lower leg stumps resulting from amputation, by ten-year age groups. The male and female diabetics' stumps have been separately indicated, regardless of age.

leg stumps occur in 59 women (81 %) and in 77 men (69 %), while 9 women (12 %) and 26 men (23 %) have bilateral stumps; the latter percentages differ at a statistically almost significant level ($P < 0.05$).

Comments on the material

The principle followed in selecting the present material was to include in the series from a 14-year material of amputations at the lower leg or thigh, only those cases in which the amputation had been caused by gangrene or an ischaemic state due to arteriosclerosis.

In previously presented, even unselected, series the majority of the patients were subjected to amputation on account of arteriosclerotic gangrene. Such series of cases involving amputation exclusively or mainly on account of arteriosclerosis (Perlow and Roth 1949, McKenzie 1953, Claugus et al. 1958, Dale et al. 1959, 1962, Schlitt and Serlin 1960, Alffram and Holmquist 1961, Perlow 1962, Lindholm 1964a, b, Hansson 1964) have some common characteristics. Nearly all patients are over 50 years old and about half of them are older than 70; the men outnumber the women; the women's age at amputation is higher than the men's; the age at amputation of diabetics is 3—10 years lower than that of non-diabetics, and women are about twice as numerously represented among diabetics, compared to the non-diabetics; the number of upper leg stumps

is usually higher than that of lower leg stumps; and bilateral stumps occur in about one out of every five cases, among the diabetics even more frequently.

Most of the features listed above are also apparent in the present series. Only three patients were under 50 years, and about one half (47 %) were older than 70. Occlusions leading to gangrene occurred more frequently in men than in women, in a proportion of 3:2. Earlier and more extensive development of arteriosclerosis in men is suggested by the fact that the men's mean age at amputation was 6.2 years lower than that of the women, differing from the latter at a statistically highly significant level, and that bilateral amputations were about twice as frequent in men as in women. These bilateral amputations also indicate that the development of the disease was fairly symmetric in a considerable proportion (19 %) of the cases. The development of arteriosclerosis was evidently more rapid and more extensive in the bilateral amputees than in the unilateral ones, at least as regards the arterial tree influencing the circulation in the lower extremities. It should be noted that the age at amputation of the bilateral amputees was lower by 3.7 years, at a statistically almost significant level, and that the time intervening between the amputations of their first and second extremity averaged 1.1 years. This implies that the majority of the bilateral amputees had lost both lower extremities at an age when most of the unilateral amputees still had the use of both legs.

There is no appreciable difference in the present series between diabetics and non-diabetics as regards age at amputation or distribution of stumps, nor in all probability in the rate of development and extent of arteriosclerosis in the region of the arterial tree affecting the circulation of the lower extremities. According to Root (1950), the atherogenesis-increasing effect of diabetes depends, among other things, on the degree of severity of the diabetic affection, on its duration and on the sugar balance. In the present series, diabetes had been established in the patients in question at a comparatively late age (on the average when they were 62.2 years old) and treatment for it had only been administered for 3.1 years on the average, prior to amputation. More than half of the diabetics managed without insulin and the insulin dosage was moderate even in the cases where it was necessary. It would seem that owing to the short duration of manifestation of diabetes and to its comparatively mild degree it did not exert any noteworthy atherogenesis-increasing effect.

B. Methods of investigation

From the case reports and associated laboratory and X-ray examinations and from follow-up study the following facts were extracted.

1. Previous history

The anamnestic data were collected from a total of 386 case reports; in the case of 38 patients they were checked on follow-up study. Of various clinical symptoms of arterial occlusion, the following were noted: intermittent claudication, angina pectoris, cardiac infarction, cerebral apoplexy, symptoms of occlusion in the region of the neck and shoulders, and angina abdominis. In addition to the time of appearance of the symptoms of occlusion and their duration prior to amputation, the number of attacks was also noted in respect of cardiac infarction and apoplexy. The time of onset of gangrene was also clarified.

2. Local symptoms

The most distal palpable pulse in the lower extremities was noted; the extremities were classified on the basis of this finding, in very much the same way as Hanley (1955) and Silbert and Zazeela (1958) have done:

(a) Pulse of the femoral artery, and those distal to it, absent;
(b) Pulse of the popliteal artery, and those distal to it, absent;
(c) Pulses of anterior and posterior tibial arteries absent;
(d) One pulse of the foot absent; and
(e) All pulses feebly palpable.

Furthermore, the following subdivision on the basis of ischaemic symptoms was made:

(f) Rest pain or continuous pain but no cutaneous lesions; and
(g) Gangrene, necrosis of skin or ulceration.

3. Records of operation

The following were noted from the records made of the operations: height of amputation, cutaneous, subcutaneous and muscular bleeding during operation, tautness of skin and sutures on closure of the wound, and application of a drain.

4. Post-operative data

The following were noted: time of removal of the drain, healing of the wound *p.p.i.*, tautness of the skin at removal of sutures, wound dehiscence on removal of sutures, purulent discharge from the wound, cellulitis, wound haematoma, sequesters, and febrility.

5. Laboratory examinations

From the urine examinations the following were noted: proteins, sugar, specific gravity, and sediment. From blood tests: haemoglobin, creatinine, and rest nitrogen. The urinary examinations were made from morning urine. Other examinations evaluated include electrocardiographic studies, of which the report of an internal specialist was available in every instance.

6. X-ray examinations

Existing aortic and lower extremity angiographies were studied and any apparent stenoses and occlusions observed, as well as the degree to which the popliteal artery and its branches were visible. Furthermore, in a manner similar to that applied by Singer (1963), the diameter of the artery was measured from the arteriographs, comparing it to normal and classifying on this basis the observed changes according to five degrees of severity, as follows. 0°: substantially normal, or atherosclerotic changes without constriction of the lumen; 1°: lumen constricted to two-thirds of normal; 2°: lumen constricted to one-third of normal; 3°: segmental occlusion completely blocking the lumen; and 4°: thrombus occluding the entire artery, or several separate occlusions.

7. Autopsies

The autopsy findings relating to arteriosclerosis have been classified according to three degrees of severity: mild, moderate, and severe. Attempts were made to apply the WHO classification principles (Technical Report Ser. No. 143). In the region of the aorta such changes were considered mild ones in which mainly fatty streaks or fibrous plaques were seen, while the changes were considered to be moderate in degree when there were mainly atheroma formations. Changes accompanied by haemorrhage, thrombus, ulcerations or calcium deposits have been denoted as severe changes. Such changes elsewhere in the vascular system in which less than one-half of the lumen was intact have been placed in the severe category, those with more than one-half of the lumen remaining intact being considered moderate changes, and the changes with mere fatty streaks or fibrous plaques but no constriction of the lumen belonging to the mild category.

8. Follow-up study

At follow-up examination, the above-mentioned anamnestic data were checked, as well as the existing status and the local symptoms in the

remaining extremity, if any. The rehabilitation expedients applied and the residual ability to move were also established, according to the following categories: able to move with prosthesis, with crutches, wheelchair invalid, bed patient. The patient's return to work was also recorded, as well as his place of residence: at home, in a home for aged people, or in a home for invalids.

9. Mathematical methods

Mean values and standard deviations. — For the entire series and for subseries consistent with various aspects, the mean ages of the patients were computed as arithmetic means, mostly also calculating the respective standard deviations. The same characteristics were calculated for the durations of various symptoms, remaining life spans and other similar times, but in such instances the usual formulae were applied to the logarithms of the time intervals, not the times themselves, the better appropriateness of this procedure being clearly indicated by the distributions of individual values.

Frequencies and distributions. — The frequencies of various symptoms etc., as well as distributions, e.g. according to positive or negative findings, were calculated as percentages of the number of patients constituting the subgroup in question.

Distribution functions; medians. — Some series of values were plotted to form cumulative frequency curves in probability chart co-ordinates. Such curves constituted an aid in determining when the mean formed on a logarithmic basis was more relevant than the arithmetic mean, employing the establishment of approximately normal (Gaussian) distribution as the criterion. In some instances, the value read from such a plot at 50 % cumulative frequency was then stated as the mean. Sometimes the median value of a series was ascertained in addition to the mean obtained, in order to confirm the justification of the latter. (Cf. Fig. 3.)

Statistical significance tests. — The mutual deviations of the means found for different groups were tested for statistically significant differences, employing Student's t test. Comparisons of distribution percentages were carried out by the aid of the χ^2 test. Statistically highly significant, significant or almost significant differences have been stated to exist if the probability of the deviation being due to random chance alone is $P < 0.001$, 0.01 or 0.05, respectively, on the strength of the test.

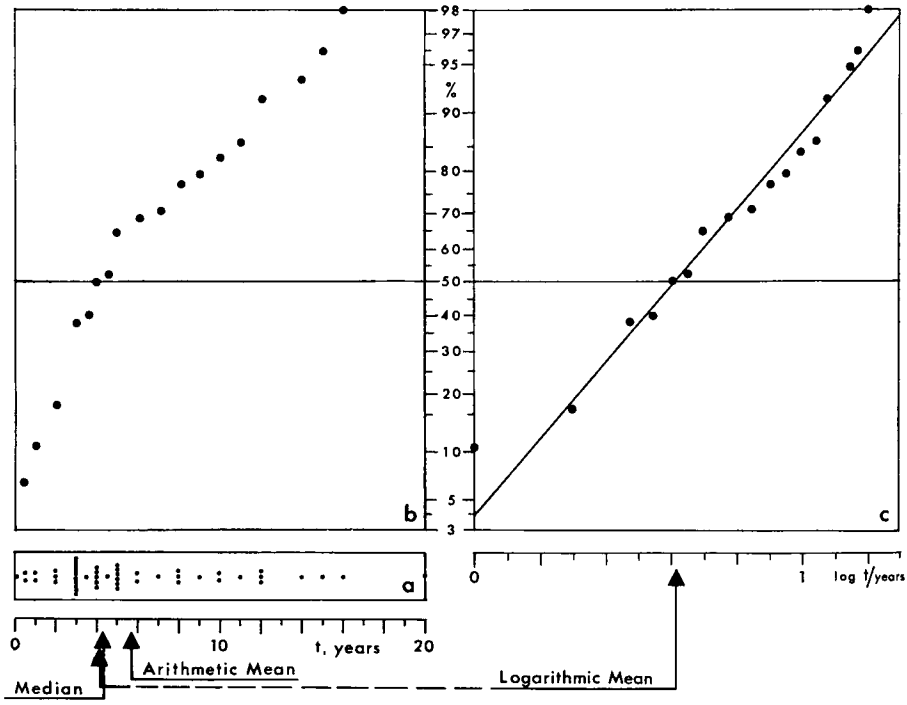

Fig. 3. Durations of presence of the intermittent claudication symptom prior to amputation in 48 unilaterally amputated cases, presented as an example to illustrate the relevance of mean values obtained by different methods.

(a) Distribution plot of individual values.

(b) Cumulative percentage of cases, plotted on a probability (or normal distribution) chart having an ordinate scale consistent with the probability integral $\frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt$ and with the durations t for abscissae.

(c) As (b) but with log t for abscissae.

In distinct contrast to graph (b), graph (c) indicates fairly good consistency with normal (Gaussian) distribution. Accordingly, the logarithmic mean relevantly reflects the probable average (fifty-fifty-chance) duration of the symptom in an arbitrary, comparable population. Its value (4.15 years) agrees, in fact, closely with the median (about 4.25 years) of the series. The arithmetic mean (5.85 years) considerably exaggerates the duration, owing to undue influence exerted by a few large values (up to 20 years). From the distribution graphs the duration of 5.85 years is seen to be one that was surpassed in only one-third of the cases.

Comments

Taking into account the age of the patients, their fundamental disease and the ailing condition in which they often were on arrival at the hospital, one might suspect the anamnestic data at the time of amputation to contain errors and inaccuracies. However, the possibility of error was lessened by the fact that case reports covering the period prior to amputation were also available for three-quarters of all the patients. The follow-up study revealed, in fact, that the information obtained from case reports was correct in the case of the 38 persons examined, to the extent that the same 44 symptoms of occlusion observed at the time of amputation were also established at follow-up and, furthermore, three additional occurrences of a symptom not stated in the case report.

As regards the pulses, it can be pointed out, as Beckwith et al. (1958) and Wylie and Goldman (1958) do, that sometimes in the absence of a proximal pulse, one distal to it may be palpable, indicating good collateral circulation. Here, however, the following rule of thumb (Schoop 1964) has been used: if a pulse is absent proximally, no pulse can be palpable more distally either, and if a pulse is present distally, then it cannot be missing more proximally either. On this basis the proximal limits of the occlusions have been assessed in the manner in which this was done e.g. by Juergens et al. (1960) and by Holopainen (1963), and classified by types of occlusion (Ratschow 1959): if, for instance, the popliteal pulse and those distal to it are missing, but the pulse of the femoral artery is palpable, then it is assumed that the proximal limit of the occlusion lies in the region of the thigh, and an occlusion in the femoral region is recorded.

Late interpretation of the autopsy findings on the basis of the autopsy report is not as reliable as when the changes are classified immediately at the autopsy, but the division into mild, moderate and severe changes still furnishes an idea of their degree of severity.

IV CLINICAL SYMPTOMS OF OCCLUSION PRIOR TO AMPUTATION

A general survey of the occurrence of clinical symptoms of occlusion prior to amputation in the present series of 184 patients is presented in Fig. 4. One or several such symptoms were present in 142 patients (77 %). The commonest symptom was intermittent claudication, which occurred in 60 % of the cases, while of those listed here, intestinal symptoms suggesting angina abdominis were the most rarely encountered (in 4 %).

Each symptom of occlusion will be scrutinized by itself, considering its distribution by age and sex and comparing the percentages, in the group presenting this particular symptom and in its complementary group, of the sexes, of diabetics, of hypertonics, of persons over 70 years in age and of the other groups of symptoms of occlusion. For each such subseries characterized by the presence of a given symptom, and for its complementary series, the mean ages at the time of amputation have, moreover, been computed and mutually compared (Table 1).

A. Intermittent claudication

Previous investigations

Intermittent claudication is the commonest symptom of occlusion occurring in association with arteriosclerosis. According to Ratschow (1959), it is present in a great majority (90 %) of patients with ischaemia of the lower extremities, and according to Wanke (1953), its cause is invariably arterial occlusion, which occurs in the region of the thigh in 63 %. Depending on the height of occlusion, intermittent claudication pain is experienced at different heights in the extremity (Leriche 1953, Wolfe et al. 1954, Ratschow 1959), but the extent and number of the occlusions and the possible existence of collateral paths also have an influence of their own on this (Beckwith et al. 1958, Allen et al. 1959).

The absence of the intermittent claudication symptom is by no means always a sign of the absence of occlusions in the lower extremity arteries, since this symptom does not manifest itself in the event of adequate collateral circulation (Widmer 1965). Another reason for intermittent claudication often failing to be apparent, even though there may be several occlusions, is the lack of activity of older persons. Older people may therefore become victims of gangrene quite unexpectedly (Weibel 1965). The symptom is also somewhat less common in diabetics than in non-diabetics (Schadt et al. 1961). Heine et al. (1965) found that in gangrenous patients, the claudication symptom had been present for three years, on an average, prior to the appearance of gangrene.

The occlusions of the lower extremity arteries are quite often nearly symmetric. According to Hasse (1959), two years after the onset of intermittent claudication, the symptom has become bilateral in 76 % and after five years in 92.2 % of the affected persons. Judmaister (1958) reports that the affection becomes bilateral in 75 % within 4—5 years.

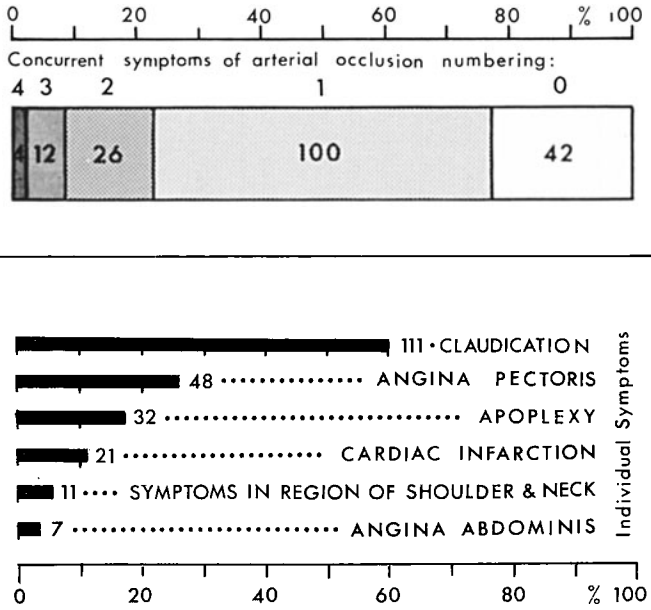

Fig. 4. Distribution of the series of 184 patients according to occurrence of 0, 1, 2, 3 or 4 different symptoms of arterial occlusion in their case history (prior to amputation), and frequencies of occurrence in the histories of six different types of symptom.

Table 1. Comparison of the groups of patients presenting given symptoms prior to amputation and their complementary groups with regard to various aspects of sex and age distribution, presence of diabetes or hypertonia and of other symptoms prior to amputation.

Aspect of comparison	*1* – Number of cases; *2* Frequency, in per cent; *3* – Frequency in remainder of the series (Complementary group), in per cent																							
	Intermittent claudication group			Angina pectoris group			Cardiac infarction group			Apoplexy group			Occlusion in region of neck and shoulders			Angina abdominis group			More than one symptom of occlusion			No prior symptoms of occlusion			Entire series	
	111 cases			*48 cases*			*21 cases*			*32 cases*			*10 cases*			*7 cases*			*50 cases*			*42 cases*			*184 cases*	
	1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*
Men	81	*73*	*41*	28	*58*	*61*	11	*52*	*61*	18	*56*	*61*	6	*60*	*60*	3	*43*	*61*	34	*68*	*58*	16	*38*	*67*	111	*60*
Women	30	*27*	*59*	20	*42*	*39*	10	*48*	*39*	14	*44*	*39*	4	*40*	*40*	4	*57*	*39*	16	*32*	*43*	26	*62*	*33*	73	*40*
Diabetics	22	*20*	*32*	10	*21*	*26*	2	*9*	*26*	6	*19*	*26*	1	*10*	*25*	2	*29*	*24*	9	*18*	*34*	18	*43*	*19*	45	24
RR over 160 mm Hg	68	*61*	*55*	29	*60*	*58*	13	*62*	*58*	21	*64*	*57*	8	*80*	*58*	4	*57*	*59*	31	*62*	*57*	23	*55*	*60*	108	*59*
Age over 70 years	42	*38*	*60*	25	*52*	*45*	11	*52*	*46*	14	*44*	*47*	6	*60*	*46*	4	*57*	*46*	17	*34*	*53*	27	*64*	*39*	68	*47*
Mean age, years	67.1		70,8	67.4		69,1	67.1		68,9	69.5		68,5	67.7		68,7	67.6		68,7	67.6		69,1	71.8		67,7	68.7	
Duration of symptom, years	2.7						1.1			1.4																
Intermittent claudication				35	*73*	*56*	14	*67*	*60*	21	*64*	*59*	6	*60*	*60*	6	*86*	*59*	48	*96*	*47*				111	*60*
Angina pectoris	34	*31*	*19*				18	*86*	*18*	10	*31*	*25*	3	*30*	*26*	6	*86*	*24*	36	*72*	*9*				48	*26*
Cardiac infarction	13	*12*	*11*	18	*38*	*2*				4	*12*	*11*	1	*10*	*12*	2	*29*	*11*	14	*28*	*5*				21	*11*
Apoplexy	21	*19*	*15*	11	*23*	*15*	5	*24*	*17*				–	*0*	*18*	2	*29*	*17*	22	*44*	*7*				32	*17*
Occlusion in region of neck and shoulders	5	*7*	*7*	4	*8*	*4*	1	*5*	*6*	3	*9*	*5*				3	*43*	*4*	7	*14*	*2*				10	*5*
Angina abdominis	6	*5*	*1*	6	*12*	*1*	2	*9*	*3*	3	*9*	*3*	3	*30*	*2*				4	*8*	*2*				7	*4*

Commonest among other symptoms of occlusion in association with intermittent claudication is angina pectoris, which McDonald (1953) observed in 29 % of the persons suffering from the former; it appeared later than the intermittent claudication symptom in most instances.

