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Post mortem coronary arteriography in Nigerians: a radiological review

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Summary

The findings in 147 unselected consecutive post mortem coronary arteriograms carried out at the University College Hospital, Ibadan, are analysed. The so-called third primary division of the left coronary artery was noted in 35% of cases which is much less than the 74% quoted for the South African Bantu. In atrial blood supply, there was a definite predominance of one coronary artery. The predominant artery to both atria originated in one-third of cases from the right coronary, in another third from the left coronary and in the remaining third from both coronary artery systems respectively. Only in eight instances was atherosclerotic disease noted and even then, this was of the mildest degree with only minimal and slight intimal irregularity. This further explains the known rarity of myocardial infarction as a cause of death in the Nigerian. The study forms a useful basis for the baseline anatomy of the coronary arteries in Nigerians as a prelude to *in vivo* studies in the cardiomyopathies.

Résumé

Les résultats de 147 autopsies successives portant sur l'artériographie coronaire faites au University College Hospital, Ibadan, Nigeria sont ici analysés. La présence de ce que certains definissent comme la troisième division primaire de l'artère coronaire gauche a été notée dans 35% des cas ce qui est bien moindre que les 74% relevés chez les Bantous d'Afrique du Sud. En ce qui concerne le sang fourni aux oreillettes, on remarque la prédominance certaine d'une des artères coronaires. L'artère la plus importante pour les deux oreillettes provient dans un tiers des cas de la coronaire droite, dans le second tiers de la coronaire gauche et dans le dernier tiers des deux systèmes coronaires. L'artériosclérose a été remarquée dans huit cas seulement et même pour ces cas, l'artériosclérose est très peu marquée avec une légère irrégularité du lumen. Ce qui tend à expliquer la rareté reconnue de la'infartus du myocarde comme cause de mort ches les Nigérians. Cette étude constitue une base utile pour une étude anatomique des artères coronaires chez les Nigérians en tant que préliminaire à une étude *in vivo* des maladies myocardiques.

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Introduction

Post mortem coronary angiography is not a new technique. Spalteholz (1924) produced an authoritative monograph on the subject by improving on the method of Gross (1921). He quotes the first study having been carried out in 1899 by Baumgarten. It is to Schlesinger (1938, 1940) that much credit should be attributed for the most widely used technique which combines a manometric method of filling of the coronary arteries with radiography. His work has served as a pivot for comparative studies by several authors (Di Guglielmo & Guttadauro, 1952; Rodriguez & Renner, 1957; Laurey & Woods, 1958; Pepler & Meyer, 1960; James, 1962; Paulin, 1964; Fulton, 1965; McNamara *et al.*, 1971; Barmeyer & Reindell, 1971).

The first coronary arteriogram *in vivo* in animals was performed by Routshoi (1933) and in man by

Radner (1945). *In vivo* coronary arteriography has now become a routine procedure in many centres (Di Guglielmo & Guttadauro, 1952; Baroldi, 1965, 1966; Weidner *et al.*, 1965; Proudfit *et al.*, 1966; Proudfit, Shirey & Sones, 1968; Judkins, 1968; Abrams & Adams, 1969 a,b; Baltaxe *et al.*, 1969; Begg *et al.*, 1969; Bjork, 1969). This has made coronary artery surgery more precise (Windsor, Sanahan & Deacon, 1971).

Materials and methods

The report is based on an analysis of the first 147 out of 300 consecutive unselected post mortem coronary arteriograms carried out at the University College Hospital, Ibadan in 1965–66. The ages varied from 8 months to 65 years and included a full-term still-born foetus. Twenty-five per cent of the 300 had cardiac disease but the rest died of non-cardiac causes. At the time of the examination, the causes of death were not known in order to eliminate bias.

The method used was a modification of the Schlesinger technique as adapted by Rodriguez *et al.* (1957, 1964). Rodriguez himself came to Ibadan to demonstrate his method prior to the study in 1965.

