Interarterial Coronary Anastomoses and Coronary Arterial Pattern

A Comparative Study of South African Bantu and European Hearts

By W. J. Pepler, D.Sc., M.D., and B. J. Meyer, D.Sc., M.B., Ch.B.

The question whether intercoronary anastomoses exist in normal and pathologic human hearts has been the subject of vigorous discussion for many decades. Apart from the purely scientific interest the problem may have, it is of the greatest clinical importance for the better evaluation of the problems and possible future treatment of angina pectoris and acute myocardial infarction. Furthermore, familial or racial differences in the degree of anastomoses might to some extent be responsible for the varying frequency of myocardial infarction among different races and also among different families in the susceptible races. The important practical aspects of the problem have been clearly summarized by Blumgart et al., who stated "anastomotic circulation to an extraordinary degree may obviate any serious consequences of complete coronary artery occlusion."

Many of the controversial results concerning the presence or absence of significant intercoronary arteriolar anastomoses can certainly be ascribed to differences in the techniques employed by the various investigators. This fact was pointed out by Laurie and Woods, but subsequently their technic has again been criticized by Blumgart and Zoll. In applying their modified Schlesinger technic to Bantu hearts only, Laurie and Woods obtained results so different from the American workers who have actually originated and standardized the technic that the entire question now needs critical reassessment. Although it has been pointed out to Laurie and Woods that their results might be due to racial or environmental factors, they have subsequently reaffirmed their statements of the existence in all races of functionally important anastomoses in the majority of healthy people over the age of 4 years, thus supporting Baroldi, Mantero, and Scomazzoni's claim that anastomoses are almost the rule in normal hearts.

In yet another article, Laurie and Woods made the controversial statement that the serious effects of atherosclerosis are seen in the Bantu hearts (coronary artery disease) and that they do not "enjoy any relative freedom from atherosclerosis." This remark has already been quoted as implying that the Bantu do develop coronary thrombosis fairly commonly. From these statements one may infer that the existence of anastomoses do not offer any relevant safeguard against the development of myocardial infarction. Yet it has been conclusively shown by other workers in South Africa that, although the incidence of coronary and aortic atheroma appears to be the same, the severer degrees of the disease appear to be less among the Bantu. The rarity of cardiac infarction in the Bantu has been confirmed by Schrire and Uys. In 1958 Becker again stressed that the incidence of the serious complications of atherosclerosis, such as coronary occlusive disease, is much lower in the Bantu than in the European but "that on occasion the Bantu can and does develop just as much atherosclerosis as the European. . . ." In the absence of complications, this in itself would seem to implicate local vascular factors in the very low incidence of myocardial infarction in the Bantu. This hypothesis is further strengthened by the observations of Laurie and Woods and of

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Walker and Simson, who reported a relatively high rate of cerebrovascular accidents in the same race.

That local anatomic variations must be considered in explaining the difference between Bantu and European hearts has been suggested in a preliminary study by Brink. The validity of his findings have, however, since then been questioned by Singer, who investigated a much larger group of subjects. Brink also suggested that the anatomic variations might be responsible for the lower incidence of angina pectoris and coronary thrombosis. This conclusion has also been questioned by Elliot.

In view of these controversial reports, it seemed advisable to investigate the question of coronary anastomoses and coronary arterial patterns in a group of European and Bantu autopsies, with the use of the same technic in both groups. The present paper reports our findings on a series of 188 Bantu and European hearts.

**Material and Methods**

**Material**

Of the 188 cases in the present study, 167 were in-patients dying in the Pretoria General Hospital, an institution with 913 European and 665 non-European beds. The remaining 21 hearts were obtained from the Government Medico-Legal Laboratories; these cases died from unnatural causes but were otherwise free from any detectable disease. Of the 21 cases, 11 were European children and adolescents and were all included in the age groups 0 to 9 and 10 to 19 years. The remaining 10 cases were old Bantu and were included in order to fill the age groups 70+ years. The age and sex incidence of the 2 racial groups is given in table 1.

Postmortem examinations are obtained on approximately 17 per cent of the patients dying in this hospital. The main reason for the low percentage of cases on whom autopsies are performed is failure to obtain permission from relatives. The cases obtained from the hospital had all died from natural causes and the series was entirely unselected, except for age. As soon as 10 to 12 cases had been investigated in a specific age group, the collection of further cases in the group in question was stopped. The cases included in the series died from a wide range of pathologic conditions. All the postmortem examinations were under our supervision.