Present studies

Fig. 5 shows the occurrence of intermittent claudication in the present series, separately for men and for women and also for each ten-year age group of both. The symptom was present prior to amputation in 111 of the 184 patients (60 %) and had persisted for 2.7 years on an average by the time of amputation. It was then bilateral in 88 patients (79 %). The diagram shows that the symptom was commoner in the younger than in the older age groups, in men as well as women. The percentage of patients with intermittent claudication is seen to diminish more markedly with increasing age in the female subseries than in the male. It was present in 17 women over 70 years of age (34 % of all women over 70) and in 25 men (66 %) older than 70, while the corresponding figures for men and women under 70 years are 56 (77 %) and 13 (54 %), respectively; the differences between these percentages are statistically significant ($P < 0.01$).

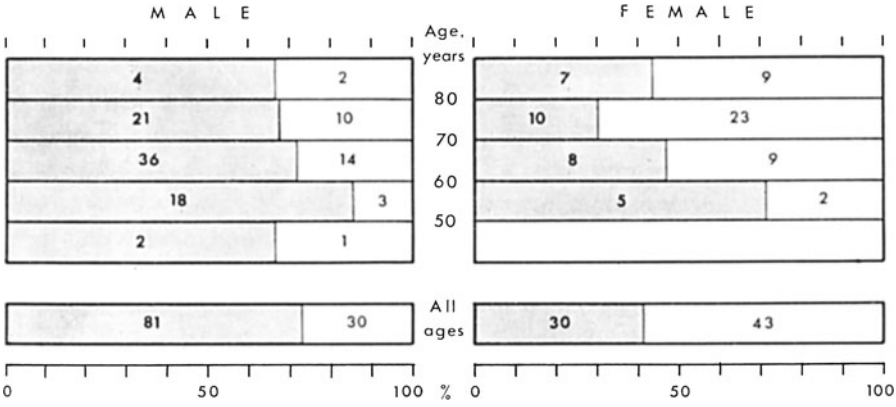

Fig. 5. Presence (shaded areas) and absence of the intermittent claudication symptom in the case histories of the male and female patients and of their different ten-year age groups.

Table 1 contains various data concerning the group of patients with intermittent claudication, which can be compared to the corresponding data for the entire series, in the last column of the table. They have also been compared to the respective values found for the complementary group (patients without intermittent claudication preceding amputation).

It is seen that 73 % of the patients with intermittent claudication are men; this differs at a statistically highly significant level ($P < 0.001$) from the percentage of men in the non-claudication group (41 %). The percentage of patients older than 70 years is only 38 % in the intermittent claudication group (statistically significant difference, $P < 0.01$, from the percentage in the complementary group, 60 %). As can be expected, the mean age at amputation in the claudication group, 67.1 years, is lower than the mean for the entire series; it differs at a statistically highly significant level ($P < 0.001$) from the mean age, 70.8 years, of the non-claudication group. Diabetes seems to occur less frequently, hypertonia and angina pectoris and apoplexy more frequently in the group of patients with intermittent claudication than among those without this symptom, but there are no statistically significant differences.

Comments

The intermittent claudication symptom is seen to have been present in 60 % of the patients in this series. In the literature, no reference could be found concerning the commonness of this symptom in amputation series, but a somewhat higher frequency is stated for it among patients suffering from arteriosclerosis obliterans. Juergens et al. (1960), in a series of 520 such patients, observed the occurrence of intermittent claudication in 73 %. The patients were all male and there were no diabetics. In the present series, again, about three-quarters of those with the claudication symptom are men, while those lacking the symptom were older persons, predominantly (60 %) women, and nearly one-third of them diabetic. It is just in such older persons that the claudication symptom has often been noted to be absent, owing to their inactivity and to the presence of diabetes.

The time prior to amputation during which the intermittent claudication symptom was present averaged 2.7 years and by the time of amputation it had become bilateral in 80 %, consistent with previous observations on claudicated patients. The duration, too, is virtually equal

to the time of three years noted by Heine et al. (1964) in gangrenous persons prior to manifestation of gangrene.

As with lower extremity occlusion patients in general, the occlusions causing claudication in the present series developed not only more frequently but also earlier in men than in women. Occurrence of this symptom also implied amputation at an earlier age than in the complementary group; the difference, about 3.7 years, is statistically highly significant ($P < 0.001$).

The frequency at which angina pectoris occurred in association with the intermittent claudication symptom agrees with the frequencies stated for claudication and amputation series in general.

B. Angina pectoris and cardiac infarction

Previous investigations

Sclerosis of the coronary arteries and the resulting ischaemic symptoms develop earlier in men than in women. Oliver and Boyd (1954) in a series of 1000 patients found for the proportion of men to women the ratio of 2:1 in the 60—69 year age group and 1:1 for those over 70. For cardiac infarctions Zimmerman et al. (1954) obtained male/female ratios of 2.2:1 and 1.5:1 with patients under and over 65 years, respectively. From Sipilä's (1966) series the corresponding ratios of 2.75:1 and 0.82:1 can be calculated. In women, infarction does not begin to occur more commonly until they have reached about 60 years (Walker et al. 1956). In Sipilä's (1966) series the proportion of men and women over 60 years with infarction is 1.1:1 and that of patients younger than 60 years, 4.5:1. Branwood and Montgomery (1956) observe that infarction occurs most numerously in young and middle-aged men and in older women, whose atheromata they report to be soft and conducive to thrombosis.

Hypertonia increases the atherosclerosis of the coronary vessels and the resultant ischaemic symptoms (Clawson and Bell 1949, Corcoran et al. 1956, Dawler 1964), as does diabetes, also (Joslin 1952).

Those suffering from peripheral arterial occlusion disease present symptoms of the coronaries in 12—37 %, according to various studies (Spandling 1956: 21 %; Juergens et al. 1960: 16 %; Singer and Rob 1960: 22—37 %; Schadt et al. 1961: 11.7—26.6 %), and Schlitt and

Serlin's (1960) amputation series included cardiovascular diseases in 46.7 %, of which the share of coronary diseases was not separately stated. The frequency of cardiac infarction in arteriosclerotic sympathectomy patients is reported as 12 % by King et al. (1964) and that in gangrenous patients as 14.3 % by Heine et al. (1965).

Present studies

The diagrams in Figs. 6 and 7 show the occurrence of angina pectoris and of cardiac infarction as a preamputation symptom in the present series, separately for men and women and for each ten-year age group of both sexes. Angina pectoris was present prior to amputation in 48 patients (26 %) and cardiac infarction in 21 (11 %). The former include 25 % of the men and 27 % of the women in the present series, the latter 10 % of the men and 14 % of the women, and there are no statistically significant differences between these percentages. Infarction appeared on the average 1.1 years before amputation. Exact information on the duration of angina pectoris is lacking in most cases. The men and women among the patients with angina pectoris number 28 and 20, respectively, (58 % and 42 %); those among the patients with cardiac infarction number 11 and 10, respectively, (52 % and 48 %). These sex distributions display no statistically significant difference from that of the entire series.

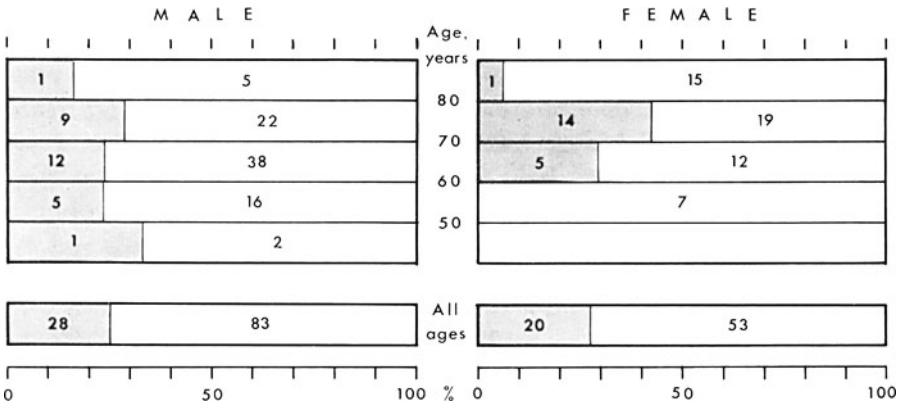

Fig. 6. Presence (shaded areas) and absence of the angina pectoris symptom in the case histories of the male and female patients and of their different ten-year age groups.

Fig. 6 reveals that the frequency of angina pectoris in men was proportionally largely equal in all age groups. In women this symptom only occurred at ages over 60 years, most numerously in the 70—79 year age group. The frequency of cardiac infarction (Fig. 7) in men was somewhat higher in young age groups, diminishing with increasing age. In the female subseries, all but one occurrence of this symptom are concentrated in the group of women subjected to amputation at the age of 70—79 years.

Table 1 (p. 28) lists various data concerning the groups of patients with angina pectoris and with cardiac infarction, for purposes of comparison with those lacking the respective symptom. Both groups show female predominance in contrast to their complementary groups; likewise, they contain persons over 70 years and hypertonics in greater number, but fewer diabetics than their counterparts lacking the symptom. No statistically significant differences were established for these deviations.

All other symptoms of occlusion considered here are more frequent in the angina pectoris and cardiac infarction groups than in the complementary groups, except for symptoms of occlusion in the region of the neck and shoulders in the cardiac infarction group. The deviation amounts to a statistically almost significant difference ($P < 0.05$) for the claudication symptom in the angina pectoris group and to a statistically highly significant difference ($P < 0.001$) for the angina abdominis symptom in the same group. The age at amputation in the angina

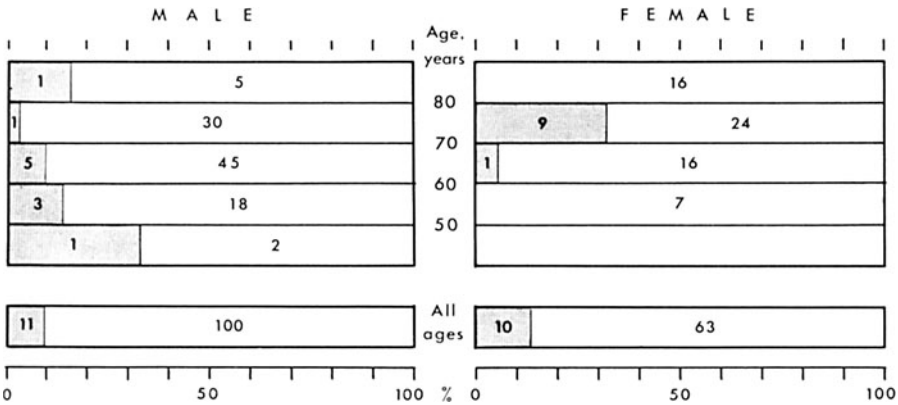

Fig. 7. Presence (shaded areas) and absence of the cardiac infarction symptom in the case histories of the male and female patients and of their different ten-year age groups.

pectoris and cardiac infarction groups is found to be lower than in the complementary groups, by 1.7 and 1.8 years on the average, but there is no statistically significant difference.

Comments

In the present series, angina pectoris occurred prior to amputation in one in every four patients and cardiac infarction in about one in every ten; coronary symptoms of one or both kinds were present in somewhat more than one-quarter (28 %) of the series. This amounts to higher incidences than are encountered in persons of equivalent age suffering from peripheral arteriosclerotic occlusion diseases. The percentage found for cardiac infarction is about the same as that observed by Heine et al. (1965) in gangrenous patients. Hansson (1964) states that he found among 236 arteriosclerotic patients "cardiac distress" in 34 %; the occurrence of coronary symptoms in the present series thus agrees rather closely with that in his material.

In the present series, angina pectoris and cardiac infarction both occurred in nearly equal percentages of men and women. However, coronary arteriosclerosis and its attendant ischaemic symptoms developed earlier in men than in women. Here, too, angina pectoris and cardiac infarction were encountered in men upwards of ages under 50 years, while they only occurred in women subjected to amputation at ages of 60 years or older. The majority of female cases with cardiac infarction (90 %) were found in the group of patients over 70 years at amputation, whereas of the men, only one in every five (18 %) presenting cardiac infarction belongs to this age group.

Roberts et al. (1959) observed that the degree of severity of occlusions of the coronary arteries also reflects the changes present elsewhere in the vascular system. More serious obliteration of the vessels of the lower extremities in the patients having coronary symptoms, as compared to those lacking such symptoms, is suggested in the present series by the fact that the claudication symptom, and angina abdominis also, was more frequent in the group of patients with angina pectoris than in its complementary group. The age at amputation, which was 1.7—1.8 years lower than in the group without coronary symptoms, is also indicative of the earlier development of the occlusions.

C. Cerebral apoplexy

Previous investigations

Concerning the genesis of cerebral ischaemic states, Millikan (1965) says that atherosclerosis is usually accompanied by some transient pathophysiological condition but that such conditions rarely appear without atherosclerotic lesion.

According to Senn (1965), the seriousness of the clinical picture and the pathological finding are often, but not always, correlated; thus in complete hemiplegias occlusion of the internal carotid artery is often present and in smaller fits, vascular stenosis. Investigations have pointed out with increasing insistence the considerable contribution of extracerebral arterial occlusions to the genesis of cerebral ischaemic symptoms and, on the other hand, the commonness of asymptomatic occlusions (Hutchinson and Yates 1957, Martin et al. 1960, Schwartz and Mitchell 1961). In an amputation series consisting of arteriosclerotic patients, Hansson (1964) found 11.4 % to have had a cerebral apoplexy prior to amputation.

Present Studies

Fig. 8 shows the preamputation occurrence of apoplexy in the present series, separately for men and women and for their different ten-year age groups.

Altogether 32 patients (17 %) had suffered from apoplexy prior to amputation but had recovered to such an extent that all but one of them were able to move at the time of amputation. In three patients subjected to amputation at ages over 70 years, apoplexy had occurred twice, and one man, who was 66 years at the time of amputation, had had three strokes. The men and women with a history of apoplexy number 18 and 14, respectively (16 % of all men and 19 % of all women), no statistically significant difference being established in this respect. The time when apoplexy had occurred was on the average 1.4 years before amputation. It can be seen in Fig. 8 that all the women with a history of apoplexy were older than 60 years at the time of amputation; of the corresponding group of men, only two were younger than 60. The percentages of women with previous apoplectic fits decrease with increasing age, but numerically most of them belong to the age group of 70—79 years. The

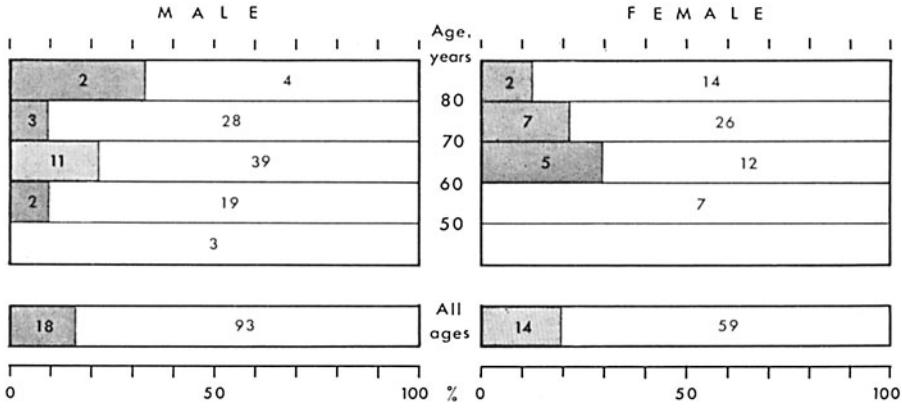

Fig. 8. Presence (shaded areas) and absence of apoplexy in the case histories of the male and female patients and of their different ten-year age groups.

men with previous apoplexy display a non-uniform age group distribution; the greatest number of such cases is found among those subjected to amputation at the age of 60—69 years. The mean age of those with apoplexy prior to amputation is 68.3 years in the men's series and 70.9 in the women's; the combined mean age is 69.5 years.

Table 1 (p. 28) enables various data concerning the patients of the apoplexy group to be compared with the complementary group. The apoplexy group is found to contain relatively more women, more hypertonics and more patients with previous claudication and angina pectoris symptoms than the complementary group in which no apoplexy occurred, but there are no statistically significant differences.

Comments

In Hansson's (1964) series about one in every nine of 236 patients subjected to amputation on account of arteriosclerosis had previously suffered from apoplexy. In the present series, apoplexy occurred somewhat more frequently, in one out of every six patients, and clearly more often than was observed by Widmer (1963) in patients with occlusion in the lower extremities. There seems to be no relationship between the degrees of severity of sclerosis in the lower extremities and that of the cerebral arteries (Roberts et al. 1959). In the present series, too, no correlation of the development of occlusions impairing cerebral circulation in arteriosclerosis elsewhere in the vascular system can be noted:

no essential deviations are observable between the apoplexy group and its complementary group, in the occurrence of other symptoms of occlusion. It is also to be noted that the age at amputation is one year higher in the apoplexy group than in that without apoplexy, suggesting that in the former the changes resulting in gangrene evolved somewhat later, although there is no statistically significant difference.

D. Symptoms of occlusion in neck, region of the shoulders and upper extremity

Previous investigations

In the symptoms of occlusion in the neck and shoulder region, Ratschow (1959) includes those due to obliterations of the aortic arch, carotid arteries and subclavian artery. Symptoms of occlusion of the aortic arch have been described under synonymous names, e.g. by Martorell and Fabre (1944), Frövig and Löken (1951), Ross and McKusick (1953) and Tala (1966). From the diagnostic point of view, the optic and cerebral symptoms are most notable among the symptoms of occlusion of the aortic arch and carotid arteries (Ratschow 1959, Mumenthaler 1965).

Circulatory disturbances due to arterial occlusions in the upper extremities are often rather inconspicuous. For instance, Kappert (1964) says that complete occlusion of the brachiocephalic trunk or subclavian artery causes functional derangement in only one-half of the cases.