The injection medium was a radiopaque paste consisting of a mixture of powdered barium sulphate, potassium iodide and gelatin produced in green and red. The green paste was injected into the left coronary arterial system and the red into the right coronary artery. The mass becomes solidified at room temperature by the addition of formalin. The injection technique uses a special manometer which delivers the contrast medium at a pressure of 200 mm of mercury maintained for 5 min. In this way, vessels of arteriolar size as small as 40 μm in diameter can be identified. The left coronary artery is injected first; a radiograph is taken (Fig. 1). then the right coronary artery is injected to complete the filling of the coronary arterial systems. Thereafter, a pair of stereoscopic radiographs is taken by rotating the heart five degrees to either side before the film is exposed (Fig. 2). Ilford fine grain non-screen films are used for improved radiographic detail. The heart is then dissected according to the technique described by Rodriguez & Reiner (1957) and a final radiograph (Fig. 3) of the 'unrolled' heart is taken. Serially cut slices of the ventricular muscles are also X-rayed (Fig. 4). The large and medium-sized

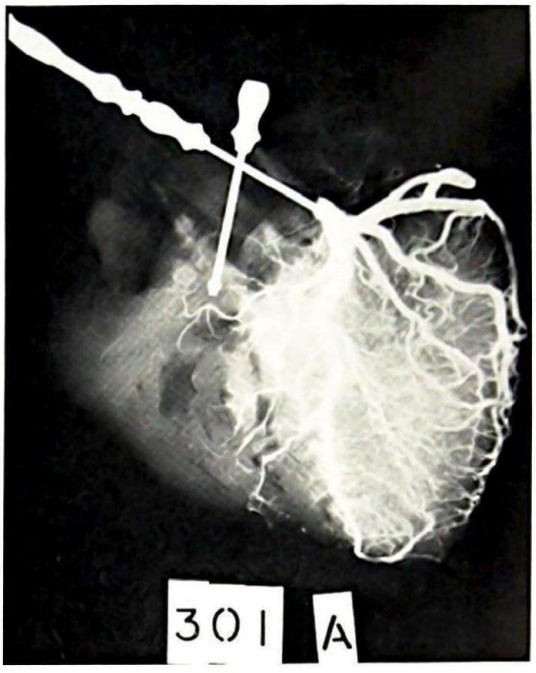

FIG. 1. The left coronary artery (LCA) is injected first. Note cross-filling of vessels in the right ventricle indicating the routes of intercoronary anastomosis which in this instance is classified as slight. The next stage is to fill the right coronary artery.

vessels are dissected and saved for further histological examination. The immersion method of radiography employed by Fulton (1965) was not used by us.

The following radiological parameters were assessed.

(1) *Arterial diagram.* A sketch of the major coronary arterial distribution to the ventricles and atria was made (Fig. 5). The variations in anatomical pattern was thus obtained paying particular attention to the position of the so-called 'U'-turn (James, 1961, 1962), and the blood supply to the atria.

(2) *Anastomosis.* The sites of anastomoses were noted. The extent of intercoronary anastomosis was studied and graded as (i) slight (ii) moderate and (iii) complete, using the degree of filling of the right coronary system when only the left coronary was injected (Table 1).

(3) *The predominance* of the distribution of one coronary artery system over the other was observed using the criteria of Schlesinger (1940) (Table 2).