**Methods**

The hearts were immediately injected after removal from the body according to the latest modification of the Schlesinger technic, in which a gelatin-potassium-iodide-barium sulfate mixture is employed. This mixture can be solidified at room temperature by adding varying concentrations of formalin prior to injection of the mass. The "viscosity conversion concentration" of every freshly prepared batch was determined, and the amount and concentration of formalin added were regulated so that solidification of the mass took place in approximately 30 minutes. Our technic conformed entirely to that of Schlesinger except that after injection of saline into both coronary ostia, the radiopaque mass was injected into the left coronary artery only for a period of exactly 3 minutes. The mass was injected at a pressure corresponding to the mean arterial blood pressure of the individual if this was known, and in all other cases at a pressure of 100 mm. Hg. During this period the hearts were closely scrutinized for any evidence of intercoronary anastomoses. The anastomoses were recorded as "good" in those cases in which the right coronary arterial tree was completely filled by the mass injected into the left coronary orifice within the specified 3 minutes. Anastomoses were recorded as "moderate" when the right coronary tree was not filled but when clear-cut evidence of an admixture of the different colors injected in the 2 trees could be demonstrated in the right coronary system on dissection of the fixed specimen. The same system was used to determine the absence of anastomoses.

Subsequently the right coronary arterial tree was injected under the same pressure. At the same time the pressure was maintained in the left coronary circulation. As soon as the injection mass stopped flowing, the cannulas were clamped and the heart was suspended in 10 per cent neutral formalin for 1 to 2 hours. The hearts were then dissected ac-

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Table 1

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>European Male</th>
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<th>Bantu Male</th>
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ECARD TO THE MODIFICATION OF RODRIGUEZ AND REINER.26 The “unrolled” hearts were fixed in neutral 10 per cent formalin for a few more days and then photographed by x-ray. Subsequently 8 blocks were taken from each heart for microscopic examination and at the same time the coronary tree was dissected and the degrees of luminal narrowing were recorded.

Four of the Bantu hearts were omitted in our assessment of the degree of anastomosis because of a faulty injection technic.

All statistical analyses were done according to the chi-square test method.

“Third Primary Division of the Left Coronary Artery”

Although the term “third primary division of the left coronary artery” was originated by Brink16 10 years ago, not until recently was the coronary artery pattern in the Bantu reinvestigated by Singer.17 The publication of this article was followed by a series of letters by both authors21,22 in which each other’s methods, terminology, and interpretations were variously criticized. Unfortunately the significance of any racial anatomic variation in collateral or anastomotic circulation was ignored. Brink16 tentatively proposed that the third primary division of the left coronary artery, which he has regarded as an extra branch of the left coronary artery, could be an important source of collateral circulation. He suggested that his findings may explain the rarity of myocardial infarction and angina pectoris in the Bantu.

In the present series it was necessary to re-evaluate these findings in an attempt to correlate the presence or absence of a third primary division of the left coronary artery with the anastomoses demonstrated with the present technic.

The x-ray films were labeled in such a way that it was not possible to identify the racial

Figure 1

Roentgenogram of the heart of a 45-year-old Bantu man with a third primary division of the left coronary artery.
group of the case. These films were then inter-
preted independently by both authors as to
the presence or absence of a third primary left
ventricular artery. The presence of such an
artery was accepted only if both branches 12
and 14 of Spalteholz23 (the nomenclature used
by Brink16), or as Singer22 has renamed them,
the major and minor left ventricular arteries,
were clearly present. Furthermore, the third
branch had to originate in the angle formed
by the primary branches (figs. 1 to 4). In any
case in which it was not possible because of
overlapping on the x-ray film to determine
the exact origin of the artery in question, the
heart was dissected. This was done in 40 per
cent of the cases in the series.

At the same time, the distribution of the
coronary arteries was also noted, i.e., whether
the heart belonged to the right preponderant,
left preponderant, or balanced type of circu-
lation.24 In this regard no significant differ-
ences were observed in the 2 groups.

By the use of the described technics, the
presence of a third primary division of the
left coronary artery was demonstrated in 38
per cent of European hearts (table 2). In the
Bantu, on the other hand, this artery was
present in 74 per cent. Therefore our findings
confirm those of Brink16 in that the presence
of the third primary division of the left coro-
nary artery is significantly higher in the
Bantu than in the European group. The prob-
ability that there is no difference in this re-
spect is extremely low (p = <0.01). No cor-
relation could, however, be established be-
tween the presence or absence of this artery
and the presence or absence of a functionally
important anastomotic circulation between the
left and right coronary arterial system. That
it may facilitate the anastomotic circulation
of the left coronary tree could not be excluded.

**Figure 2**
Roentgenogram of the heart of a 19-year-old European man with a small third primary
division of the left coronary artery.
Figure 3
Roentgenogram of the heart of a boy aged 17 in which the third primary division is a replacement of branch II of the Spalteholz classification.