Ratschow estimates that at least about 2 % of those suffering from arterial occlusion have occlusions in the region of the upper extremities. In mass examinations Widmar et al. (1963) found for the upper extremities a share of about 14 % in the observed extremity occlusions, but about two-thirds of them were asymptomatic at the first enquiry.

Present studies

Symptoms indicative of occlusion in the neck and shoulder region other than of the apoplexy type were present prior to amputation in 10 patients (5 % of the entire series), four women and six men (Table 1). The duration of the symptom was known with any greater accuracy in two cases only (1.5 and 2 years, respectively). The mean age of the

women with this symptom was 74.3 and that of the men was 63.3 years, the mean age of all ten patients being 67.7 years.

Six of these patients complained of rapid tiring and coldness of one upper extremity. Four patients had cerebral symptoms or optic disturbances, but no previous apoplexy or epilepsy had been established. After amputation, however, three of these four suffered from apoplexy. Two of the four patients had brief spells of unconsciousness. Two patients had attacks of vertigo and one of these, moreover, optic disturbances, which were attributed to disturbance of circulation.

Comments

Symptoms of occlusion from the upper extremities were recorded in comparatively few instances in the present series (3 %) and the symptoms were fairly slight. The frequency of occurrence agrees in order of magnitude with previous findings concerning arterial occlusion patients. Cerebral symptoms suggesting arterial stenosis or occlusion, partly of "little stroke" type were noted in four cases (2 %) prior to amputation. Three of these patients suffered apoplexy later. Nothing can be stated on the strength of the symptoms observed here as regards the extent and location of the potential occlusions. To make this possible, thoracal arteriographs would have to be available; as, e.g., Fuchs (1965) and Mumenthaler (1965) point out, this is the sole method of examination furnishing any idea of the pathological changes and topographic-anatomical state of the blood vessels in the region of the aortic arch.

E. Angina abdominis

Previous investigations

Angina abdominis or "intermittent mesenteric claudication", as it was called by Klein (1921), is a rarely diagnosed disease. Owing to the good collateral circulation in the intestines, stenosis of one main artery of the bowels does not usually suffice to produce the symptoms; what is needed is functionally significant stenosis in two of the three arteries: the superior mesenteric, the inferior mesenteric and the coeliac artery, or complete occlusion of one main artery (Rob 1965, Schobinger 1965). The symptom is commonest in the sixth to eighth decades, but as a

result of the rare occurrence of the typical angina abdominis symptom, larger series are lacking (Schobinger 1965), as well as more detailed information on its commonness. Possibilities to be eliminated in differential diagnosis include cholecystitis, duodenal stomach ulcer, pancreatitis and tumours in the abdominal region (Chinaglia 1964).

Present studies

Symptoms indicative of angina abdominis were present prior to amputation in seven patients (4 %), three men and four women (Table 1). In two cases (1 % of the entire series) angina abdominis had been diagnosed; the other five patients had typical pain and displayed loss of weight, without any other disease in the abdominal region having been established. In one of the two patients with angina abdominis symptoms, these symptoms had appeared 0.5 years before amputation; there are no data on the duration of the disease in the other instances. The mean age of the men concerned here was 66.4 years, that of the women was 68.8 years, and the mean of all seven was 67.6 years. Owing to the small number of cases, the data concerning the group of amputees with previous angina abdominis symptoms entered in Table 1 permit, at the most, the observation to be made that this group displays a tendency towards a higher frequency of other symptoms of occlusion in comparison to its complementary group.

Comments

The angina abdominis symptom is a rare one. Here, too, it was only observed in two patients, while five other patients had symptoms indicating chronic circulatory insufficiency of the bowels.

F. Concurrence of symptoms of occlusion

Previous investigations

According to Widmer (1963), arteriosclerotic changes in the extremities suggest diffuse arterial disease, and he observed that of 64 patients with occlusion of the extremity arteries, one-tenth had suffered apoplexy and about one-third had a coronary disease. He says, as do also Dawber et al. (1957), that arterial occlusions of the extremities and coronary

diseases begin to appear at about the same time and that they occur in an equal amount. Hansson (1964) states that multiple manifestations of vascular diseases occurred in 44.8—37.6 % of 236 persons subjected to amputation on account of arteriosclerosis. Even if there are occlusions, they may remain asymptomatic in the region of the lower extremities owing, for example, to lack of activity (Widmer 1963, Weibel 1965).

Present studies

The frequency at which one or several symptoms of occlusion occurred prior to amputation in the present series is elucidated by the figures in Table 2 (also shown in Fig. 4, p. 27). It can be seen that symptoms of occlusion were present in about three-quarters of the patients. Of the six individual symptoms considered, angina pectoris and cardiac infarction have been treated here as only one symptom since all but three of the patients with cardiac infarction had also displayed the angina pectoris symptom. Two or more symptoms of occlusion occurred in about one-quarter of the series, three or more symptoms occurred simultaneously even more rarely (in 9 %), and only four patients displayed simultaneous symptoms suggestive of four different symptoms of occlusion.

Table 2. Presence of one or more symptoms of arterial occlusion in the case histories of 184 patients.

Number of concurrent symptoms of arterial occlusion	Cases	Per cent
4	4	2
3 or more	16	9
2 or more	42	23
One or more	142	77
None	42	23

The data compiled in Table 1 (p. 28) for the patients having more than one symptom of occlusion, show that this group contains a distinctly higher proportion of patients with coronary symptoms and also with intermittent claudication symptoms than its complementary group; the difference is statistically highly significant ($P < 0.001$) in both respects. The same trend observable with regard to apoplexy and to the angina

abdominis symptom, does not produce any statistically significant differences. The frequency of symptoms of occlusion in the region of the neck and shoulders is higher at a statistically almost significant level ($P < 0.05$).

The group of patients who had no symptoms of occlusion prior to amputation, also similarly tabulated in Table 1, contains proportionately more women than its complementary group, and the mean age at amputation is 4.2 years higher. The former difference is statistically significant ($P < 0.01$) and the latter is statistically almost significant ($P < 0.05$).

Comments

Hansson's (1964) series of amputees showed multiple manifestations of arterial occlusion in an average number equivalent to 42 %. In the present series, the proportion is the same (43 %) if the ischaemic state of the extremity leading to amputation is counted as one type of manifestation. If only intermittent claudication and other symptoms of occlusion occurring prior to amputation are taken into account, the manifestations of arteriosclerosis producing multiple symptoms amount to slightly more than one-quarter (28 %). Correlation exists between the arteriosclerotic changes in the coronary arteries and those in the arteries of the lower extremities (Dawber et al. 1957, Roberts et al. 1959, Widmer 1963). In the present series, too, symptoms of occlusion of the coronary and lower extremity arteries could be noted as occurring concurrently in the same patients in the group of amputees with two or more symptoms of occlusion at a frequency higher than in the complementary group, at a statistically highly significant level ($P < 0.001$). No such trend concerning the claudication symptom is displayed by the patients who suffered apoplexy. Symptoms of occlusion were more numerous in men than in women and amputation occurred on the average 4.2 years earlier in those with symptoms of occlusion than in those having none.

V THE SPREAD OF ARTERIOSCLEROTIC CHANGES AT THE TIME OF AMPUTATION

In the reports on examinations at the time of amputation, results have been included of those examinations made within two weeks before and after the amputation. Such examinations were: pulse examinations of the extremities, measurements of blood pressure, angiographies, electrocardiographic studies. Results of laboratory tests were also included: urine examinations, and determinations of blood urea and creatinine. These examinations have been evaluated in an attempt to obtain an idea of the extent of the spread of the arteriosclerosis at the time of amputation.

A. Extremity pulses

Previous investigations

In Schoop's (1964) opinion, palpation of the arterial pulse is the most important method in examining arterial occlusion diseases. But this does not reveal the extent nor the number of occlusions, although it is true that an idea is gained of their localization and proximal limit (Ratschow 1959, Juergens 1960). This constitutes, for instance, the basis of Ratschow's (1959) classification of occlusion types by the localization of the occlusions.

The commonest state of the lower extremities in peripheral arterial occlusion diseases is that the pulse of the femoral artery is palpable but not that of the popliteal artery, in which case there is an occlusion in the femoral region. Wanke (1959) found such occlusions in the femoral region in 65 % of 371 patients with peripheral arterial occlusion; Hasse (1950) state a corresponding percentage of 47.6 % and Heine et al. (1965) one of 51.2 % for gangrenous patients. Patients of the latter category have often, according to Heine et al. in 48.7 %, occlusions both

in the femoral and in the lower leg regions, although the occlusion in the lower leg cannot be discovered by pulse examination (Schoop 1964). Occlusions in the femoral region often turn into occlusions in the pelvic region owing to thrombosis, in which instance the prognosis becomes unfavourable (Leriche 1953, Ratschow 1959, Wanke 1959).

According to Ratschow (1959) only about 2 % of the persons suffering from arterial occlusion disease have occlusions in their upper extremities and can thus be expected to display pulse changes in that region. Widmer (1963) says that occlusions in the region of the upper extremities occur in about one-seventh of the patients with extremity occlusions but that they are usually adequately compensated and so are more seldom clinically manifest.

Present studies

The diagram in Fig. 9 gives a synopsis of the findings at the time of the first (or only) amputation concerning pulses and the ischaemic state of both extremities, i.e. the extremity amputated at that time and the one remaining intact permanently or until further amputation. The most notable differences between the extremity subjected to amputation (A) and the extremity remaining intact (B) are noted in the most proximal and most distal pulses. On the side on which amputation was performed, the pulse of the femoral artery was absent in 63 cases (35 %) against 21 cases (13 %) on the other side; this is a statistically highly significant difference ($P < 0.001$). All pulses were palpable on the amputation side in only three cases (2 %) against 32 cases (21 %) on the side left intact, which amounts to a statistically highly significant difference ($P < 0.001$), too. One of the two pulses of the foot could be palpated in only four cases (2 %) on the amputated side but in 23 (14 %) on the other. The popliteal pulse was absent in the first-amputated and intact extremities in 64 and 54 cases (36 and 33 %), respectively; the pulses of the anterior and posterior tibial arteries were both absent in 44 and 32 cases (25 and 20 %) in the respective extremities. No statistically significant differences were established from these latter comparisons.

At the time of the first amputation, gangrene was present in the extremity subjected to amputation in 152 cases (84 %) and rest pain in 28 cases (16 %). The corresponding figures for the extremity left intact at this stage are 26 (15 %) and 3 (2 %). Gangrene had set in on the average 3 months before amputation. All the 29 last-mentioned cases,

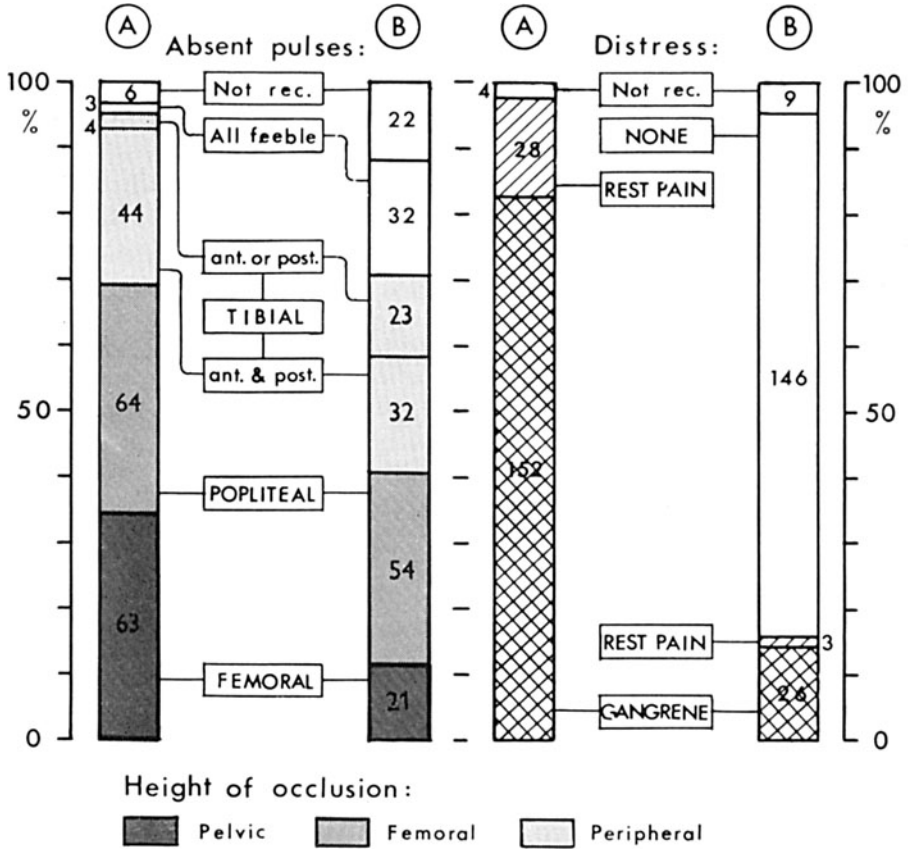

Fig. 9. *Left:* Distribution of 184 patients according to non-palpability of different pulses and type of occlusion consistent with these findings, in the amputated extremity (A) and in the extremity left intact (B) at the time of the first (or only) amputation.

Right: Distribution of 184 patients according to ischaemic condition of the amputated extremity (A) and the extremity left intact (B) at the time of the first (or only) amputation.

and another six cases in which no gangrene or rest pain was yet present in the other extremity at the time of the first amputation, had to be subjected to bilateral amputation later.

In Table 3, the cases of the present series have been arranged according to types of occlusion, taking into account the pulse findings in both extremities at the time of the first amputation. In this representation the lowest diagonal gives the numbers of cases displaying symmetric occlusion in both extremities, at various heights. The cases with sym-

metrical occlusion amount to 47 % of the men and 35 % of the women, and 41 % of the entire series. There is no statistically significant difference between men and women. Nearly symmetrical conditions, which include, e.g., occlusion in the femoral region on one side and in the pelvic region on the other, were present in 30 % of all cases, without any statistically significant difference between men and women. In the diabetics, symmetrical states were more frequent than among the non-diabetics (50 and 36 %, respectively), at a statistically almost significant level ($P < 0.05$).

Table 3. Percentages of different combinations of types of occlusion present on both sides in the entire series of 184 patients and in the male, female, diabetic and non-diabetic subseries.

Type of occlusion	Pelvic	Femoral	Peripheral	All pulses feeble	Not rec.	Pelvic	Femoral	Peripheral	All pulses feeble	Not rec.
ENTIRE SERIES, 184 patients										
Pelvic	10	13	5	4	3					
Femoral		15	9	7	3					
Peripheral			15	8	2					
All pulses feeble				1	–					
Not recorded					4					
MEN, 111 patients						**WOMEN, 73 patients**				
Pelvic	14	16	6	4	3	4	10	4	6	3
Femoral		14	7	5	3		19	13	10	4
Peripheral			18	7	1			12	8	4
All pulses feeble				1	–				–	–
Not recorded					3					3
DIABETICS, 45 patients						**NON-DIABETICS, 139 patients**				
Pelvic	4	7	2	7	–	12	16	7	4	4
Femoral		13	4	2	2		13	11	8	4
Peripheral			31	16	4			11	5	1
All pulses feeble				2	–				–	–
Not recorded					5					2

As regards the distribution of different types of occlusion among men and women, there is a statistically almost significant difference ($P < 0.05$) in the number of occlusions of the pelvic region between men and women, but no other differences of a statistically significant level can

be noted. Diabetics, on the other hand, displayed the symmetrical peripheral type of occlusion more frequently than the non-diabetics (31 and 11 %, respectively) at a statistically highly significant level ($P < 0.001$), and the type with peripheral occlusion on one side and all pulses feebly palpable on the other is also more numerous than in the non-diabetic group, at a statistically almost significant level ($P < 0.05$). The combination of pelvic occlusion on one side and femoral occlusion on the other occurred less often than among the non-diabetics at a statistically almost significant level ($P < 0.05$).

The pulses have further been tabulated in Table 4 by pulse types in the light of the findings in the first-amputated extremity and the extremity left intact, at the time of amputation and at that of preceding sympathectomy. The intervals between sympathectomy and amputation averaged 0.36 years. Pelvic, femoral and peripheral occlusions are seen to have been almost equally frequent at the time of amputation in the amputated extremities. Comparison of the amputated and intact extremities reveals that the pelvic type of occlusion occurred more often in the amputated than in the intact extremities, at a statistically almost significant level ($P < 0.05$). Palpability of all pulses was recorded more frequently in the latter extremities at a statistically significant level ($P < 0.01$).

In Table 4, from the distribution by type of occlusion at the time of sympathectomy and at amputation, the observation can be made that during the intervening time of 0.36 years on the average, the occlusions of the pelvic region more than doubled in frequency on the amputated

Table 4. Types of occlusion according to palpation of pulses at the time of sympathectomy and of amputation in the amputated extremity and in the extremity left intact.

Type of arterial occlusion	At the time of sympathectomy		At the time of amputation			
			Amputated extremities		Intact extremities	
	Amputated extremities	Intact extremities	All cases	Sympathectomized	All cases	Sympathectomized
Pelvic region	11 *20* %	–	73 *35* %	29 *46* %	11 *8* %	2 *13* %
Femoral region	24 *45* %	5 *33* %	79 *38* %	21 *33* %	39 *30* %	4 *27* %
Peripheral	15 *28* %	9 *60* %	55 *26* %	11 *18* %	48 *37* %	8 *53* %
All pulses feeble	4 *7* %	1 *7* %	*3* *1* %	2 *3* %	33 *25* %	1 *7* %
	54 *100* %	15 *100* %	210 *100* %	63 *100* %	131 *100* %	15 *100* %
Not recorded	9		9		18	

side at the expense of the most peripheral occlusion, giving rise to a statistically highly significant difference ($P < 0.001$). In the intact extremities, too, the pelvic occlusions showed some increase in number, during this period, without any statistically significant difference.

In the upper extremities, changes in the pulse of the radial artery were noted in four of the 184 patients: this pulse was absent on both sides in one patient so that his blood pressure could not be taken, absent on one side in two others, and less strong on the left than on the right side in one patient.

Comments

On the basis of the pulses established by palpation, rough conclusions are possible as regards the localization of arteriosclerotic obliterations and their development, in respect of the parts of the arterial tree supplying the lower extremities. The most essential difference noted between the status in the first-amputated extremity and in that left intact in this connection was that fewer occlusions of the pelvic region occurred in the latter and all pulses were palpable in this extremity in more numerous instances.

Men presented occlusion more frequently in the pelvic region than women, and non-diabetics more frequently than diabetics; the characteristic feature of the latter seems to be the presence of the peripheral and symmetric type of occlusion.

A certain idea can be gained of the development of the occlusions by observing in sympathectomized patients the changes the pulses have undergone during the time intervening between sympathectomy and amputation, which covered 4 months and 10 days on the average. No substantial changes were noted in the extremities which escaped amputation, while in the extremities which had to be amputated, the pelvic occlusions had doubled in number. These changes took place within a few months, and therefore thrombosis was probably largely responsible for the changes in pulse status.

The pulse studies suggest a fairly symmetrical progress of the disease in the region of the lower extremities and pelvis in that the pulses were symmetric in about one-half of the cases.