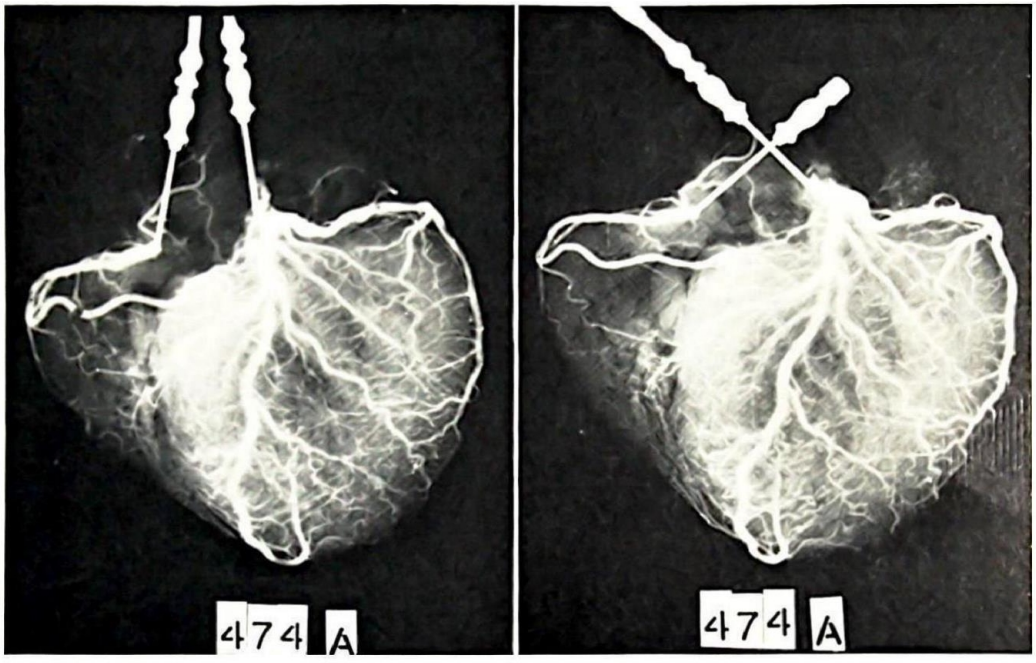

FIG. 2. Represent a pair of stereoscopic radiographs of the fully filled coronary artery system. In this case, the whole coronary artery system was filled by injecting the left coronary artery alone. This is classified as a case with complete intercoronary anastomoses (see Table 2). No pathology detected.

FIG. 3. Radiograph of the injected 'unrolled' heart cut according to the method of Rodriguez & Reiner (1957) Numerous areas of intercoronary and homocoronary anastomoses are present.

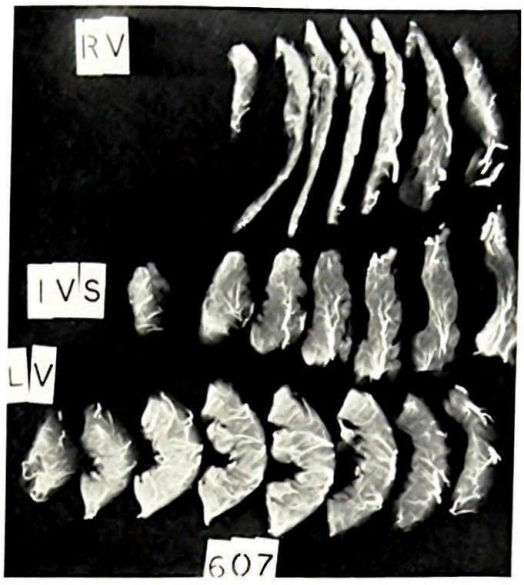

FIG. 4. Radiographs of cut sections of the previously injected heart showing the terminal vessels within the myocardium and the anastomotic pattern. RV, Right ventricle; IVS, inter-ventricular septum and LV, left ventricle.