Table 2
Incidence of Third Primary Division of the Left Coronary Artery

<table>
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<th>Age group</th>
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<th>Bantu</th>
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<td>3rd P. absent</td>
<td>Number of cases</td>
<td>3rd P. present</td>
<td>3rd P. absent</td>
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*Third primary division of the left coronary artery.

χ² = 24.3; degree of freedom = 1; p = <0.01.

Intercoronary Arteriolar Anastomoses
The age and sex distribution of the cases with "good," "moderate," and "no" demonstrable interarterial coronary anastomoses are depicted in table 3. This analysis includes all cases of the 2 racial groups irrespective of associated pathologic changes. In the Bantu series we confirmed the findings of Laurie and Woods that functionally important anastomoses do exist in a high percentage of cases: "good" anastomoses were demonstrated in 54 of 94 hearts, i.e., in 57 per cent. In the European group, on the other hand, only 23 of 90 cases (26 per cent) showed anastomoses of a comparable degree. This difference is highly significant statistically as measured by the chi-square test or standard error of difference. Separate analysis of the age groups above and below 20 years shows the same significant statistical difference. This result clearly indi-
INTERARTERIAL CORONARY ANASTOMOSES

Figure 4
Roentgenogram of the heart of a Bantu woman aged 80 with very severe coronary atherosclerosis and narrowing of the lumen. On dissection a third primary division of the left coronary artery was demonstrated.

dicates that the findings of Laurie and Woods cannot be applied to all ethnic groups as they have done. On examination of the age distribution of the cases with functionally important anastomoses it becomes apparent that, whatever the cause of the development of the anastomoses, it must be present at a very early age because 7 of the 10 Bantu cases in the age group 0 to 9 years had excellent anastomotic circulation. It was then decided to reclassify the cases into groups with normal hearts, hypertrophied hearts, and hearts with severe coronary atherosclerosis in order to assess the various factors that may be involved in the development of interarterial coronary anastomoses.

Normal Hearts and Coronary Anastomoses

The hearts included in this group showed no macroscopic or microscopic evidence of peri-

Table 3
Degree of Intercorony Anastomoses in Both Racial Groups

<table>
<thead>
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<th>Age group</th>
<th>European Anastomosis</th>
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<td>No. cases Good Moderate Nil</td>
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<td>10 2 3 5</td>
<td>10 10 2</td>
</tr>
<tr>
<td>20 - 29</td>
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<td>10 6 2 2</td>
</tr>
<tr>
<td>80 - 89</td>
<td>11 3 2 6</td>
<td>8 2 3 3</td>
</tr>
<tr>
<td>Total</td>
<td>90 23 24 43</td>
<td>94 54 20 29</td>
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</tbody>
</table>

All age groups: $x^2 = 17.02$; degree of freedom = 2; $p < 0.01$.
Under 20 years of age: $x^2 = 13.18$; degree of freedom = 2; $p < 0.01$.
Over 20 years of age: $x^2 = 11.24$; degree of freedom = 2; $p < 0.01$. 

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cardial, myocardial, endocardial, or valvular disease. The coronary arteries were macroscopically completely free from atherosclerosis. The presence or absence of hypertrophy was determined by comparing the heart weight to body length with use of the tables of Zeek and of Roessle and Roulet. Furthermore, no adult hearts weighing more than 350 Gm. were included in the group. On the basis of all these criteria 23 European hearts were classified as normal; 8 of these showed excellent anastomoses (35 per cent), and in the remaining 15 cases anastomoses were poor or absent. In the Bantu series 49 hearts were found to be normal; 54 per cent had excellent anastomoses and the remaining 23 hearts either showed poor or no evidence of anastomoses. These anastomoses were found in all age groups. It therefore appears that the anastomoses are present in both racial groups irrespective of concomitant heart disease, but that the normal hearts in the Bantu show a higher incidence of intercoronary arteriolar anastomoses than the European hearts.

Coronary Atherosclerosis and Coronary Anastomoses

The appraisal of the degree of coronary heart disease was based on the degree of least luminal patency at any specific point in the vascular tree. For this purpose the entire arterial tree (left and right coronary distribution) was transected at intervals of 3 to 5 mm. and the grading of Gore and Tejada was applied with the following minor modifications: in those classified as grade 0 luminal patency was more than nine tenths normal; grade 1 indicated luminal patency of more than three quarters normal; grade 2 more than half normal; grade 3 more than quarter normal; and grade 4 less than quarter normal.