If at the time of the first amputation the other extremity is also gangrenous or in the stage presenting rest pain, bilateral amputation is to be expected.

B. Arteriographic studies

Previous investigations

Although arteriosclerotic occlusions are segmental in nature, diffuse changes become rather common when the disease has progressed farther. For instance, Beckwith et al. (1958) observed from the arteriographs of 35 patients with occlusion of the iliac artery that the spread of arteriosclerosis was diffuse.

Humphries et al. (1963), in their study of the arteriographs of 548 gangrenous patients, noted segmental occlusion in 210 patients and in 181 non-segmental occlusion showing no refilling of the main artery below the point of occlusion. Singer (1963) analyzed the lumbar arteriographs of 205 patients with intermittent claudication, observing that in most instances (92 %) the superficial femoral artery was affected; the same has also been noted by Lindbom (1950) and Mavor (1956). The deep femoral artery was affected in the fewest instances. Similar observations are also reported, e.g. by Lindbom (1950) and by Dible (1960). Furthermore, Singer noted total occlusion of the common iliac artery in 30 %, while the common femoral artery was comparatively free from arteriosclerosis in 68 % and the popliteal artery in 55 %. Babbeley et al. (1964), in their femoral arteriographs of diabetic and arteriosclerotic gangrenous patients made prior to amputation found that diffuse arteriosclerosis of the femoral artery and several stenoses were commonest. Next most common was occlusion of the popliteal artery. Karstila (1965) and Soila and Laitinen (1963) observed that as the occlusions in the main branches of the abdominal aorta gain in extent, the collateral circulation is impaired when the starting points of the collateral paths are obliterated. Lindbom (1950) and Köhler and Viljanen (1964) note that the changes are frequently symmetric.

Present studies

In the present series, 21 patients were subjected to angiographic examination, 14 lumbar and seven femoral arteriographies having been performed. The changes observed have been classified in five degrees of severity (see p. 22) as compared to normal. The results appear in Table 5.

All 21 patients were unilateral amputees and it is consequently possible to compare the changes in the amputated extremity and in the one left intact. The entries in the column "Number of arteries examined" indicates the number of patients in whom each particular part of the artery was

Table 5. Changes in the arteries of the pelvic region and lower extremities revealed by 21 arteriographies, in per cent of cases examined.

Part of arterial tree (a) – on amputated side (b) – on side left intact		Number of arteries examined	Degree of severity of change					Entirely or partly patent lumen	Complete occlusion
			0°	1°	2°	3°	4°	(0° to 2°)	(3° or 4°)
Aorta		14	43	36	14	7	–	93	7
Iliac artery									
– common	(a)	14	14	14	7	7	57	36	64
	(b)	14	14	50	14	7	14	79	21
– external	(a)	14	7	29	7	14	43	43	57
	(b)	14	14	21	29	7	29	64	36
– internal	(a)	14	21	14	14	21	29	50	50
	(b)	14	36	21	14	21	7	71	29
Totals:	(a)	42	14	19	10	14	43	43	57
	(b)	42	21	31	13	12	17	71	29
Femoral artery									
– common	(a)	14	50	14	14	7	14	79	21
	(b)	14	50	21	7	14	7	79	21
– superficial	(a)	16	–	14	7	14	64	21	79
	(b)	14	14	29	14	7	36	57	43
– deep	(a)	16	50	29	7	7	7	86	14
	(b)	16	72	14	14	–	–	100	–
Totals:	(a)	46	33	19	10	10	29	62	38
	(b)	44	45	21	12	7	14	79	21
Popliteal artery									
	(a)	14	7	43	14	7	29	64	36
	(b)	6	50	50	–	–	–	100	–

sufficiently visible in the arteriograph to enable the degree of severity of its changes to be determined. The distributions have been stated as percentages of the total number of subjects assessed for the artery concerned.

The abdominal aorta was visible in its entirety in the lumbar arteriograph in three cases only, while in the others usually only its lower third appeared in the X-ray. In this region, only one total occlusion (7 % of the cases) about 1 cm in length was noted immediately above the bifurcation, continuing into both common iliac arteries. The number of normal findings amounts to 43 %.

Disregarding the abdominal aorta, which was only partly examined, the smallest changes were observed in the region of the deep femoral artery: total occlusion occurred in 14 %, while this artery was normal in half of the cases. In the intact extremity no total occlusions were seen, and the finding was normal in 72 %.

Occlusions occurred most profusely in the region of the superficial femoral artery: on the amputated side there were total occlusions in 79 % and the normal findings were nil; the side of the intact extremity presented total occlusions in 43 % and a normal condition in only two cases (14 %). In the iliac arteries, total occlusion was established on the amputated side in more than one-half (57 %) and normal status in 14 % only; on the other side in 29 and 21 %, respectively. The occlusions in the popliteal artery on the amputated side amounted to 36 %, with only 7 % normal; the other side presented no total occlusions at all and a normal condition in one-half of the subjects.

In 14 arteriographs of the amputated extremity, all three branches of the popliteal artery were made visible in three instances, two branches in five, and one branch or none in three instances. Of the six arteriographs of the intact extremity two were such in which all branches of the popliteal artery were visible, while two branches could be seen in the other four.

The most notable difference between the amputated extremity and that left intact at the amputation, is that concerning occlusions of 4°; they occurred 2—4 times as frequently on the amputated side as on the other side. With regard to the combined number of occlusions of the iliac arteries this produced a statistically significant difference ($P < 0.01$), whereas no difference on a statistically significant level exists in respect of the combined occlusion in the femoral arteries.

Comments

Among the occlusions of major arteries in the pelvis and lower extremities, those in the region of the superficial femoral artery have proved to be commonest. In the present study, too, occlusion in this region was most frequently present, occurring on the amputated side in about three-quarters and on the side of the non-amputated extremity in nearly one-half of the cases examined.

Obliterations were less often encountered in the region of the deep femoral artery, which presented a normal condition on the amputated side in 50 % and on the other side in 72 %, consistent with the percentage of 72 % observed by Singer (1963) for patients with ischaemia of the lower extremities. There were no total occlusions on the side of the intact extremity, and even on the amputated side they only occurred in about one out of every seven patients.

Commonest among the occlusions in the pelvic region was that in the region of the common iliac artery, occurring in two-thirds and in about one-fifth of the cases on the amputated and intact side, respectively. Singer observed, in patients with intermittent claudication, occlusion in a corresponding area in about 30 %. The common femoral artery and popliteal artery, too, had been fairly well preserved on the non-amputated side so that about one-half of them were normal.

On the whole, the number of changes noted on the non-amputated side was consistent with that observed by Singer (1963), for example, in 205 arteriographs of ischaemic patients, whereas they were more frequent on the amputated side. The most notable difference concerns occlusions covering the entire length of an artery, or multiple occlusions. These are more numerous on the amputated side than on the opposite side by a factor of about 2—4. The difference is statistically significant ($P < 0.01$) in respect of the total numbers of occlusions in the iliac arteries.

C. Electrocardiographic studies

Previous investigations

Coronary sclerosis or coronary insufficiency cannot be diagnosed on the basis of the ECG alone, without knowledge of the clinical picture, because similar ECG changes are produced by many other factors, including metabolic disturbances, disturbances of liquid balance, and digitalization (Hauss 1954, Holzmann 1960, Schettler 1961).

On the other hand, clinical findings indicative of changes in the coronary arteries do not necessarily imply changes in the ECG. Cardiologists have thus established, for instance, in angina pectoris a normal ECG in 25—40 % of the cases (Rinzler 1957, Schettler 1961). The information furnished by the ECG is thus not unambiguous and ECG diagnostics may be comparatively problematic. In the opinion adopted by the World Health Organisation (1959), only ECG changes indicating cardiac infarction possess actual value as evidence. In patients with arterial occlusion, ECG changes are fairly common: Hasse (1959) gives their percentage as 42.8 % and Beckwith et al. (1958) as 63 %. Singer et al. (1960) observed signs of previous ischaemic heart disease in 24 % of 219 patients with intermittent claudication.

Present studies

At the time of amputation the ECG was taken of 87 patients. Changes were observed in 60 of them (69 %); Table 6. Changes indicative of cardiosclerosis were shown by 40 patients (46 %), inveterate infarct by ten (12 %), recent infarct by one (1 %), myocardial ischaemia by three (3 %) and a myocardiac defect by six (7 %).

Table 6. Distribution of 87 patients according to electrocardiographic findings.

ECG finding indicating:	Cases	Per cent
Cardiosclerosis	40	46
Inveterate infarction	10	12
Recent infarction	1	1
Ischaemia of myocardium	3	3
Myocardial lesion	6	7
No changes	27	31
Total	87	100

The ECG changes showed an increasing tendency with increasing age: ECG changes were seen in 78 % of the patients over 70 years (31 out of 40) and in 62 % of those younger than 70 (29 out of 47).

Infarctions were noted in seven men and four women (15 and 11 %, respectively); there is no statistically significant difference between sexes.

In 43 of the 87 patients subjected to ECG examination, angina pectoris had been clinically established. 32 of them (74 %) showed ECG changes, while 11 (26 %) had a normal ECG. Of the 60 patients with ECG changes, 36 (60 %) were such whose clinical examination had revealed angina pectoris.

Of the eleven infarctions determined from ECG, ten had also been established in the patient's previous history.

Comments

Changes in the ECG are rather common in patients with arteriosclerosis obliterans. For instance, Beckwith (1958) in iliac artery occlusion patients, observed ECG changes in 63 %. The present series displays ECG changes in a somewhat higher proportion (69 %), but changes consistent with infarction are not quite as numerous; their rate of occurrence (13 %) is closer to the "post ischaemia" frequency (16 %) noted by Singer and Rob (1960) in patients with intermittent claudication. Infarctions were present, according to the ECG, in about one out of every eight patients (13 %) in close agreement with the number established anamnestically (12 %). About one-quarter of the angina pectoris patients had a normal ECG, in agreement with Schettler's (1961) observations on such patients.

D. Renal and renovascular hypertension

Previous investigations

According to various authorities (Howard and Conner 1964, Poutasse 1964), hypertonia is due in about 5—15 % to renal arterial stenosis. However, such stenosis does not invariably imply the presence of hypertonia. Holley et al. (1964), for instance, noted in an unselected autopsy series of 256 patients without hypertonia, more or less strong renal arterial stenoses in 49 %. It is possible, however, to distinguish the stenoses causing hypertension by means of Howard's test (Stamey 1963, Howard 1964) and Kaplan's hypertension test. Lemann (1964) states that he observed the following kinds of urinary changes in cases of

hypertonia due to constriction of the renal arteries: merely minimal or moderate proteinuria, variably red and white cells and cells of renal origin usually in increasing amounts, and sometimes hyaline and granular cylinders. The quantitative proteinuria is less than 0.5 g per day. The changes were dependent on the degree of arteriolar nephrosclerosis.

There is also a great number of other diseases causing hypertonia (Kinsey and Whitelaw 1964), of which glomerulonephritis and chronic pyelonephritis are the commonest. Page et al. (1959) maintain that it is not possible by means of examination of the bladder urine and function tests to distinguish bilateral from unilateral lesions nor arterial lesion from pyelonephritis.

Concerning the commonness of hypertonia, the fact may be mentioned that Bøe et al. (1957) found at mass examination in Norway the percentage of hypertonics (with 160 mm Hg or higher systolic blood pressure) to be 40 % of 60-year-old men and 50 % of women of the same age. In Finland, calculation from Tuomi's (1965) mass examination shows that hypertonics (with a blood pressure of 160/95 mm Hg or higher) among persons aged 60—65 years account for 16 % of the men, 53 % of the women and 37 % of both together. In arteriosclerotic patients with gangrene Heine et al. (1965) obtained a value of 32.3 % for the percentage of hypertonics (with 155/100 mm Hg or higher blood pressure).

Present studies

The presence of proteins in the urine was investigated in 173 patients of the present series (Table 7). On the basis of the results the patients were divided into two main groups: those with and those without proteinuria. In the group of patients with proteinuria, the boiling test elicited positive albumin reaction in 11 cases and opalization in 37; altogether 48 (28 % of those examined) were thus affected with proteinuria. Ten of them had chronic pyelonephritis and all gave a positive albumin reaction. No information exists on any other diseases of the urinary organs in them. Among the patients whose albumin test produced an opal response, cardiac insufficiency had been established in 15. In the proteinuria group 16 patients had a blood pressure of 160/100 mm Hg or higher. In seven of them chronic pyelonephritis was responsible for their hypertonia. In the remaining nine hypertonic (RR 160 mm Hg or higher) patients, or in 15 % of all those with hypertonia, renovas-

Table 7. Distribution of 48 proteinuric patients and of 125 patients without proteinuria according to rest nitrogen, s.g. of the urine and blood pressure. (In brackets: individual values found by the respective determinations, rest nitrogen expressed in mg%.)

Blood pressure, mm Hg		Number of patients	Rest nitrogen		Specific gravity of urine		
Systolic	Diastolic		Normal	Elevated	Over 1025	1025–1014	Less than 1014
		Proteinuric patients:					
< 160	< 100	16	4	2 (*49, 62*)	2	3	1 (*1008*)
≧ 160	< 100	13	6	2 (*74, 54*)	3	2	–
≧ 160	≧ 100	9	6	2 (*90, 60*)	3	2	–
		Proteinuric patients with chronic pyelonephritis:					
< 160	< 100	3	1	–	–	1	1 (*1012*)
≧ 160	< 100	–	–	–	–	–	–
≧ 160	≧ 100	7	4	–	2	2	–
	Total	48	21	6	10	10	2
		Non-proteinuric patients:					
< 160	< 100	54	19	5 *	7	6	–
≧ 160	< 100	27	13	1 (*72*)	2	3	–
≧ 160	≧ 100	44	18	1 (*78*)	4	11	1 (*1010*)**
	Total	125	50	7	13	20	1

*) (*51, 55, 65, 72, 120*) **) Rest nitrogen normal

cular hypertension may have been present. Their renal changes cannot be very severe however, seeing that only two out of eight cases examined presented moderately elevated rest nitrogen (60 and 90 mg %, respectively) and one of these two had a 1.017 specific gravity of the urine. The urine of four other patients was also examined for specific gravity, which was higher than 1.025 in three cases and 1.022 in one, the latter also having normal rest nitrogen.

No grave renal lesions were elicited in the group of non-proteinuric patients either: only one of them had a specific gravity of the urine less than 1.014 and the amount of creatinine was found to be normal (0.84) even in this case. Five of the normotonics had somewhat elevated rest

nitrogen, but this was not accounted for by renovascular causes either, since the diastolic blood pressure of all these patients had remained normal.

The series of 173 patients included 60 (35 %) hypertonics (with RR 160/100 mm Hg or higher) whose diastolic blood pressure was elevated, too. If increased systolic blood pressure alone (RR 160 mm Hg or higher) is considered, the hypertonics number 93 (60 %).

Comments

In the series of patients with gangrene due to arteriosclerosis of Heine et al. (1965) about one-third were hypertonics (with 155/100 mm Hg or higher). Almost the same proportion of hypertonics (with 160/100 mm Hg or higher) was found in the present series, consistent with the numbers usually encountered among persons of the same age.

If the standpoint is assumed that proteinuria is associated with renovascular hypertonia due to arteriosclerosis, then in about 15 % of the hypertonics of the present series there is a possibility of renovascular hypertonia. Such a rate of occurrence is possible in the light of previous investigations, since hypertonia is considered to be ascribable to stenoses of the renal arteries in about 5—15 %.

VI EXTENT OF POST MORTEM ARTERIOSCLEROTIC CHANGES

A. Autopsies

Previous investigations

On the strength of 200 autopsies, Glagov and Rowley (1959) observed differences in the degree of severity of arteriosclerosis in different parts of the vascular system. They found the following scheme for its distribution: coronary arteries > thoracic aorta > abdominal aorta > renal arteries, and they noted the relatively high degree in which the renal arteries were spared.

The typical primary localizations of arteriosclerosis obliterans changes are the abdominal aorta, the arteries of the pelvis, and the femoral artery. The changes increase in the aorta in the distal direction and are most powerful in the terminal aorta (Allen et al. 1959, Roberts et al. 1959). According to Ratschow (1959), 1.1 % of the circulatory disturbances are caused by obstruction of the artery.

The degree of severity of the occlusions in the coronary arteries also reflects increased changes elsewhere in the vascular system; for instance, a distinct correlation exists between the changes found in the abdominal and coronary arteries (Roberts et al. 1959).

Milles (1925) and Moschkowitz (1929) already observed changes in the pulmonary arteries in only 6—8 % of arterioslerotic patients. Roberts et al. (1959), too, on the basis of 500 autopsies, observed a noteworthy increase of arteriosclerosis in these arteries only in patients with cardiac infarction. The changes in the intestinal arteries up to the age of 70 years were approximately consistent with those of the pulmonary arteries. Holley et al. (1964) established moderate and severe stenoses in patients over 50 years due to renal arteriosclerosis at an almost equal frequency in normotonics and hypertonics (64 and 76 %, respectively).

As regards the region of the lower extremities, Lindbom's (1950)

Table 8. Arteriosclerotic changes observed in a total of 32 autopsies in different parts of the arterial tree and their frequencies (in per cent, in brackets). Only arteries mentioned in five or more autopsy reports have been listed.

Part of the arterial tree	Number of examinations	Normal	Changes of degree:			Thrombus present		Involvement as cause of death		Symptoms of occlusion prior to amputation
			Slight	Moderate	Severe	Obliterative	Adjacent to wall	Basic	Immediate	
Arteries of the base of the brain	29	6 (*21*)	6	7	10 (*34*)	1 (*3*)	–	3 (*10*)	5 (*17*)	5 (*17*)
Common carotid artery, right	7	–	2	3	2 (*29*)	2 (*29*)	–	–	–	1 (*14*)
Common carotid artery, left	6	–	2	3	1 (*17*)	1 (*17*)	1 (*17*)	–	–	–
Coronary arteries	30	1 (*3*)	4	8	17 (*57*)	7 (*23*)	–	10 (*33*)	3 (*10*)	7 (*23*)
Pulmonary artery	18	16 (*89*)	2	–	–	3 (*17*)	–	–	3 (*17*)	–
Mesenteric artery	5	–	1	2	2 (*40*)	2 (*40*)	–	–	–	2 (*40*)
Aortic arch	5	–	5	–	–	–	–	–	–	–
Thoracal aorta	21	–	11	4	6 (*29*)	–	1 (*5*)	–	–	–
Abdominal aorta	29	–	4	9	16 (*55*)	4 (*14*)	5 (*17*)	–	–	–
Common iliac artery, right	9	–	2	2	5 (*56*)	5 (*56*)	–	–	–	–
Common iliac artery, left	9	–	1	2	6 (*67*)	5 (*56*)	–	–	–	–
Superficial femoral artery, right*)	6	–	1	1	4 (*67*)	2 (*33*)	–	–	–	–
Superfical femoral artery, left*)	5	–	1	–	3 (*60*)	1 (*20*)	–	–	–	–

*) Upper parts

arteriographic and autopsy series showed changes in this region in the femoral artery in Hunter's canal to be commonest and severest. On the other hand, the deep femoral artery was less affected by arteriosclerosis and rarely obliterated.