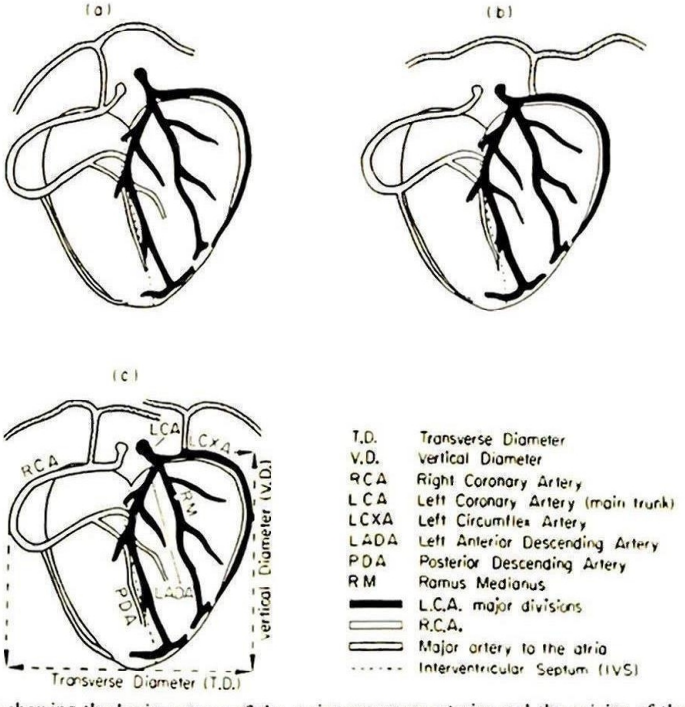

FIG. 5. Sketches showing the basic pattern of the major coronary arteries and the origins of the arteries to the atria. The latter shows three distinct patterns (a–c). In (a), (one-third of cases), the RCA is predominant in atrial blood supply; in (b) the predominant atrial artery originates from the LCA (also in one-third of cases); and (c) is a mixed supply (also in one-third of cases)— see text.

TABLE 1. Extent of inter-coronary anastomosis

	Nil	Slight	Moderate	Complete	Total
No. of cases	39	66	23	19	147
Percentage	26	45	16	13	100

The table shows a 74% incidence of intercoronary anastomoses as demonstrated by the degree of filling of the RCA system when only the LCA system was injected.

TABLE 2. Predominance of coronary artery circulation

	RCA predominance	LCA predominance	'Balanced' circulation	Total
No. of cases	11	33	106	150
Percentage	7	22	71	100

Right or left coronary artery predominance was also dependent on whether the posterior descending artery originated from the RCA or LCA respectively.

TABLE 3. Coronary artery diameter

Diameter (mm)	No. of cases		
	RCA	LADA	LCXA
1·0	5	1	5
1·5	4	4	6
2·0	16	7	12
2·5	13	2	23
3·0	40	29	49
3·5	13	14	12
4·0	44	62	32
4·5	2	12	2
5·0	10	12	10
5·5	0	1	0
6·0	0	2	0
	147	147	151

No correction has been made for magnification which is a factor of 10–20%.

The LADA is of a larger mean diameter, 88% being from 3 to 5 mm, while for the RCA or LCXA 85% vary from 2 to 4 mm in diameter. In the case of the LCXA in four instances there were two main trunks of equal calibre instead of one.

There was either a (i) right or (ii) left coronary predominance or (iii) a balanced circulation.

(4) *The diameters* of the main stems of the right and left coronary arterial systems was measured in millimetres at their proximal 1 cm (Table 3).

(5) The number of the major primary and secondary sub-divisions of (4) were enumerated.

(6) The transverse and vertical dimensions of the ventricular arterial 'skeleton' were measured from the radiograph (Fig. 5c) in cm at their widest portions.

(7) The site and extent of any pathological changes in the arterial lumen were noted.

Results

Right coronary artery (RCA)

The course of the main trunk of the RCA is in the majority of instances fairly constant and conforms to the description of several authors (James, 1961; Paulin, 1964; Di Guglielmo & Guttadauro, 1952; Abrams & Adams, 1969). This main trunk runs in the right atrio-ventricular sulcus, first anteriorly as far as the right cardiac border (or acute margin) from where it turns posteriorly to its termination at the crux. This termination is marked in arteriograms by a 'U'-turn, first described by James (1962). The crux is the confluence of the inter-atrial and inter-ventricular septa on the one hand and the atrio-ventricular sulci on the other and this corresponds to the partition between the mitral and tricuspid orifices. This 'U'-turn could be identified in 111 of 147 instances (75·5%) in our series. It was absent in eleven instances (7·5%) and its determination equivocal in twenty-five instances (17%) in three of which the RCA had divided proximally into two branches before terminating at the crux. Paulin (1964) could not determine the 'U'-turn in 20% of his series.