Figure 5

Roentgenogram of the heart of a European child aged 10 with Fanconi's anemia. Extensive interarterial anastomoses are present.
or total occlusion. The point of severest narrowing in either the left or right coronary tree was taken as an index of the degree of atheromatosis in the individual case. Since Zoll, Wessler, and Schlesinger have shown that cases with slight coronary artery narrowing do not differ significantly in the degree of anastomoses from their control group with no narrowing, it was decided to compare the cases with group 0 and 1 narrowing with those classified as grades 2 to 4. The results obtained are shown in tables 4 and 5.

In the European group 17 of 58 cases having grade 0 and 1 narrowing showed "good" anastomoses (29 per cent); 32 cases were classified as having grade 2 to 4 atherosclerosis and 6 of these showed good anastomoses (19 per cent). The Bantu hearts with grade 0 to 1 luminal narrowing showed "good" anastomoses in 59 per cent of cases. In the small group of cases with severe narrowing, 4 showed comparable anastomoses, i.e., 44 per cent.

The number of European and Bantu cases with severe narrowing are too small to permit statistically valid conclusions but it seems as if the severity of the atherosclerosis had not influenced the development of coronary anastomoses to any marked degree. The small number of Bantu cases that could be classified as having severe atherosclerosis in the present study has again forcibly demonstrated that the Bantu do not develop the same degree of atherosclerosis as the European.

**Myocardial Hypertrophy and Coronary Anastomoses**

In this series only the hearts in the age groups above 20 years were considered. All hearts weighing more than 350 Gm. were regarded as hypertrophic. In view of the small number of cases it was not possible to subdivide them according to the various causes of hypertrophy. As a result these cases included hypertensive hearts, cases of cor pulmonale, longstanding anemia, valvular disease, and in the Bantu group a few with idiopathic cardiac hypertrophy were also present. In the European group (table 6) 37 per cent of the cases had "good" anastomoses and in the

### Table 4

<table>
<thead>
<tr>
<th>Age group</th>
<th>Number of cases</th>
<th>Degree of luminal narrowing</th>
<th>Anastomoses in grade 0-1</th>
<th>Anastomoses in grade 2-4</th>
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<tr>
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\[ \chi^2 = 2.12; \text{degree of freedom} = 1; p = 0.30-0.20. \]

Bantu group 71 per cent showed comparable anastomoses. The hypertrophic Bantu hearts showed a higher percentage of anastomoses than the control group, but the hypertrophied European hearts did not. However, one does not expect better communications, since Dock has shown that the hypertrophic heart does not necessarily have an inadequate oxygen supply. Zoll et al. had similar results before they took the fact of anemia into consideration. Their total group of hypertrophied hearts did not show a statistically significant difference in anastomoses from their control group until hearts from patients with anemia were removed from both groups.

**Discussion**

The most significant observation in the present investigation has been the consistently higher frequency of interarterial coronary anastomoses shown by Bantu hearts as compared with European hearts. This difference has been present irrespective of hypertrophy or coronary arterial disease, despite more severe atherosclerosis in the older European hearts. It has therefore been established that the difference cannot be explained on the basis of any acquired intrinsic organic heart disease or to differences in the gross anatomic vascular pattern.

It has, however, been clearly established in humans, and in experimental ani-
mals, that cardiac anoxia stimulates the development of intercoronary arteriolar anastomoses. Of the factors that have been cited as causing cardiac anoxia, such as coronary heart disease, cor pulmonale, valvular disease, cardiac hypertrophy, and anemia, only the latter factor need be considered in a group of people in whom anastomoses are present from a very early age and in whom it persists throughout adult life. This is, however, difficult to prove, since hemoglobin estimations at the time of death obviously have limited values and may be misleading. The time required for anastomoses to develop is not known with certainty, and whether these anastomoses are permanent has not yet been conclusively proved. Furthermore, since both our own and the findings of Laurie and Woods indicate that these anastomoses develop at a very early age, one would expect anemia to be prevalent among the Bantu during infancy and childhood. Until fairly recently no data were available in this respect, but at the beginning of 1959 Lanzkowski and McKenzie published their results of a survey carried out to determine the incidence of iron-deficiency anemia in pre-school Coloured and Bantu children in Cape Town. They found the incidence of anemia to be 65 per cent for Coloured children and 67 per cent for African children.

At Baragwanath non-European hospital, Metz and Stein found iron-deficiency anemia to be common among Bantu infants and they reported the highest incidence to be between 6 and 18 months of age. They, furthermore, stress the importance of kwashiorkor as a possible etiologic factor.