Sclerosis of the cerebral arteries is not distinctly correlated with changes in other arteries. Frövig and Löken (1951), for instance, found the arteries of the brain to be well-preserved even if the branches departing from the arch were completely obliterated. The cerebral arteries did not present any regularity in spread and degree of severity of arteriosclerosis either (Roberts et al. 1959).

The commonness of arterial occlusions in the region of the neck has not been noted until the last ten years. Fischer (1954) presented 432 consecutive autopsies in which 28 occlusions and 13 constrictions of the carotid arteries of a more serious degree were observed. Seven of the subjects presented unilateral occlusion without symptoms. Hutchinson and Yates (1957) described the autopsy findings on 83 patients who had clinical symptoms of cerebrovascular diseases, finding that in 40 of them, at least one-half of the lumen of the carotid and/or vertebral arteries had been obliterated.

In persons over 50 years, moderate and severe arteriosclerotic changes of the renal arteries are fairly common, and stenosis of the renal arteries does not necessarily imply hypertonia (Schwartz and White 1964). In an unselected autopsy material of 154 patients older than 55 years, Schwartz and White (1964) noted severe arteriosclerotic changes in about one-half.

Present studies

As can be seen from Table 8, in which the results of 32 autopsies are presented, all parts of the arterial tree were not systematically examined. Only such arteries for which observations from at least five autopsies exist have been included in the table. The arteries of the base of the brain were examined in nearly all autopsied cases. Severe changes were present in one-third (34 %), but only one case displayed an obliterative thrombus. The findings were normal in one-fifth of the cases (21 %), and only the pulmonary arteries yielded a higher percentage of normal findings. Five of the 32 subjects had had apoplexy prior to amputation, but all five had made a good recovery. In five cases, too, the cause of death was cerebromalacia, but previous apoplexy had

occurred in only one of these. In all five the vessels of the base of the brain were strongly calcified, and one of them also had a thrombus of the middle cerebral artery, while one of the vertebral arteries was narrow in another and the common carotid arteries of a third subject were constricted. The heart compression test had shown the internal carotid and vertebral arteries of these three patients to be open. In the remaining two patients of this particular group the presence of extracerebral occlusions was not ascertained.

The internal carotid artery was not examined at all, and the vertebral artery was only partially investigated in one case. Examination of the common carotid artery was made in seven instances, six of them bilaterally; severe changes were noted in two (29 %) and a unilateral obliterative thrombus in three (43 %). Ischaemic symptoms had occurred in one of these prior to amputation but were not the cause of death in any of the cases.

The most numerous examinations were those made of the coronary arteries, i.e., in 30 patients. More than one-half (57 %) presented severe changes, while a normal finding was made only once (i.e., in 3 %). Cardiac infarction occurred in nine cases (30 %), of which five had an old infarction, two an old infarction and a recent one, and two had a recent infarction only. The cause of death was due to the coronary arteries in 10 cases (33 %), of which seven had had symptoms prior to amputation.

The pulmonary arteries were normal in the majority (89 %) of the cases examined; there were no severe changes at all. Thrombus or embolism was noted in three cases (17 %), in which it had also been the cause of death.

The mesenterial arteries were examined in five cases only; they revealed severe changes in two cases, accompanied by an obliterative thrombus. Intestinal infarction due to thrombus was the intermediate phase (I b) between the fundamental and immediate causes of death in two cases. Ischaemic symptoms of the intestinal circulation had been present in both prior to amputation.

The severe changes observed in the aorta increased in the distal direction, so that they occurred in the region of the abdominal aorta in more than one-half of the cases (55 %), that is, at nearly the same frequency as in the regions of the common iliac artery (55—67 %) and the superficial femoral artery (60—70 %). Only the proximal part of

the latter was examined. The highest number of thromboses was noted in the iliac arteries (57 %).

The kidneys were examined in 30 cases. Apart from the autopsy findings, the clinical results of observation concerning the kidneys and the interval between clinical examination and autopsy have also been entered in Table 9. Arteriosclerotic nephrosis of a severe degree was noted in seven of the autopsied cases (25 %), in two of which hypertonia had been present. The nephrosclerotic kidneys were found to have an average weight of 245 g.

A cicatricial kidney without specified cause occurred in six cases, in two of which renal infarction had been diagnosed. The kidneys in this group showed an average weight of 278 g.

Chronic pyelonephritis occurred in five cases (17 %) and diabetic nephropathy combined with pyelocystitis in one. These kidneys had an average weight of 304 g.

The remaining 12 cases revealed no changes of the kidneys worth mentioning; they also showed the highest average kidney weight, 330 g. The difference of 85 g in comparison to the group affected with nephrosclerosis is statistically almost significant ($P < 0.05$).

Altogether nine of the autopsied patients (31 %) had hypertonia, and two of these showed severe sclerosis of the renal arteries.

Comments

The same observation can be made in the present series as was noted by Roberts et al. (1959) in their autopsy series, that the pulmonary arteries escaped arteriosclerosis fairly well. They constitute the group showing the smallest number of arteriosclerotic changes, i.e., only slight changes in every ninth case. The arteries of the base of the brain were also free of atheroma to rather a great extent (occurrence in one out of every five cases). Commonest and roughly equal in frequency (in 1/2 to 2/3) were severe changes in the coronary arteries, abdominal aorta and arteries of the pelvis. The changes increased in the aorta in the distal direction, as was also observed by Allen et al. (1959) and Roberts et al. (1959) in patients suffering from arteriosclerosis obliterans. Obliterative thrombus was commonest (in about 1/2) in the region of the common iliac artery. The same amount of fresh thrombi completely occluding

the lumen was observed by Wessler and Schlesinger (1953) in amputated extremities. The coronary arteries contained a thrombus in about one out of every four cases.

Even heavy changes may often be asymptomatic unless accompanied by thrombus (Scheidegger 1965). In our series, too, those presenting severe changes in the cerebral and coronary circulation had displayed symptoms prior to amputation in about one-half of the cases only; they were also responsible for death in only about one-half of the cases.

According to Schwartz and White (1964) most of the obliterations (88 %) in the renal arteries are found in the proximal third of the arterial tree; the autopsy reports seem to indicate that this portion was usually not included in the specimens excised for examination together with the kidneys, and was therefore not examined. In the distal two thirds, the above-mentioned authors observed severe changes in about 1/4 (27 %). The present series, too, displayed severe changes in the same region in about 1/4 (23 %). Hypertension is due to stenosis of the renal arteries in about 5—15 % (Poutasse 1959, Howard and Conner 1964). Hypertonia at the time of amputation was recorded in nine of the present autopsied cases, of which two displayed sclerosis of the renal arteries of a severe degree and potential renovascular hypertonia at autopsy. The interval between clinical examination and autopsy had been longer than one year in about one-half of the cases, but on the strength of the examinations dating back less than one year the kidneys seem to have retained their function, so that specific gravity, rest nitrogen and creatinine were normal in all arteriosclerotic kidneys examined. No connection between the kidneys and the causes of death was established in the autopsied cases nor in any of the other deaths. Such relative escape of the kidneys from damage has also been noted, e.g. by Glagov and Rowley (1959).

B. The contribution of arteriosclerosis as a cause of death

Previous investigations

Among persons suffering from arteriosclerosis and among those subjected to amputation on account of this disease, cardiovascular diseases are the commonest cause of death. Juergens et al. (1960) in their study on the prognosis of 520 patients with arteriosclerosis obliterans, observed

Table 9. Renal autopsy findings in 30 patients and the same patients' urinary findings at the time of amputation.

Case No.	Finding at autopsy	Time from clinical examination to autopsy y.	m.	d.	Weight of kidneys, g Left	Right	Total	Mean	Blood press., mmHg	Urinary findings at amputation Albumin	Rest Nitrogen or Creatinine	S.G.
1	Arteriosclerotic nephrosclerosis			5	28	130	153		165/85	Opal.	54	
2	Arteriosclerotic nephrosclerosis	3	8		95	105	200		185/105	—	30	1020
3	Cicatrized arterioslecrosis of kidneys	2	7		116	138	254		180/85	—		1022
4	Arteriosclerotic nephrosclerosis	4			100	180	280	245	160/100	—	35	1027
5	Arteriosclerosis of kidneys			10	130	95	225		175/80	—	1.09	
6	Nephrosclerosis				190	170	360		140/90		1.18	
7	Arteriosclerosis of kidneys			3	—	—	—		140/80	—		
8	Surface uniformly uneven	4	5		100	100	200		180/85	—	35	
9	Surface somewhat rough	6	2		100	100	200					1026
10	Small recesses	2	4		90	85	175		190/100	+		
11	Some recesses			2	155	165	320	278	150/85	—		1021
12	Inveterate infarction of left kidneys			3	180	170	350		180/100	—	34	
13	Infarction of right kidney			2	210	215	425		180/80			
14	Chronic pyelonephritis			20	55	120	175		150/80			1012
15	Chronic pyelonephritis	1	8		120	320	440					
16	Pyelocystitis		5		180	190	370	304	205/100	+		
17	Chronic pyelonephritis	2			115	130	245			Opal.		
18	Chronic pyelonephritis		8		150	140	290		170/100		30	1022
19			5		135	125	260		165/80	—	45	
20				13	—	—	—		170/100	+		1016
21				3	140	145	285		230/100	Opal.	36	1022
22				4	160	190	350		175/80	+		
23		1	11		200	205	405		150/85			1027
24		2			125	125	250		120/60			
25		1	3		180	170	350	330	160/90	—		
26		4	8		165	145	310		170/90	—		1020
27		1	2		190	185	375		170/90	+		1022
28		1	3		Normal				180/100	+	32	1027
29		2	3		160	165	325		135/85	—	35	1020
30				1	175	220	395		140/90	—	1.18	

Table 10. Basic and immediate causes of death according to autopsies or death certificates.

Cause of death	Basic cause of death (117 cases)						Immediate cause of death (109 cases)					
	Autopsied *32 cases*		Not autopsied *85 cases*		Total		Autopsied *31 cases*		Not autopsied *78 cases*		Total	
Arteriosclerotic causes:												
Coronary arteries	10 (*32* %)		3 (*3* %)		13 (*11* %)		3 (*10* %)		12 (*15* %)		15 (*14* %)	
Cerebral arteries	3 (*9* %)		12 (*14* %)		15 (*13* %)		5 (*16* %)		14 (*18* %)		19 (*17* %)	
Lower extremities	–		20 (*24* %)		20 (*17* %)		–		13 (*17* %)		13 (*12* %)	
General arteriosclerosis	8 (*25* %)		27 (*32* %)		35 (*30* %)		–		3 (*4* %)		3 (*3* %)	
	21 (*66* %)	21 (*66* %)	62 (*73* %)	62 (*73* %)	83 (*71* %)	83 (*71* %)	8 (*26* %)	8 (*26* %)	42 (*54* %)	42 (*54* %)	50 (*46* %)	50 (*46*
Other causes:												
Cardiac disease (other than coronary)	–	–	8 (*9* %)	8 (*9* %)	8 (*7* %)	8 (*7* %)	5 (*16* %)	5 (*16* %)	20 (*26* %)	20 (*26* %)	25 (*23* %)	25 (*23*
Diabetes	6 (*19* %)		–		6 (*5* %)		1 (*3* %)		–		1 (*1* %)	
Pneumonia	–		2 (*2* %)		2 (*2* %)		8 (*26* %)		7 (*9* %)		15 (*14* %)	
Miscellaneous infectious diseases	3 (*9* %)		2 (*2* %)		5 (*4* %)		2 (*6* %)		4 (*5* %)		6 (*5* %)	
Pulmonary infarction	–	–	3 (*4* %)	3 (*4* %)	3 (*2* %)	3 (*2* %)	3 (*10* %)	3 (*10* %)	1 (*1* %)	1 (*1* %)	4 (*4* %)	4 (*4*
Carcinoma	–		3 (*4* %)		3 (*2* %)		–		3 (*4* %)		3 (*2* %)	
Miscellaneous	2 (*6* %)		5 (*6* %)		7 (*7* %)		4 (*13* %)		1 (*1* %)		5 (*5* %)	
	11 (*34* %)		23 (*27* %)		34 (*29* %)		23 (*74* %)		36 (*46* %)		59 (*54* %)	
Total	32 (*100* %)		85 (*100* %)		117 (*100* %)		31 (*100* %)		78 (*1000* %)		109 (*100* %)	
Cardiovascular diseases		21 (*66* %)		73 (*86* %)		94 (*80* %)		16 (*50* %)		63 (*81* %)		79 (*72* %

that three-quarters of these patients die of coronary diseases. Beckwith et al. (1958), too, found among patients with intermittent claudication and thrombosis of the iliac aorta, of whom one-third were subjected to amputation, coronary thrombosis to be the principal (60 %) cause of death. Schadt et al. (1961) reports cardiovascular disease as the cause of death in 81.8 % of patients with arteriosclerosis obliterans, of whom one-third had been amputated.

Present studies

Table 10 shows the causes of death attributable to arteriosclerosis. The basic cause of death has been stated for 117 of the 127 patients who died; in 83 of them (71 %) it was attributable to arteriosclerosis. On separate scrutiny of the autopsied and non-autopsied patients, the contribution of arteriosclerosis is seen to be 66 and 73 %, respectively.

In addition to the lower extremities, of the arteries supplying various organs only the cerebral and coronary arteries are shown by the table as contributing to the basic cause of death. According to the autopsy findings, death was due to the coronary arteries at a frequency three times higher than to the cerebral arteries. Arteriosclerosis of the intestine or kidneys does not occur as the basic cause of death in any instance, but in two cases arteriosclerosis of the mesenterial arteries was present as an intermediate phase (I b) between the basic and immediate causes of death. The share of general arteriosclerosis among the basic causes of death is about one-third.

Comments

Clinical and autopsy statistics concerning causes of death often contradict each other (Lew 1957). In the present series, too, autopsies showed a higher frequency of arteriosclerosis of the coronary arteries than clinical examination. The high prevalence of arteriosclerosis is confirmed by the fact that about two-thirds show arteriosclerosis in one form or another as the basic cause of death, which equals the frequencies at which it has been encountered in patients suffering from arteriosclerotic gangrene or from severe arteriosclerosis obliterans. The commonest site of manifestation of arteriosclerosis, as elucidated by causes of death, has usually been the coronary arteries in amputation series (Beckwith et al. 1958, Schadt et al. 1961). The same is true in the present autopsy series.

VII SYMPATHECTOMY AS AN AMPUTATION-PRECLUDING TREATMENT

Previous investigations

It has been said that sympathectomy is an operation producing vasodilation and hyperaemia (Block 1957, Fontaine 1959) and improving the collateral circulation (Edwards 1957, Mayer-Burgdorff 1960, Ballinger 1965). The frequency of favourable results after sympathectomy performed in association with peripheral arterial occlusion diseases varies between 17 % and 88 % (Senn 1965).

Reported experiences (Nyström 1949, Wanke 1953, Berry et al. 1955, Block 1957, Fontaine 1959, Kunlin 1959, Holopainen 1963, Dale 1965, Szilagyi 1965) indicate that the results obtained by sympathectomy are least favourable in the rest pain and necrosis stages, which are exceedingly difficult to influence. In the opinion of Berry et al. (1955) sympathectomy is contraindicated in gangrenous patients over 60 years if their popliteal artery pulsation is absent. If cutaneous lesion is present when sympathectomy is made, major amputation rather often ensues (Telford and Simmons 1946: in 49 %, De Bakey et al. 1950: in 65 %, Berry et al. 1955: in 41 %, Pratt 1955: in 66 %, Gillespie 1961: in 37 %).

Better results have been reported after sympathectomy at the intermittent claudication stage (Hämäläinen 1943, Nyström 1949, Lindström 1952, Bittner 1958, Kunlin 1959, Wanke 1959, Dale 1963, Holopainen 1963, Ballinger 1965), after which gangrene develops in less than one-third (Bittner and Stephan 1958: in 30 %, Gillespie 1960: in 15 %, Mayer-Burgdorff 1960: in 20—30 %).

The success of the operation is also affected by the height of occlusion. The results are poorer when occlusion of the abdominal aorta or of its main arch is concerned (Silbert and Zazeela 1958, Fontaine 1959, Gillespie 1961), while good results have been obtained in peripheral occlusions in the region of the lower leg (Holopainen 1963, Ballinger 1965, Schoop 1965, Szilagyi 1965). Mavor (1956) thinks that the height

of occlusion has no effect on the result of sympathectomy. Koskinen (1963) has drawn attention to the favourable effect of sympathectomy in distal arterial lesions due to trauma.

Most important among concomitant diseases is diabetes, which impairs the results, e.g. according to Nelson and Trimble (1956), Silbert and Zazeela (1958) and Thimming et al. (1958), but Edwards (1957), Gillespie (1961) and King et al. (1964) maintain that sympathectomy is also suitable for diabetics. Furthermore, the general extent of arteriosclerosis exerts an influence on the outcome. In the case of previous cardiac infarction, cerebrovascular accident or visceral ischaemic symptoms, poorer results have been noted than in the absence of such manifestations (Ballinger 1965), particularly if the patients are hypertonics or diabetics over 65 years of age (Berry et al. 1955).

Present studies

The distribution of amputations among the 64 sympathectomized patients of the present series is given in Table 11. Of 93 extremities treated by sympathectomy, 78 were subsequently amputated and 15 extremities escaped amputation.

The mean age of the sympathectomized patients was 62.3 years and that of the patients whose one extremity was saved and of those who underwent amputation after sympathectomy, was 61.9 and 62.6 years, respectively. The proportion of diabetics in these two groups was 13.3 and 20.4 %, respectively. No statistically significant differences exist

Table 11. Distribution of 64 patients' extremities according to unilateral or bilateral sympathectomy and amputation.

	Number of patients	Number of sympathectomized extremities	Number of amputated extremities	Number of extremities saved
Unilateral amputations:				
Unilateral sympathectomy	33	33	33	
Bilateral sympathectomy	15	30	15	15
Bilateral amputations:				
Unilateral sympathectomy	2	2	2	
Bilateral sympathectomy	14	28	28	
Total	64	93	78	15

between the groups. The age at amputation of the non-sympathectomized patients was 71.7 years on the average; the difference of 9.4 years in comparison to the sympathectomized patients is statistically highly significant ($P < 0.001$).

Table 12. Clinical and operative-prognostic classification of 78 sympathectomized extremities.

Classification	Amputated extremities		Extremities saved	
	Number	Average sympathectomy – amputation interval, months*	Number	Average time from sympathectomy to death, years*
Clinical classification (Leriche-Fontaine):				
Little or no symptoms	–		–	
Intermittent claudication	32	34	15	4,5
Rest pain	16	3,5	–	
Necrosis or gangrene	30	1.4	–	
Total	78	4.3	15	4.5
Operative-prognostic classification (Wanke):				
No necrosis	48	23	15	4.5
Necrosis or gangrene	30	1.4	–	
Total	78	4.3	15	4.5

* Logarithmic means

Sympathectomy was performed (Table 12) on the side of the amputated extremity at the intermittent claudication stage in 32 cases (41 %), at the rest pain stage in 16 (20 %) and at the gangrenous stage in 30 (39 %). The average time interval between sympathectomy and amputation was 2 years 10 months in the cases sympathectomized at the claudication stage, but only 3.5 and 1.4 months, respectively, in those subjected to sympathectomy at the rest pain and necrosis stage. On the side of the extremity left intact, sympathectomy had invariably taken place at the intermittent claudication stage and the time the extremity remained intact (up to death) averaged 4.5 years.