The other branches were variable in calibre, course and site of origin except the branch to the acute margin, which was most often almost as large as the RCA itself and may at times be its direct continuation. The dominating branch to the posterior inter-ventricular groove, i.e. the posterior descending artery (PDA) took origin from the RCA in 7% of cases. The RCA is sometimes called the right circumflex coronary artery because of its analogous position with respect to the left circumflex coronary artery. The first branch of the RCA described by others (Paulin, 1964) as the fairly constant right

pulmonary conus branch was found in our series not to be always so constant, its pride of place being usurped by the atrial artery of which it was sometimes seen to be a branch. In other instances, the region of the pulmonary conus was not supplied by this vessel but by a plexus of many tiny twigs.

Left coronary artery

The left coronary artery main trunk divides into two major branches (i) the left anterior descending artery (LADA) and (ii) the left circumflex coronary artery (LCXA). The former is the more constant of the two, running in the inter-ventricular sulcus to end slightly to the right of the cardiac apex to which it sends terminal branches. It sends septal branches to the anterior part of the inter-ventricular septum, the most constant of which is its first septal branch which may be as big as the main artery itself. Terminal twigs of this branch is a source of inter-coronary anastomoses with the RCA through the papillary muscles in the right ventricle. In seventeen cases (11·5%) the LADA terminates by bifurcating into an inverted 'Y' shape to anastomose with the vessels on the right and left sides of the cardiac apex.

The left circumflex coronary is a more variable vessel. On four occasions, it was made up of two vessels of equal diameter instead of one. It runs in the left atrio-ventricular sulcus as far as the obtuse margin where its main trunk continues along the left cardiac border to its termination at the cardiac apex. In four instances (2·6%) this so-called branch to the obtuse margin was a minor twig. Sometimes, it sends a branch to the region of the RCA in the posterior inter-ventricular groove. This was observed in thirty instances (20%).

In our material, the area of the left ventricle between the LADA and left cardiac border was supplied by branches from both the LADA and LCXA. This was often by a big vessel—the ramus medianus (Bianchi, 1904) or ramus diagonalis (of Crainicianu, 1922) which ran obliquely or diagonally across from the region of the bifurcation of the left coronary artery trunk or more often from the LADA and least often the LCXA. The variations were so numerous that an analysis was pointless.

Third coronary artery or conus artery

The so-called third coronary artery or conus artery which is a second RCA originating by a separate ostium from the aortic bulb which was seen in 50% of both Schlesinger's (1949) and James' (1961) material, was not observed by us.

Anastomoses

Stereoscopy and radiography of the 'unrolled' heart (Fig. 3) as well as those of the serially cut sections of the ventricular walls (Fig. 4) substantially contributed to the identification of anastomoses. The anastomoses were of two types:

(i) between the terminal branches of the right and left coronary arterial systems (inter-coronary anastomoses) observed in 74% of the series with this figure broken down as in Table 1; and

(ii) between finer twigs of the vessels of the same side (homolateral coronary anastomoses).

In respect of the latter, these anastomoses were more evident in the left ventricle, where they were found in 100% of cases between the terminal twigs of the left major coronary artery subdivisions. In the former, the anastomoses were very often seen in (i) the upper part of the inter-ventricular septum in the region of the crux, between the mitral and tricuspid openings, (ii) the apical region mostly to the right of the septum and (iii) in the lower part of the inter-ventricular septum coinciding with the region of the atrio-ventricular node. Although no special study was made of the variations of the A-V node artery, its origin from the apex of the 'U'-turn according to James (1962) was confirmed in every instance in which the 'U'-turn could be identified.

Anastomoses in the wall of the atria will be discussed separately. The left anterior descending artery at the apex often typifies the two types of anastomoses—providing anastomoses with the RCA to the right of the inter-ventricular septum (VS) and with its own branches or those of the LCXA or ramus medianus to the left of the IVS. Extracardiac anastomoses were not studied.