In those sympathectomized at the intermittent claudication stage, the claudication symptom had been present for 2.4 years on the average, and in those whose extremity was saved after sympathectomy, for 2 years. The time which the extremity remained intact after sympathectomy in the same groups was 2 years 10 months and 4.5 years, respectively.

Table 13 shows the types of occlusion observed at the time of sympathectomy, and for each such type the average interval between sympathectomy and amputation. It can be seen that in the case of high occlusion, amputation followed sooner than when peripheral occlusion was involved, the difference between the peripheral type of occlusion and that involving the region of the thigh being statistically significant ($P < 0.01$) and that between the pelvic and peripheral occlusion types, statistically almost significant ($P < 0.05$).

Table 13. Types of occlusion at the time of sympathectomy, and time from sympathectomy to amputation, in series of 78 sympathectomized patients.

Type of occlusion	Number of patients	Average sympathectomy – amputation interval, years*
Pelvic region	11	0.27
Femoral region	29	0.31
Peripheral	24	0.9
All pulses feeble	5	
Not recorded	9	
All cases	78	0.68

* Logarithmic means

Expedients of vascular surgery other than sympathectomy were applied in attempts to improve the circulation of extremities in four cases, with rather satisfactory results. In the case of three patients, arterial reconstruction was performed and in another, thromboendarterectomy in the thigh. One gangrenous extremity thus escaped amputation; in the other three amputation did not follow until after 1.5—3 years.

Comments

The mean age of the sympathectomized patients in the present series was found to be 9.4 years lower than that of the complementary group, which amounts to a statistically highly significant difference. However, this can hardly be claimed to be a consequence of sympathectomy, since the disease had already reached the rest pain and necrosis stage in about one-half of the patients prior to sympathectomy, and no paradoxical reactions were noted after sympathectomy. It seems that in the group of sympathectomized patients, the disease progressed rapidly and extensively more often than average so that the results of sympathectomy were poorer (cf. De Bakey 1958, Senn 1965), as were also those of sympathectomy in the gangrenous stage. Here, as in general, the best results were elicited by sympathectomy performed at the intermittent claudication stage: in one out of every three such cases amputation was avoided and in the rest, too, on the average nearly three years passed before amputation ensued, whereas amputation followed as soon as 1.4—3.5 months after sympathectomy at the rest pain and gangrenous stage. The height of occlusion, too, affects the results (Silbert and Zazeela 1958, Gillespie 1961). Here, too, better results are noted when the occlusions were peripheral. In such cases the interval between sympathectomy and amputation was on an average three times that observed in connection with occlusions in the pelvic region. The extremities that remained intact presented peripheral occlusions at a frequency twice as great as that for the amputated extremities, and there were no occlusions at pelvic height, which occurred at the time of sympathectomy in about one of every five patients subjected to amputation (Table 4, p. 46).

VIII HEIGHT OF AMPUTATION AND HEALING OF THE STUMP

Previous investigations

In series of amputations in which arteriosclerosis was the sole or principal reason for amputation, amputation at the thigh has been commoner than amputation at the lower leg (Table 14), but in a few series compiled in recent years the latter begins to be almost as frequent or even more common than amputation at the thigh (Alffram and Holmquist 1961, Eraklis and Brownell 1963, Hallen and Hult 1964). However, in 1961 in the 13 biggest Swedish hospitals, lower leg stumps accounted for 32 % of the thigh and lower leg amputees (Hallen and Hult 1964). Prior to the introduction of antibiotics, most amputations had to be performed at the thigh, owing to the common imminence of sepsis and wound infection after amputation at the lower leg. For instance, Perlow (1962) observed that in his series of amputations those at lower-leg height had increased from 6 % of all amputees in 1936—1938 to 32 % in 1945—1956. At the same time the mortality went down from 29 % to 14.4 %.

Digital and metatarsal amputations are less frequently successful in arteriosclerotics than in diabetics (McKittrick et al. 1949, Regan et al. 1949, Warren et al. 1952, Wheelock 1961) and they are often intermediate to final upper or lower leg stumps.

The optimum height at lower-leg amputation is, according to Perlow (1962), from the middle third to 8 cm below the tuberosity of the tibia, but 2—3 cm below the latter is sufficient for a lower leg prosthesis. According to Mercer and Duthie (1963), a serviceable prosthesis can be fitted to a 2-inch stump, and in Thompson's (1963) opinion a 3-inch stump is adequate for a total contact patellar-bearing prosthesis.

If no possibility exists for lower leg amputation, then exarticulation of the knee is recommended by McKenzie (1953) and by Hopkins and Harris (1965), while Record (1963) and Thompson (1963) advocate amputation at the thigh.

Table 14. Healing of lower and upper leg stumps in some previous series and in the present series.

Reference	Number of amputations	Amputations at (1) Lower leg	Amputations at (2) Upper leg	Reamputations After (1)	Reamputations After (2)	Secondary healing Lower leg	Secondary healing Upper leg	Cause of amputation
Silbert and Haimovici (1950)	213	213		10 (5 %)				3/4 of series diabetics
Kelly and Janes (1957)	245	131	114	9 (9 %)				
Claugus et al. (1958)	118	47	71	6 (13 %)	1 (1 %)	(26 %)*	(21 %)*	Arteriosclerosis
Dale and Capps (1959)	284	65	219			33 (51 %)	75 (34 %)	259 arteriosclerotics
Schlitt and Serlin (1960)	96	28	68	7 (25 %)	0	9 (32 %)	10 (15 %)	87 arteriosclerotics
Harris et al. (1961)	52	52		10 (19 %)		(21 %)*		
Dale and Jacobs (1962)	About 270*)	45*)	225*)			(39 %)	(25 %)	Arteriosclerosis
Lempke et al. (1963)	200	**)	**)			(28 %)	(4 %)	Arteriosclerosis
Present series	219	24	195	9 (37 %)	9 (5 %)	5 (21 %)	26 (13 %)	Arteriosclerosis

*) Calculated from data presented. **) Amputations both at lower leg and at thigh; numbers not stated.

As contraindications to lower leg amputation, Claugus (1958) enumerates the following: abrupt change in temperature above the planned incision; flexion contracture of the knee; scanty haemorrhage during operation, particularly from subcutaneous tissue; absent pulsation of the femoral artery. These are generally acknowledged (Silbert and Haimovici 1950, Kelly and Jones 1957, Thompson 1963). Concerning the pulses, however, opinions differ. Silbert and Haimovici (1951) and Thompson (1963) consider that if there is extensive gangrene, infection in the lower leg and absence of the femoral artery pulse or acute occlusion of the femoral artery, lower-leg amputation will not be successful. In the absence of pulsation in the popliteal artery, lower-leg amputation will be successful (Perlow 1962, Eraklis and Brownell 1963), but according to Harris et al. (1961) the chances of success are smaller than if the pulse of the popliteal artery is palpable.

The basic cause of wound complications may be considered to be poor vascularization of the tissues and infection in the lymph passages of most patients (Dale and Capps 1959), but surgical assessment of the tissues and amputation technique also play an essential role (McKittrick and Pratt 1934, Perlow et al. 1949, Silbert and Haimovici 1951, Kendrick 1956, Claugus et al. 1958, Dale et al. 1959, 1962, Perry 1963) so that most wound complications can be avoided by using the correct amputation technique and antibiotics (Dale and Capps 1959).

Various opinions have been expressed concerning the effect of sympathectomy on the height of amputation. It has been said that a longer stump is obtained on a sympathectomized extremity (Perlow and Roth 1949, Pratt 1955, Flotte 1959) or that the expedient does not affect the height (Kirschner 1951, Lempke et al. 1963). Gibbel (1960) and Gillespie (1961), among others, think that sympathectomy has a favourable influence on the healing of the stump.

Present studies

a) The effect of sympathectomy on the healing of the stump

Table 15 shows a comparison between the healing of the amputation stump in extremities subjected to sympathectomy and those on which this was not performed. Objects of comparison are the occurrence of reamputations and wound complications of considerable seevrity (cases in which the stump did not heal in four weeks), and the distribution of stumps in both groups.

Table 15. Healing of the stumps of sympathectomized and non-sympathectomized extremities; numbers and percentages referred to number of primary stumps.

	Number of primary stumps	Wound complications				Ultimate stumps	
		(1) Causing reampu-tation	(2) Other fairly serious complications	(1) + (2)	None, or slight	Lower leg	Upper leg
Lower leg amputation:							
Symphathectomized	16	7 (*44 %*)	2 (*12 %*)	9 (*56 %*)	7 (*44 %*)	10 (*63 %*)	6 (*37 %*)
Not sympathectomized	8	2 (*25 %*)	3 (*37 %*)	5 (*62 %*)	3 (*38 %*)	7 (*87 %*)	1 (*13 %*)
	24	9 (*37 %*)	5 (*21 %*)	14 (*58 %*)	10 (*42 %*)	17 (*71 %*)	7 (*29 %*)
Upper leg amputation:							
Sympathectomized	62	4 (7 %)	10 (*16 %*)	14 (*23 %*)	48 (*77 %*)		62
Not sympathectomized	133	5 (4 %)	16 (*12 %*)	21 (*16 %*)	112 (*84 %*)		133
	195	9 (5 %)	26 (*13 %*)	35 (*18 %*)	160 (*82 %*)		195

At the height of the lower leg, altogether 24 primary amputations were performed, in nine of which (37 %) later reamputation was carried out, two at the lower leg and seven at the thigh. Reamputations were more numerous in the sympathectomy group and other wound complications were more numerous in the group of non-sympathectomized subjects than in the complementary group, but there are no statistically significant differences. Wound complications occurred in altogether more than one-half (58 %) of those amputated at the lower leg and at an approximately equal frequency in the sympathectomy and non-sympathectomy groups (56 and 62 %, respectively). The distributions of ultimate stumps in the sympathectomy and non-sympathectomy groups display no statistically significant differences.

Only two of the primary lower leg stumps were shorter than 15 cm (12 and 14 cm), both occurring in sympathectomized extremities. All other stumps were of the order of 15 cm up to half the length of the lower leg.

At the height of the thigh, 195 primary amputations and nine reamputations were performed, four of the latter on sympathectomized extremities (7 % of such extremities) and five on non-sympathectomized ones (4 %); there is no statistically significant difference. Other wound complications were encountered in 16 % and 12 %, and the total frequency of wound complications is 23 % and 16 %, respectively. The upper leg stumps varied in length from those of Callander type to amputations at the height of the trochanter minor. Wound complications occurred both in the sympathectomy and the non-sympathectomy groups at about three times higher a frequency in the lower leg stumps than in the upper leg stumps. All told, 58 % of the former and 18 % of the latter presented wound complications, statistical analysis revealing a highly significant difference ($P < 0.001$) in this respect.

b) Causes of wound complications

Table 16 shows the observations made concerning lowered vitality of the tissue, infection and local factors in their effect on the healing of the stump. The criteria presented by Lempke et al. (1963) were applied in assessing the contribution of the different causes. The criteria of infection were: purulent exudation from the wound, cellulitis, febrility, healthy granulation tissue, and secondary healing. Criteria of lowered vitality of the ischaemic tissue: absence of the above-mentioned symptoms

Table 16. Causes responsible for reamputation or more serious wound complications and their frequencies, referred to number of respective stumps.

	Complications resulting in reamputation			Other wound complications		
	Upper leg stumps (195)	Lower leg stumps (24)	Total (219)	Upper leg stumps (195)	Lower leg stumps (24)	Total (219)
Stumps presenting complications (Percentage of all respective stumps)	9 (5 %)	9 (37 %)	18 (8 %)	26 (13 %)	5 (21 %)	31 (14 %)
Lowered vitality of tissue	6 (*67* %)	6 (*67* %)	12 (*67* %)	7 (*27* %)	1 (*20* %)	8 (*26* %)
Infection	4 (*44* %)	3 (*33* %)	7 (*39* %)	12 (*46* %)	3 (*60* %)	15 (*48* %)
Local factor or technical fault	5 (*56* %)	6 (*67* %)	11 (*61* %)	15 (*58* %)	3 (*60* %)	18 (*58* %)

of infection, wound dehiscence on removal of the sutures, and wound necrosis; those depending on a local factor, that is some technical fault: tautness at closure of the wound, wound haematoma, sequester, and trouble caused by the drain.

Commonest among the causes responsible for reamputation (in 67 %) was lowered vitality of the tissues. A local factor was responsible at almost the same frequency (56—67 %) and infection somewhat less often (33—44 %). Mostly two or three of these causes acted simultaneously. However, local factors were assessed as constituting the sole or principal reason for reamputation in four cases reamputated at the lower leg and in three cases of reamputation at the thigh; it is to be concluded that the primary stumps might have remained final in these seven instances if a different amputation technique had been used.

In other wound complications local factors are predominant as the responsible cause (58—60 %), while infection was not quite as often involved (46—60 %). Lowered vitality of the tissues has been estimated to be the cause leading to wound complication other than amputation in only about one-fourth (20—27 %) of the cases.

The amputations of this series were performed by 55 surgeons, of whom seven performed a total of five or more, while 33 of them were responsible for one or two amputations.

Table 17. Influence of height of occlusion on the healing of the stumps.

Healing of the stump	Lower leg stumps Type of occlusion:			Upper leg stumps Type of occlusion:		
	Pelvic	Femoral	Peripheral	Pelvic	Femoral	Peripheral
P.p.i.	1 (33 %)	5 (50 %)	4 (36 %)	32 (54 %)	51 (89 %)	37 (97 %)
Wound complication causing reamputation	2 (67 %)	3 (30 %)	4 (36 %)	8 (13 %)	2 (4 %)	–
Other wound complications	–	2 (20 %)	3 (28 %)	20 (33 %)	4 (7 %)	1 (3 %)
Total	3(100 %)	10(100 %)	11(100 %)	60(100 %)	57(100 %)	38(100 %)

c) The effect of height of occlusion on the healing of the stump

In Table 17 the influence of the height of occlusion on the healing of the wound is shown. Within two weeks after amputation, 38 patients were lost, and the records of two patients have no entries concerning the healing of the wound. These 40 cases have therefore been excluded from the study concerning the healing of the stump.

The lower leg stumps which healed *p.p.i.* were equal in proportion among the cases presenting occlusion in the peripheral and the pelvic region, while reamputations were more numerous in the latter group, though without any statistically significant difference.

On the other hand the influence of the height of occlusion is clearly evident in the healing of the upper leg stumps in that nearly all those with occlusion of the peripheral type (97 %) but only about one-half (54 %) of those with occlusion at pelvic height healed *p.p.i.* The difference is statistically highly significant ($P < 0.001$). There were no reamputations in cases presenting occlusion of the peripheral type, whereas their occurrence in association with occlusions in the pelvic region amounts to 13 %. Other wound complications, too, were encountered more often in patients with pelvic height of the occlusion than in those with the peripheral type of occlusion, at a statistically almost significant level ($P < 0.05$). Healing also proceeded more favourably in the cases with occlusion in the region of the thigh than in those with occlusion at pelvic height, the percentages of healing achieved *p.p.i.* showing a statistically significant difference ($P < 0.01$).

Comments

It can be seen from Table 14 that in the patients subjected to amputation on account of gangrene caused by arteriosclerosis, wound complications of the stump are fairly common. Secondary healing of extremities amputated at the lower leg took place in 25—51 %, and the reamputation frequency was up to 25 %. Upper leg stumps display wound complications less often than lower leg stumps and reamputations at the thigh are rarely necessary.

In the present series, amputation at the lower leg was performed in only about one out of every nine cases and reamputation was needed in somewhat more than one-third of them. While there were more wound complications and reamputations after amputation at the lower leg than usual, the wound complications after amputation at the thigh were less numerous than average, but reamputations were rather numerous in this group, too.

Dale and Capps Jr. (1959) observed that profuse wound complications are due to inappropriate amputation techniques and incorrect surgical assessment of the tissues. In the present series, too, wrong surgical assessment of the tissues constituted the principal cause of wound complications and a nearly equal share is attributable to faulty amputation techniques; the former finds an obvious explanation in attempts to obtain stumps of optimum dimension: nearly all lower leg stumps were 15 cm in length or longer. Infections contributed less to reamputation than they did to other wound complications.

The effect of the height of occlusion was clearly established in respect of the upper leg stumps, which healed better when a peripheral occlusion was concerned than in the case of occlusion in the pelvic region. Amputation at the lower leg was not more often successful in those whose popliteal artery pulse was palpable than in those failing to present this pulsation. Sympathectomy was not found to have any influence on the healing of the stump.

IX RECOVERY, LIFE SPAN, ABILITY TO MOVE, AND CAUSES OF DEATH

Previous investigations

Factors affecting the recovery and life span after amputation are, e.g., age at amputation, height of amputation, sex, concurrent diseases such as diabetes and coronary arteriosclerosis, and preoperative and postoperative treatment (Veal 1938, McKenzie 1953, Dale and Capps 1959, Lempke et al. 1963). The data compiled in Table 18 show that the average life span after amputation varied between 1 year 8 months and 2 1/4 years.

In addition to the data concerning life span, information on amputation mortality and causes of death has been compiled in Table 18 from some previously published series. Before the era of antibiotics, the operation mortality varied between 13 and 60 %; in a composite material of 2,682 cases, for instance, it was 27 % (Silbert and Haimovici 1950).

The mortality of patients amputated at the lower leg varies in the series covered by Table 18 from 0 (Claugus et al. 1958) to 9 % (Silbert and Haimovici 1950) and that recorded at amputation at the thigh, from 6.1 % (Claugus et al. 1958) to 60 % (Morrisania 1942, rev. by Silbert and Haimovici 1950).

In rehabilitation, arteriosclerosis is the most essential factor restricting the use of a prosthesis (Bugel and Carlson 1961). After amputation only about one-half of the older gangrenous patients become prosthesis-walkers (McKenzie 1933: 49.7 %, Alffram and Holmquist 1961: 50 %, Claugus et al. 1958: 49 %). The percentage of amputees walking at the time of follow-up examination is reported as 28 % by Lindholm (1964a), as 44 % by Gingres et al. (1954) and as 31 % by Hansson (1964).

Lower leg stumps present several advantages over upper leg stumps: lower operative mortality; better ultimate function of the extremity and better chances of rehabilitation; less strain on the contralateral extremity; better equilibrium without prosthesis in moving about on crutches, in a wheel-chair and in bed; lighter weight of the prosthesis, for which

an older person's strength is more adequate; easier sitting and moving in bed for bilateral amputees (Abramson 1942, Silbert and Haimovici 1950, Claugus et al. 1958, Harris et al. 1961, Perlow 1962, Perry 1963, Record 1963).

In Hansson's (1964) series of unilateral amputees older than 60 years, 72 % required constant home or institutional care. The proportion of such patients in Lindholm's (1964a) series was 91.9 %.

Since arteriosclerosis is present in a considerable portion of the amputees, it is not surprising that cardiovascular diseases constitute the principal cause of death. For instance, Lindholm (1964a) noted that of 86 patients subjected to amputation at an age of over 65 years, 40 died within 2 1/2 years of the amputation, and that in 77.5 % of these the basic cause of death was arteriosclerosis. In Hansson's (1964) series the postoperative deaths during the first year amounted to 41 %, and of those over 60 years 90 % died of a cardiovascular disease.

Present studies

a) Recovery and life span after amputation

Those who died within 14 days of the amputation were considered to represent the operative mortality; they numbered 38 (21 %). Another 15 patients died in the hospital after this period and the hospital mortality thus took a toll of 53 patients (29 %). Of those who were discharged, 74 had died at the time of writing this report (40 %). The mean life span after amputation of all patients who have died up to now is 1.8 years. For bilateral amputees, the life span was counted from the later amputation.

The patients living at the time of follow-up examination numbered 57 (31 %). The shortest and longest life spans after amputation of the patients subjected to follow-up examination were 1 year 1 month and 13 years 10 months, respectively, the average life span being four years.

The life spans after amputation of all patients in the present series have been analyzed and the results presented in Fig. 10, curve A. The cumulative distribution curves were plotted for different ten-year age groups, including both those who died before follow-up and those still alive. Entering these graphs at 50 % decession, the mean post-amputation life spans for these groups were found and entered in Fig. 10, and thus represent the times after which one-half of the patients in each such group had died. The curve B has been drawn for purposes of comparison

Table 18. Postoperative mortality, life span after amputation, and causes of death in some previous series of amputations at thigh and lower leg.

Reference	Period covered	Amputations: Number[1])	Cause	Height[2])	Primary mortality: Deaths	Per cent	Life span after amputation	Cause of death
McKittrick and Pratt (1934)	1923–33	326 A	Diabetes	L & T	49	15	About 2/3 survived over 2 years	Infection in more than 1/2
Faxon (1939)	1929–39	262 A	Peripheral vascular disease	Major amputation		13.1	61 % of the arteriosclerotics died within 5 years	
Taylor (1939)	1930–38	117 P 137 A	Arteriosclerosis	Major amputation	44	32*		
Morrisania (rev. by Silbert and Haimovici, 1950)	1931–35	45 P	Diabetes	T	27	60		
Lindholm (1964b)	1930–61	492 P	Peripheral vascular disease	Digit, L & T		26.6		
Perlow (1961)	1936–44	112 A	Arterial occlusion disease	L & T	24	21*		Operative deaths from cardiovasc. dis., infection and other cause: in 43, 35 and 25 % respectively
	1945–58	157 A	Arterial occlusion disease	L & T	22	14.4		
Silbert and Haimovici (1950)	1940–49	213 A 196 P	Diabetes	L	20	9.4		
Hansson (1964)	1947–56 & 1961	331 P	Arteriosclerosis in majority (236)	L & T	59	18	19 months those over 60 years 20 months in entire series Deaths within 0.5, 1, 2 and 5 years: 36, 41, 58, 82 %, resp.	
Claugus et al. (1958)	1946–56	118 A	Arteriosclerosis	T – 71 L – 47	5 –	4.2 0	Within 1 and 2 years 15.5 and 22.5 %, respectively	
Dale and Capps (1959)	1948–58	284 A 237 P	Arteriosclerosis in 259	T – 219 L – 65	44 3	20* 4.6*	20*	Operative deaths: cardiac infarction 9 (18 %), cardiac insufficiency in 6 (12%)
Harris et al. (1961)	1948–58	52 P	Peripheral v. dis.	L	3	6		
Alffram and Holmquist (1961)	1949–58	149 P	Peripheral vascular disease; 102 arteriosclerotics	L & T	20	13.4	Average 27 months 31.5 % died within 1/2 year 40 %of those over 60 died within one year	Pulmonary infarction in 18 (37 %), pneumonia 3 (6 %), cardiovascular disease in 77 %
Schlitt and Serlin	1953–58	96 P 129 A	Peripheral vascular disease	L – 28 T – 68	2 9	7 13	12*	
Dale and Jacobs (1962)	1956–60	337 P	Mostly peripheral vascular disease	L T	36			Cardiac infarction or failure in 10 (27.5 %) Pulmonary embolism in 9 (25 %)
Lindholm (1964a)	1961–63	86 P	Over 65 years	T L – 16		19*	41.5 % died within 2.5 years Mean age of deceased 78.6, of entire series 76.2 years	Cerebrovasc. accident in 5 (14 %) Cardiovascular complication or pulmonary embolism in 83 %
Present series	1950–63	184 P 219 A	Arteriosclerosis	L – 24 T – 195	– 53	0 27	24 Deaths within 0.5, 1 and 2 years: 36, 41, 48 % respectively. Total deaths 58 %.	Cardiovascular disease in 80 % at least

[1]) A – Number of amputations; P – Number of patients; [2]) L – Lower leg, T – Thigh; *) Calculated from data presented

and indicates the mean life expectation of corresponding age groups in an unselected population. The values for this graph were calculated from data referring to the periods of 1951—1955 and 1956—1960 taken from the Finnish Statistical Yearbook; in the calculations the specific sex distribution of each ten-year age group of the present series was taken into account.

In the group of patients subjected to amputation at an age below 50 years, no deaths occurred. All these three patients are alive, the time since amputation varying from 6 to 14 years. In the group of patients aged 50—59 years at the time of amputation, 13 had died and 14 were alive at the time of the follow-up study, with time intervals after the amputation ranging from 1 to 11 years. On the strength of the cumulative distribution graph, the mean life span after amputation was 3 years in this group. In the 60—69 age group, 45 patients had died and 20 were still alive, the latter after periods between 1 and 8.5 years, counted from the amputation. As before, a mean life span of 2 years 2 months

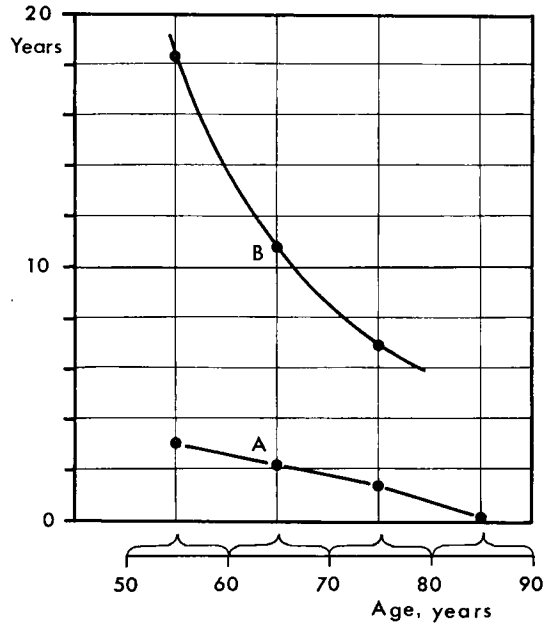

Fig. 10. Graph (A) showing the survival time after amputation of 50 % of the patients in different ten-year age groups (age at time of amputation; deaths prior to follow-up study and survivors at follow-up both taken into account). For comparison, graph (B) indicates the mean (50 %) life expectancies calculated from data obtained from the Statistical Yearbook of Finland for unselected populations in the same age brackets and having male/female compositions equivalent to those in the present series.

was found for this group. The corresponding figures for the 70—79 age group are 49 deaths and 16 survivors with post-amputation periods ranging from 1 to 10 years, and mean life span 1 year 4 months. Of those amputated at an age of 80—89 years, 19 had died and three were alive, three years having passed since the amputation in all three cases. For the amputees of this group, the cumulative distribution analysis gives a mean life span of only about one month. The longest postoperative survival time noted among those who were still alive at the time of follow-up examination was not exceeded by the final life span of any individual in the respective age group, except for one case in the 80—89 year group, in which the patient had lived for 4.5 years after the amputation.

It is evident from Fig. 10 that the life expectation of those subjected to amputation at ages between 50 and 60 years was shortened by about 15 years and that of the patients whose amputation occurred at an age between 60 and 69 years, by nine years. In the age group of 70—79 years and presumably also in that of 80—89 years, the shortening of life expectation seems to be 5—6 years, when compared with an equivalent, unselected population.

In Table 19, a comparison has been made between those who died in the hospital, those who died later, and the patients who survived the amputation by more than three years, and an additional group of all cases with fatal termination during the period of observation. Both sexes are about equally represented in all groups, except that men are relatively more numerous among those whose survival time was longer than three years, though not at a statistically significant level. But on comparison of these survivors with the groups of patients who died in the hospital and those who died later, statistically highly significant differences ($P < 0.001$) are noted in their mean age at amputation in every instance. Those who died in the hospital were older, on an average, by 2.1 years than those who died later, and 7.9 years older than the three-year survivors. Patients older than 70 years at the time of amputation account for about 1/4 (24 %) of those who survived more than three years and for about one-half (50—57 %) of the other groups, which amounts to a statistically highly significant difference ($P < 0.001$). No statistically significant differences were elicited from the number of instances in which haemoglobin values over or under 12 g per 100 ml occurred in the different groups. In the entire series, 59 % of the patients had haemoglobin values lower than 12 g, indicating anaemia. The frequency of diabetes was fairly equal in all groups, but angina pectoris occurred onlv

half as often in the three-year survivor group as in the other groups, the differences being statistically highly significant ($P < 0.001$). No statistically significant differences are noted in other symptoms of occlusion, in hypertonia, or in the distribution of different types of occlusion between the groups.

All the patients who died in the hospital had had their extremity amputated at the thigh. The percentage of lower leg amputees is accordingly higher among those who died later and among the three-year survivors than among the hospital deaths. The group of three-year survivors also contains a greater number of bilateral amputees than the group of those who died earlier. All these differences are statistically almost significant ($P < 0.05$).

Among those who died in hospital, a good general condition was recorded in two cases (4 %) only, while a corresponding assessment has been made in nearly one-third (30—32 %) of those who died later or who survived longer than three years, the differences being statistically almost significant ($P < 0.05$). A poor general condition was noted in about two-thirds (62 %) of those who died in the hospital but only in about every eighth (12 %) of the three-year survivors. The differences between this group and the group of later deaths as well as that between the three-year survivors and all deaths combined are statistically highly significant ($P < 0.001$).

In 179 of the 219 amputees, amputation at the lower leg or thigh was the sole operation, whereas digital amputation, sympathectomy or other operations immediately preceded the leg amputation in the rest. The preoperative treatment in these 179 cases had an average duration of 4.4 days; 48 % of them were operated within 1—3 days after admission to the hospital, 80 % within 1—6 days and all 179 within 12 days.

b) Rehabilitation of the follow-up patients

At the time of the follow-up study, 57 patients of the series were alive and 38 of them (67 %) were subjected to follow-up examination. The examination revealed (Table 20) that 18 patients (47 %) walked with a prosthesis and six (16 %) on crutches; six examinees (16 %) were wheel-chair patients and eight (21 %) were confined to bed. These latter were on an average 10.9 years older than the prosthesis users, the difference being statistically almost significant ($P < 0.05$).

The patients able to walk included 12 % bilateral amputees and 58 % wheel-chair and bed patients combined, with a statistically almost

Table 19. Comparison of the groups of patients who died in hospital, later, and altogether, and of those who survived three years after amputation.

	Patients lost						Patients surviving three years	
	in hospital		later		altogether			
	53 cases		*74 cases*		*127 cases*		*50 cases*	
	Number	%	Number	%	Number	%	Number	%
Men	28	*53*	42	*57*	70	*55*	35	*70*
Women	25	*47*	32	*43*	57	*45*	15	*30*
Mean age, years	71.4		69.3		70.3		63.5	
Patients over 70 years	30	*57*	37	*50*	67	*53*	12	*24*
Hb over 12 g per 100 ml	21	*40*	18	*24*	39	*31*	17	*34*
Hb less than 12 g per 100 ml	25	*47*	42	*57*	67	*53*	32	*64*
Blood pressure over 160/100 mm Hg	32	*60*	50	*67*	82	*65*	26	*52*
Diabetes	13	*26*	21	*28*	34	*27*	11	*22*
Angina pectoris	15	*28*	21	*28*	36	*28*	7	*14*
Apoplexy	12	*23*	13	*17*	25	*20*	7	*14*
Intermittent claudication	28	*53*	47	*63*	75	*59*	32	*64*
More than one symptom of occlusion	16	*30*	22	*30*	36	*28*	13	*26*
No symptoms of occlusion	12	*23*	17	*23*	29	*23*	18	*36*
Occlusion in pelvic region	23	*43*	22	*30*	45	*35*	17	*34*
Occlusion in femoral region	15	*28*	26	*35*	41	*32*	16	*32*
Peripheral occlusion	13	*25*	22	*30*	35	*28*	14	*28*
Amputation at thigh	53	*100*	74	*100*	127	*100*	46	*92*
Amputation at lower leg	–		6	*8*	6	*9*	4	*8*
Bilateral amputation	8	*15*	14	*19*	22	*17*	14	*28*
General condition at amputation – good	2	*4*	22	*30*	24	*19*	16	*32*
– fair	15	*28*	30	*40*	45	*35*	25	*50*
– poor	33	*62*	20	*27*	53	*42*	6	*12*

significant difference ($P < 0.05$). Of the bilaterally amputated prosthesis users, two had pylons in their upper leg stumps and the third had lower leg and upper leg stump prostheses. Pylons had also been made for the two bilaterally amputated wheel-chair patients but had been used a few times only.

Only two of the prosthesis walkers (11 %) had visited the rehabilitation department for walking exercise and rehabilitation, while the others had taught themselves to walk at home after receiving some instructions at the prosthesis workshop. Attempts had been made among the unilateral upper leg amputees who were under institutional care, to make two wheel-chair patients and two bed patients walk on crutches, but without success. One of the crutch walkers had been hospitalized in a rehabilitation institution for two weeks after apoplexy and had then learned to walk on crutches. In connection with the follow-up examination, prostheses were recommended to four of those walking on crutches. No essential difference was noted in the occurrence of diabetics among the walking and non-walking examinees, but cardiac insufficiency and cerebral circulatory disturbances were more common among the latter.

Table 20. Comparison of 38 patients subjected to follow-up examination, classified according to their ability to move.

	Prosthesis walkers *18 cases*	Walking with crutches *6 cases*	Wheel-chair patients *6 cases*	Bedfast patients *8 cases*
Men	12 (67 %)	5 (83 %)	4 (67 %)	5 (62 %)
Women	6 (33 %)	1 (17 %)	2 (33 %)	3 (38 %)
Mean age, years	64.9	70.3	71.0	75.8
Unilateral amputations at lower leg	6 (33 %)	2 (33 %)	–	–
Uniteral amputations at thigh	9 (50 %)	4 (67 %)	3 (50 %)	3 (37 %)
Bilateral amputation	3 (17 %)	–	3 (50 %)	5 (62 %)
Walking exercises held	2 (11 %)	2 (33 %)	2 (33 %)	2 (25 %)
Diabetes	5 (28 %)	–	1 (17 %)	2 (25 %)
Angina pectoris	5 (28 %)	2 (33 %)	2 (33 %)	3 (37 %)
Cardiac insuffiency	3 (17 %)	1 (17 %)	2 (33 %)	5 (68 %)
Disturbance of cerebral circulation	–	–	1 (17 %)	2 (25 %)
At work	3 (17 %)	–	–	–
Living at home	7 (39 %)	4 (67 %)	3 (50 %)	–
Living in home for aged	10 (56 %)	–	2 (33 %)	3 (37 %)
Living in nursing home	1 (6 %)	2 (33 %)	1 (17 %)	5 (63 %)

Three of the prosthesis walkers (17 %) went to work. All these were younger than 55 years at the time of examination: a machinist, aged 52.2 years with one extremity amputated at the thigh and the other at the lower leg; an insurance salesman, aged 53.8 years; and a typesetter, aged 54, who had had both extremities amputated at the thigh and who could take the lift to his place of work in the house where he lived. Of the follow-up examinees 14 (37 %) lived at home and 24 (63 %) in institutions.

c) Causes of death

The observation has already been made that the contribution of arteriosclerosis to the basic causes of death was 71 %. This percentage is somewhat lower (66 %) when taken from autopsies than when taken from death certificates written without autopsy (73 %).

Causes of death other than arteriosclerosis were found in 34 cases (29 %) under 33 different headings, which have been combined to form seven larger groups (Table 10, p. 64). The deaths are fairly equally distributed among these groups. The highest percentage (7 %) is that of diseases of the heart other than coronary sclerosis (mostly cardiac insufficiency). However, in about one out of every five autopsied cases, diabetes has been considered the basic cause of death.

As immediate causes of death, cardiac diseases (23 %) and pneumonias (14 %) are commonest. Cardiovascular diseases account for 80 % of the basic and for 72 % of the immediate causes of death; based on autopsies, however, the percentages are lower (66 and 50 %, respectively).

Comments

Consideration of the patients' recovery after amputation reveals that about one out of every five patients died within 14 days of the operation. Still further deaths occurred in the hospital at a later time, and the hospital or primary mortality in the series thus amounts to about one-quarter of all amputees. Series reported by previous investigators (Table 18) show lower amputation mortalities. However, six months after the amputation, the series of Alffram and Holmquist (1961) and Hansson (1964) and the present series already display the same percentage of deaths (31,5—36 %). One of the causes responsible for the comparatively high operative mortality in the present series can be considered to be the fact that most amputations were made at the thigh, which implies a

higher fatal risk than amputation at the lower leg. None of the lower leg amputees died in this series. The patients' age and their preoperative and postoverative treatment also affect the operative mortality. Those who died immediately after operation in the present series had a higher mean age than those who succumbed later. The preoperative treatment had only a mean duration of 4.4 days, whereas Record (1963), for example, recommends 2—3 weeks of such treatment prior to amputation.

The average life span after amputation was 3 years for patients aged 50—59 years and only one month for those between 80 and 89 years. Compared to unselected populations of equivalent age, the life span of the former had been shortened by about 15 years on the average and that of the latter by 4—5 years. Thus no long life expectations can be given after amputation. All possible expedients of vascular surgery and conservative treatment should therefore be applied, at the gangrenous stage at the latest, in order to save the extremity so that the patient may have the chance of continuing a fairly normal life in his home surroundings. It should be noted that according to the follow-up study of the amputees, only one-third of them were able to manage at home, while two-thirds were in institutions. Amputation also causes considerable restrictions of movement; only one half of the patients could move with a prosthesis, as has been noted in general concerning such patients, too. The decisive influence of age in the successful use of a prosthesis has been stressed, e.g. by Schlitt and Serlin (1961), Wolters (1961) and Lindholm (1964a). In the present series, those walking with a prosthesis show a mean age of 65 years, which is nearly 11 years less than the mean age of the patients who were unable to move and confined to bed. It cannot be said on the basis of the present study, to what extent the ability to walk may be influenced by exercise. In addition to age, an important part is played by the height of amputation and by unilateral vs. bilateral amputation.