Unilateral coronary artery predominance/balance of arterial circulation

Table 2 shows the result of determining which artery dominated the topographic supply of the ventricles. A right-sided coronary arterial predominance was noted in 7%, a left-sided predominance in 22% and a 'balanced' circulation in 71%. The doubtful significance of such a system of classi-

fication *vis-à-vis* the myocardial blood supply will be discussed further in this paper.

Diameters of the arterial 'skeleton'

Of the vertical and transverse diameters of the injected part, the latter was more often the greater (Fig. 5c). This was even more so in the enlarged hearts. The transverse diameter ranged from 48 to 140 mm and the vertical diameter from 35 to 130 mm. In the presence of gross cardiomegaly, there was often observed a wider separation between individual vessels. These measurements of the topography of the coronary arterial distribution constitute a useful index of ventricular size and indirectly cardiac size even though it is inaccurate for assessing atrial size.

Coronary artery diameter

The results are as in Table 3, without correction for magnification which is of the order of 10 to 20%. In the majority of cases (85%) the measurements for the RCA or LCXA vary from 2 to 4 mm while the LADA tends to be larger, varying from 3 to 5 mm in 88%.

The blood supply to the atria

With the exception of a few reports, the literature on post mortem coronary arteriography is rather silent on atrial blood supply, most concentrating on the blood supply to the ventricles. In this study, atrial arteries were assessed in the first 100 cases and found to follow a definite pattern in which the right or left coronary artery was dominant in atrial blood supply (Fig. 5 a–c). The blood supply to both atria originated from (i) the RCA alone in one-third of cases (Fig. 5a), (ii) the LCXA alone in another third (Fig. 5b) and (iii) both of these arteries in the remaining third (Fig. 5c). The vessel of supply to the atria often arose from the right or left coronary arteries as the second branch. It is in effect the same vessel as the artery to the sino-atrial node (James & Burch, 1958; James, 1961; Paulin, 1964; Romhilt, Hackel & Estes, 1968).

In the third of the cases in which the atrial blood supply was derived from both coronary arteries (Fig. 5c) three modes of presentation could be observed. (a) The RCA is the major supplier of both sides with tiny twigs contributed from the LCXA. This was noted in fifteen cases (43%). (b) The LCXA is the predominant artery to both atria supplemented by minor twigs from the RCA in seven cases (20%) and (c) there is an equal contribution from RCA and LCXA in thirteen cases (37%).

In three instances, there were two separate atrial arteries—proximal and distal—arising from the RCA with supplementary twigs from the LCXA. In another two cases, the atrial artery originated principally from the LADA with the LCXA contributing additional minor twigs to the left atrium. In all instances, a rich anastomotic network could be visualized in the atrial walls.

Pathological findings

Artherosclerotic narrowing of Grade 1 type, i.e. minimal intimal irregularity and narrowing (Grade 2 according to the classification of Proudfit *et al.*, 1966) were noted in eight of 147 cases (5%). Of these, three were females aged 50, 60 and 65 years and one female aged 31 years was a known diabetic.

In three instances, microaneurysms of the coronary arteries were noted as follows: (1) female aged 50 years, died of hepatoma, had aneurysm of proximal RCA, (2) male aged 57 years had two aneurysms on either side of distal LADA; cause of death was biventricular endomyocardial fibrosis, and (3) female, aged 28 years with aneurysm of proximal LCXA; cause of death was tetanus.

Discussions

The basic anatomical pattern and vessel calibre that has been observed from coronary artery injection studies in Caucasians are similar to the present findings in Nigerians in many respects.

The variations that have been reported in Caucasians are also found in varying degrees in the Nigerian series. The probable exception to this anatomical pattern is the absence of the third coronary artery. This artery was noted in 50% of cases by both Schlesinger, Zoll & Wessler (1949) and James (1961).

The first primary branch of the left coronary artery or ramus medianus (Bianchi, 1904) or ramus diagonalis (Crainicianu, 1922) or the third primary branch of Brink (1949), was found in 35% of our 147 cases. This is much less than the 74% quoted for the South African Bantu by Brink (1949) and Pepler & Meyer (1960) but similar to their 38% incidence in South

African whites. This finding led the former to assign a protective role to this vessel in an attempt to explain the low incidence of myocardial infarction in the Bantu, claiming that it acted as an additional source of intracardiac anastomosis in the event of coronary occlusive disease. Our study did not support this contention but agrees with Singer (1959) who found no significant difference in the incidence of this vessel among the black, white and 'coloured' South Africans.

In regards to the so-called predominance of the coronary artery system, our findings support the view that this is an entirely misguided concept (James, 1961; Paulin, 1964). This predominance of the right or left coronary arterial system should be regarded as a variation of the distribution pattern as it bore no relationship to the total blood supply delivered to the myocardium. This point was not appreciated by Schlesinger (1940) who initiated this terminology, nor by Di Guglielmo & Guttadauro (1952). This has, however, been confirmed by the perfusion studies of Vasko, Gutelius & Sabiston (1966). Also in this study, predominance was found to depend on whether the posterior descending artery originated from either the right or left coronary artery—a point that was first noted by Bianchi in 1904 (according to James, 1961). In this series, left predominance was more prevalent than right in a ratio of 22 to 7%. In Fulton's series, the right coronary artery predominated over the left in the ratio of 50 to 20%.

Inter-coronary anastomoses (Table 1) could be observed in 74% of our cases. In 13%, there was complete filling of the right coronary system after injecting the left coronary artery. In 45% of cases, the anastomosis was slight, and in 16% moderate. Homolateral coronary anastomoses, i.e. anastomoses between the branches of the same coronary artery was noted in 100% of cases. This confirms the view (Zoll, Wessler & Schlesinger, 1951) that the coronary artery can no longer be regarded as end arteries as previously held.

In 100 cases in which the atrial blood supply was studied, the origin was from (i) the right coronary artery in one-third of the cases (ii) the left coronary artery in another third and (iii) both arteries in the remaining third. In all instances, there was a definite predominance of either the right or left coronary arterial systems in atrial blood supply. It is, therefore, pertinent to suggest that the concept of dominance which had been applied, albeit wrongly, to the ventricular blood supply should be better reserved for the atrial arterial blood supply.

Of particular interest in this study was the rarity of atherosclerotic disease in Nigerians. The narrowing of the arterial lumen observed in only eight cases in this series was only of a mild degree. This fact has been noted by Williams (1971) who observed no demonstrable atherosclerosis of the coronary arteries in 71% of 279 consecutive unselected autopsies of Nigerians over the age of 10 years and recorded only ten deaths from myocardial infarction in 8000 necropsies at the University College Hospital, Ibadan, Nigeria in a 10-year period. This observation is in marked contrast to the finding of relatively severe atherosclerotic disease in young American soldiers who died in North Korea (Enos, Holmes & Beyer, 1953) and South Vietnam (McNamara *et al.*, 1971).

Although the cardiomyopathies will require a separate study, it is of interest to note that in the presence of gross bi-ventricular cardiac enlargement, the transverse and vertical diameters of the atrial 'cardiac skeleton' are often correspondingly increased. Furthermore, the distance between the individual branches of the coronary arteries tend to be more widely spaced in enlarged than in normal hearts, although the basic anatomical pattern is maintained.

The micro-aneurysms observed in three instances should be regarded as incidental findings which are difficult to explain on the basis of intimal disease which were not present in the region in which they were noted. There was no reason to suggest that they contributed to the cause of death in these patients.

It should be noted that the injection method used by us is adequate for the larger calibre arterial sub-divisions; the finer calibre sub-endocardial anastomotic pattern cannot therefore be visualized as in Fulton's studies. However, these latter vessels are not shown in *in vivo* studies for which our present post mortem injection technique is a prelude. Sufficient information has, however, been obtained for the baseline anatomical pattern in Nigerians.

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