As regards the causes of death, the observation can be made that 80 % of the patients lost during the period of observation died of cardiovascular diseases and more than two-thirds of a disease due to arteriosclerosis. This is rather common in series of this kind; in the series of Lindholm (1964a), for instance, universal arteriosclerosis was the cause of death in about three-quarters (77.5 %). According to autopsies, about one-third of the deaths in the present series were due to coronary diseases, and nearly the same proportion has been reported by Dale and Jacobs (1962). The mortality of pulmonary embolism in the present series (3 %) was perhaps lower than usual.

X DISCUSSION

In persons older than 50 years, gangrene of the extremities is a common manifestation of arteriosclerosis. However, the basic disease of those subjected to amputation on account of arteriosclerotic gangrene, its gradual development, and the extent of arteriosclerotic changes present in the different parts of the arterial tree, have received little attention. As a consequence, fully relevant observations could not always be found in previous amputation series for comparison with the results obtained in the present study. In such cases, series of patients with arteriosclerosis obliterans or gangrenous patients were used for purposes of comparison, some of whom were amputees or underwent amputation later in most instances.

Arteriosclerosis usually begins to develop earlier and at greater strength in men than in women. This fact is also evident in the present series of 184 patients subjected to lower extremity amputation on account of arteriosclerosis: male patients dominated in a ratio of 3:2, the mean age of the men at amputation was 6.2 years lower than that of the women, and bilateral amputations were about twice as frequent in men as in women.

As a rule, symptoms of occlusion produced by the effects of thrombosis begin to appear in patients with arteriosclerosis only from the age of 50 years onwards (Allen et al. 1962, Sandler and Bourner 1963). In the present series, too, only three patients (2 %) were amputated at an age under 50 years; the mean age of the amputees was nearly 70.

No arteriosclerosis-increasing effect of hypertonia (RR systolic 160 mm Hg or over) and diabetes was displayed in the present series. As regards diabetes, this is probably attributable to the fact that the disease was rather short in duration and of a slight degree, as would be consistent with the clarification of the causality presented, e.g. by Root (1950).

Consideration of the frequency of symptoms of obliteration in various parts of the arterial tree and the extent of arteriosclerotic changes in the corresponding areas, reveals that the commonest symptom of occlusion

(60 %) was intermittent claudication, which was usually the first symptom to become manifest (on an average 2.7 years before amputation) and which became bilateral in most (80 %) of those affected with the symptom. The duration of intermittent claudication and the proportion of bilateral symptoms are consistent with previous observations on intermittent claudication and gangrenous patients, but the incidence is fairly low, owing to the comparatively high proportion of older patients and diabetics.

The arteriosclerotic changes were rather strong in the region of the lower extremities and pelvis, as evidenced by arteriographies and autopsy findings. According to the arteriographies, the changes on the side of the extremity that remained intact were equal in order of magnitude to those observed by Singer (1963) in arteriosclerotic patients with ischaemia of the lower extremities, but the number of multiple occlusions or occlusions obliterating the entire lumen of the vessel was 2—4 times as great on the amputated side. Changes consistent with the arteriographs were found at autopsy. Severe changes in the region of the abdominal aorta occurred in more than one half, and in the common iliac and superficial femoral arteries in about two-thirds of those examined. About one half of the iliac artery occlusions were associated with thrombus. The most notable difference as regards pulsation in the lower extremity arteries was that both pedal pulses were palpable in only three cases (2 %) on the amputated side but in 32 (17 %) on the other side.

Next in commonness to the intermittent claudication symptom were (in about one-quarter) symptoms from the coronary arteries, infarctions beginning to be manifest on the average one year before amputation. According to case histories and electrocardiograms, cardiac infarction was present in about every eighth to tenth patient, in conformity with the frequency observed by Heine (1965) in gangrenous patients. According to the autopsies the number of infarctions was even higher, amounting to nearly one in every three patients (30 %).

Symptoms of occlusion of the arteries branching from the arch of the aorta were somewhat less frequent than those of the coronary arteries, that is, about once in every five cases (22 %). They were mostly (in 19 %) cerebral ischaemic states which had resulted in apoplexy, while only a few patients (3 %) had upper extremity symptoms. Changes of the upper extremity pulsations were likewise rare (2 %). These findings are consistent with the frequencies noted in amputation and arterial occlusion patients (Ratschow 1959, Hansson 1964). The autopsies revealed severe

changes in the common carotid artery and in the arteries in the base of the brain in about one out of every three cases (34 and 29 %, respectively).

Special examinations, which were not made in the present series, would be required to reveal occlusions of the renal arteries (renal arteriography, Howard's test, angiotensin-infusion test). However, it can be said on the strength of normal routine examinations, that about every seventh proteinuric patient (15 %) had hypertonia (RR 160/100 mm Hg or higher). Similary, in every fifth autopsied case (22 %) arteriosclerotic nephrosclerosis and associated hypertonia was present, and in these patients the possibility of renovascular hypertonia has thus to be taken into account, which occurs in about 5—15 % of hypertonics (Poutasse 1959, Howard and Conner 1964). But the changes cannot have been very severe since there were no remarkable disturbances of renal function in any instance. Such relative sparing of the kidneys has been noted, e.g., by Glagov and Rowley (1959). This is confirmed by the fact that no disease of renal origin occurred as a basic or immediate cause of death in any case in the present series.

In the intestinal region only two patients displayed distinct symptoms of obliteration, in addition to which there were ischaemic symptoms suggestive of chronic circulatory derangement of the intestines in five. The angina abdominis symptom occurred in one out of every 25 patients.

Prior to gangrene and to the amputation stage in about one-quarter of the present patients no symptoms of arterial occlusion had been noted. However, absence of symptoms of obliteration does not imply absence of arteriosclerotic changes and obstruction. Thus, for instance, the pulmonary arteries alone were found to be normal in nearly all autopsies and the arteries of the base of the brain in about one-fifth of them, while there was hardly any instance in which the major arteries elsewhere had escaped arteriosclerosis.

Sympathectomy was applied as treatment intended to obviate amputation in about one-third of the cases. In more than one half of these (59 %) it was performed at the gangrene or rest pain phase. Sympathectomy was undertaken in an attempt to restore the blood circulation of the limb, but amputation followed rather soon (within 1.4 to 3.5 months). The results were better after sympathectomy performed at the intermittent claudication phase. In about one-third the extremity was saved, and in the other two-thirds amputation ensued on an average only

after three years. It cannot be said what the fate of the extremities would have been without sympathectomy, but it was not seen to have any harmful effects. Sufficiently early sympathectomy would seem to be beneficial, particularly for peripheral occlusions.

Expedients of vascular surgery intended to prevent amputation were only performed in four cases, with fairly satisfactory results. Amputation of one gangrenous extremity was avoided, and amputation of the other three ischaemic extremities became necessary after 1.5 to 3 years. Among the reports supporting vascular surgery as a suitable measure is that by Taylor (1964) on 120 extremities with indication for amputation, about half of which could be saved.

Amputation at the thigh, particularly when it is bilateral, is a rather highly disabling operation. The present series contains a higher than normal percentage (89 %; cf. Table 14 and 18) of such amputations, and the amputation was bilateral in about one out of every six cases. The high frequency of these amputations was obviously caused by unfavourable experience with amputations at the lower leg; about one half of the lower leg stumps showed wound complications and reamputation was performed in about one-third of them. As in some other amputation series reported (Record 1953, Dale and Jacobs 1962), the results obtained by usual techniques of operation were not satisfactory. Good results imply atraumatic or minitraumatic handling of tissues. Furthermore, the optimum length of the stump was always aimed at in the present series, independent of the vitality of tissues, and this is another partial cause of the wound complications and reamputations. Higher amputation at the lower leg might have been successful in many instances and furnished the advantage which even a shorter lower leg stump has over a stump after amputation at the thigh. According to previous observations, concentration of amputations or of their supervision to a few persons tends to improve the results as regards wound complications and to increase the number of peripheral stumps. Similar principles might have been conducive to more favourable results in the present series, too, considering that the amputations were performed by 55 different surgeons and there was no consistent supervision.

Both operative and hospital mortality were higher than in comparable series as a rule. This is thought to be mainly attributable to the high percentage of amputations at the thigh, which are mostly followed by higher primary mortality than those made at the lower leg (Table 18). In the present series, too, none of the 24 lower leg amputees died at

operation; e.g., according to Harris et al. (1961), lower leg amputees of equivalent age showed a primary mortality of only 6 %. Other causes that have to be considered include inadequate preoperative treatment; it should be noted that more than one half of the patients (59 %) were anaemic (Hb less than 12 g per 100 ml) and that the mean duration of preoperative care was 4.4 days against 2—3 weeks as recommended, e.g., by Record (1963).

As with observations made in series of general surgery patients (Andersen et al. 1965) and of amputations (Veal 1938) in general, the operative and hospital mortality was dependent on the patients' age. Those who died in the hospital had a mean age 8 years higher than those who survived the amputation for three years. The former also showed a higher frequency of coronary diseases.

In persons subjected to amputation on account of vascular insufficiency, Thompson et al. (1965) observed a higher rate of postoperative complications than in those whose amputation had been caused by malignant tumour or accident, and also a higher rate after amputation at the thigh than at the lower leg. They think that particularly after amputation at the thigh, postoperative anticoagulant treatment is worth considering. In the present series its appropriateness seems to be corroborated by the fact that autopsy revealed about one-quarter of the deceased patients to have a thrombus of the coronary arteries as the basic cause of death, and obliterative thrombosis of the common iliac arteries, for instance, occurred in about one-half of those examined.

The walking ability after amputation is perhaps most strongly affected by age (Schlitt and Serlin 1961, Lindholm 1964a). In the present series, too, the mean age of the prosthesis walkers was 65 years, while that of the amputees confined to bed was ten years higher. The height of amputation has an influence, too, since all six lower leg amputees were able to walk, but no more than about two-thirds of the patients subjected to amputation at the thigh and about one-quarter of the bilateral amputees were walkers. Age also plays an essential role in respect of working ability. The three amputees who went to work were all younger than 55 years at the time of follow-up examination.

The extent of arteriosclerotic changes is also reflected by the causes of death, 71 % of the deceased having a disease due to arteriosclerosis as the basic cause of death, which is virtually the same figure as stated by Lindholm (1964a), 77.5 %.

After amputation, the arteriosclerosis progresses at a rather rapid rate

and amputees do not survive for very long. As in the series of Hansson (1964), nearly one out of every two patients (41 %) was dead one year later, and the remaining life expectancy of those amputated at an age between 50 and 59 years was about 3 years, i.e., 15 years less than for a normal population of equivalent age. The average life span of those subjected to amputation when they were 80—89 years old was only one month, falling short of the normal life expectancy by 4—5 years.

The observation can indeed be made that with the continuous increase of the average life span, gangrene due to arteriosclerosis also increases and, with unchanged indications of operation, the amputations increase in frequency. In the case of persons subjected to amputation on account of arteriosclerosis, the diffuse changes associated with their basic disease and especially their high age make normal life possible in rare instances, while the majority (two-thirds in the present series, 91.9 % in that of Lindholm, 1964a) have to be placed in an institution or constant home care after amputation. Accordingly, all possible care in obviating amputation should be introduced at the gangrenous phase at the latest. The situation might be changed either by revising the indications of amputation so that part of the amputations could be avoided by means of vascular surgery, of which fairly favourable experience has been gained (Linden 1962, 1967, Morris et al. 1962, Lebedev 1964, Taylor 1964, Slätis 1965, Spencer and Winslow 1965), or by rendering the conservative treatment more efficient (Foley 1957, Heine et al. 1964).

That expedients of vascular surgery were applied to rather a limited extent in the present series is revealed by a comparison with the series of Thompson Jr. et al. (1964), comprising 222 patients with vascular insufficiency who were subjected to amputation between 1952 and 1963. Of these, 31 % had undergone lumbar sympathectomy and endarterectomy, or a grafting procedure on the extremity involved, before amputation in 16 %. In the present series, the corresponding figures are: sympathectomy performed in 35 % of the cases and some expedient of vascular surgery in 2 % only. Even with the present indications of amputation, the patients' position may be improved merely by amputation technique. If it is possible to increase the proportion of the less disabling lower leg stumps and in the most favourable case that of the even more peripheral stumps, the operative mortality will decrease and the patients' chances of rehabilitation will improve.

XI SUMMARY AND CONCLUSIONS

In the present series, comprising 184 patients subjected to amputation at the lower leg or at the thigh on account of arteriosclerosis, the gradual development of arteriosclerosis has been studied on the basis of the symptoms of occlusion shown prior to amputation, of examinations at the time of amputation and of death certificates and autopsies. Attention has furthermore been paid to sympathectomy as a treatment precluding amputation, to the healing of the leg stump, to recovery after amputation and to the remaining life span.

Of the present patients, 97 were operated at the Clinic for Orthopaedics and Traumatology of the University Central Hospital, Helsinki, in 1950—1963, and the amputations on 87 patients were performed in the former Hospital of the Finnish Red Cross during the period 1950—1959. The mean age at amputation was 68.7 years, and men outnumbered women in a ratio of 3:2.

8 % of the patients were left with lower leg stumps and 92 % with upper leg stumps. Every fifth patient underwent bilateral amputation.

At the time of the follow-up study, 127 patients (69 %) had already died and 57 (31 %) were alive, of whom 38 (67 %) were subjected to follow-up examination.

Symptoms of arterial occlusion had occurred prior to amputation in about three-quarters of the series. The commonest symptom was intermittent claudication (60 %), while angina abdominis was most rarely encountered (4 %), angina pectoris was present in one out of every four patients (26 %), cerebral apoplexy in one out of every six (17 %) and symptoms of occlusion in the region of the neck and shoulders in about one out of every twenty. About one-fourth had two or several simultaneous symptoms of occlusion. The intermittent claudication symptom mostly appeared first, on an average 2.7 years before amputation.

At the time of amputation, 87 patients were examined by electrocardiography, which revealed changes in 69 %. Arteriographic exam-

ination of 21 patients showed ample changes, which were more frequent in the region of the pelvis and lower extremities on the side of the amputated extremity than on that of the extremity left intact. In respect of pulsation, the most notable differences between the amputated and contralateral extremity were observed in the most distal and the most proximal pulses of the extremity. The possibility of renovascular hypertonia was considered to exist in about 15—22 % of the patients.

Autopsies showed the pulmonary arteries to have been almost entirely spared from arteriosclerosis, only 11 % of the autopsies revealing slight changes. The arteries of the base of the brain were also normal in about one-fifth of the cases. On the other hand, there were hardly any large arteries of the pelvic region or superficial femoral arteries which had not been affected by arteriosclerosis; they presented severe changes in about 50—70 %, and cardiac infarction was established in 30 %.

Sympathectomy had been performed on 93 extremities of 64 patients, and 78 of these extremities (84 %) were subsequently amputated. Sympathectomy was undertaken on the side of the amputated extremity at the intermittent claudication stage in 32 cases (41 %) and at the gangrene or rest pain phase in 46 (59 %). In the case of all the 15 extremities saved, the sympathectomy had been made at the intermittent claudication stage, and these patients had no occlusion in the pelvic region. Sympathectomy was not seen to have any effect on the healing of the wound after amputation.

The wound complications encountered were due to lowered vitality of the tissue and to local factors in about equal proportions, whereas the contribution of infection was smaller. The height of occlusion, however, exerted an influence in that the upper leg stump healed better when a peripheral occlusion was involved than in the case of an occlusion at a higher level.

The primary operative mortality after amputations was 21 %. All those who died of the operation had been amputated at the thigh. The deaths that occurred within one year account for 41 % of the patients. 71 % of all deceased patients had some disease due to arteriosclerosis as the cause of death.

Of 38 patients subjected to follow-up study, 47 % walked with a prosthesis and 21 % were confined to bed. The latter were, on an average, 10.9 years older than the prosthesis users.

The following conclusions can be drawn on the basis of this study:

1. Clinical symptoms of occlusion occurred prior to amputation in three-quarters of the patients, the commonest among them (in 60 %) being intermittent claudication, which had usually first appeared, on an average, 2.7 years before amputation. Obliterative symptoms from the coronary arteries occurred in about one-quarter and symptoms of cerebral ischaemia in about one-fifth of the cases. Angina abdominis occurred most rarely (4 %).

2. Examinations of pulsation at the time of the first amputation revealed on the amputated side a higher frequency of occlusions in the pelvic region, and the pedal pulses were absent in almost every instance, whereas they were palpable on the contralateral side in about one out of every five cases. According to arteriography, the changes in the pelvic region and in the extremities were consistent with the numbers encountered in patients with ischaemia of the extremities, but multiple occlusions and occlusions filling the entire lumen were 2—4 times more frequent on the amputated side than on the side which was left intact. On the evidence of electrocardiograms, as on that of the case histories, cardiac infarction was seen to be present in about one out of every ten patients and the possibility of renovascular hypertonia existed in about one out of every twenty.

3. At autopsy, nine out of ten patients showed no arteriosclerotic changes of the pulmonary arteries, and the cerebral arteries were normal in about one-fifth. In the highest, and about equal, number (1/2 to 2/3) there were severe changes of the coronary arteries, abdominal arteries and arteries of the pelvis. No normal findings at all were made in these respects.

4. Lumbar sympathectomy had been performed on about one-third of the patients. In more than one-half of the cases it had taken place when the disease had already progressed to the gangrene or rest pain stage and it was then fairly soon followed by amputation (after 1.4 to 3.5 months). The best results were recorded on sympathectomy made at the intermittent claudication stage when the occlusions in the extremities were peripheral in location.

5. Wound complications were mainly caused by wrong assessment of the vitality of tissues, local factors, or incorrect amputation technique, while infections contributed less to their number. Upper leg stumps healed better in cases involving peripheral rather than higher occlusions.

6. Of the patients subjected to follow-up examination about one-half were prosthesis users. The average remaining life span after amputation was only about 1/5 to 1/4 of the life expectancy of an unselected population of equivalent age. The cause of death was due to arteriosclerosis in 71 %, and the commonest cause of death elicited by the autopsies (30 %) was attributable to sclerosis of the coronary arteries.

ERRATA

Page	8	Line	1u.	for: medical	read: medial
	9		9u.	lower leg	upper leg
	10		6u.	polyaethiology	polyaetiology
	24		6	The exponent in e^{-t^2} is out of line.	
	37		15	for: Tala (1966)	read: Tala et al. (1966)
	41		12u.	slightly more than one-quarter (28 %).	about one-quarter (23 %).
	42		3u.	state	states
	48		20	Babbeley et al.	Baddeley and Fulford
	53		2u.	hypertension	angiotensin infusion
	57		15u.	artery	aorta
	61		13	five cases (17 %)	four cases (13 %)
	65		5	reports	report
	68		5	(Caption of Table 12): 78	93
	71		9	Eraklis and Brownell	Eraklis and Wheeler
	73		1	enumerates	enumerate
	73		12	Eraklis and Brownell	Eraklis and Wheeler
	73		3u.	seevrity	severity
	82		14	60–69	60–69 year
	83		1	70–79	70–79 year
	84		16u.	219 amputees	219 amputations
	91		8	had hypertonia . . . . . or higher).	with hypertonia (RR 160/100 mmHg or higher) presented proteinuria not accounted for by pyelonephritis.
	106			Solonen, K. A. 1961	
				Brances	Braces

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