With regard to megaloblastic anemia, Walt et al. reported an incidence of 9 per cent in Bantu infants admitted to a Durban hospital. These findings have also been confirmed by Cassel and Metz, who stated that megaloblastic anemia was "common in Bantu infants."

From the foregoing data it is obvious that iron-deficiency anemia and megaloblastic anemia are prevalent among Bantu infants and children. In view of the experimental data available, it seems justifiable to propose that these diseases are responsible for the higher incidence of intercoronary anastomoses in normal Bantu than in European hearts in this series. Zoll, Wessler, and Schlesinger, with a somewhat similar technic, found an incidence of anastomoses of 9 per cent in a group of normal hearts from whom patients with anemia had been removed. A high incidence of anemia in the control group of this series may well obscure the effects of other factors on anastomoses; for example, the failure to find an effect of hypertrophy on anastomoses in the European group and an effect of increasing degrees of coronary arterial narrowing, which are contrary to the results of Zoll et al., may be accounted for on this basis.

Although the present study has confirmed the findings of Laurie and Woods of a high incidence of coronary anastomoses in Bantu

### Table 5

<table>
<thead>
<tr>
<th>Age group</th>
<th>Number of cases</th>
<th>Degree of luminal narrowing</th>
<th>Anastomoses in grade</th>
<th>Anastomoses in grade 2-4</th>
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<tr>
<td>40-49</td>
<td>14</td>
<td>14</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>50-59</td>
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<td>9</td>
<td>5</td>
<td>1</td>
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<tr>
<td>60-69</td>
<td>10</td>
<td>8</td>
<td>3</td>
<td>-</td>
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<tr>
<td>70-79</td>
<td>10</td>
<td>7</td>
<td>4</td>
<td>2</td>
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<tr>
<td>80-89</td>
<td>8</td>
<td>6</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>94</td>
<td>85</td>
<td>9</td>
<td>50</td>
</tr>
</tbody>
</table>

χ² = 0.69; degree of freedom = 1; p = 0.30-0.50.

### Table 6

<table>
<thead>
<tr>
<th>Heart weight</th>
<th>European</th>
<th>Bantu</th>
</tr>
</thead>
<tbody>
<tr>
<td>HH</td>
<td>HHₐ</td>
<td>HH</td>
</tr>
<tr>
<td>350-449</td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td>450-549</td>
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<td>3</td>
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<td>550+</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>11</td>
</tr>
</tbody>
</table>

*Hypertrophic hearts without anastomoses.

†Hypertrophic hearts with anastomoses.
INTERARTERIAL CORONARY ANASTOMOSES

hearts, the clear-cut differences of the anastomotic pattern in the ethnic groups studied invalidate the conclusions of the latter authors, that "a majority of healthy people have a functionally important inherited coronary anastomotic blood supply."

The lower incidence of the severer degrees of coronary atherosclerosis in the Bantu is re-emphasized in this investigation and, therefore, a firm conclusion is not possible as to what extent the better anastomotic circulation protects the Bantu heart against ischemic heart disease.

Summary

The coronary arterial pattern and coronary anastomoses have been investigated in 90 European and 98 Bantu hearts.

A significantly better coronary anastomotic blood supply has been demonstrated in Bantu hearts. This was found to be present from a very early age onward and not related to hypertrophy, atherosclerosis of the coronary arteries, or to gross anatomic differences of the arterial tree, such as a third primary division of the left coronary artery. The latter was found to be more common (74 per cent) in Bantu than in European hearts (38 per cent).

It is suggested that the reason for the better anastomoses might be the high incidence of megaloblastic and iron-deficiency anemia in Bantu children.

The low incidence of the severe degrees of coronary atherosclerosis and its complications has been reaffirmed in the Bantu hearts.

Acknowledgment

The authors acknowledge, with appreciation, the criticisms of Professor J. Barnetson. Professor C. J. N. Loubser has kindly provided us with some hearts from the Medico-Legal Laboratories. We are indebted to Professor D. G. Halet for the statistical analyses and to Mr. C. J. de Swardt for the photomicrography.

Summario in Interlingua

Le configuration del arterias coronari e le grado del anastomoses coronari eseva investigate in le cordes de 90 europeos e de 98 bantus. Un signifiutivamente melior provision anastomotic de sanguine coronari eseva demonstrate in le cordes bantu. Esseva trovate que isto eseva presente deposit le etates le plus juvene e que le phenomenon non eseva relatonate a hypertophia, atherosclerosis del arterias coronari, o macrodifferencias anatomic del vasculatura arterial, como per exemplo un tertie division primari del arteria sinistro-coronari. Iste tertie division eseva plus commun in cordes bantu que in cordes europee (74 e 38 pro cento, respectivamente).

Es opinate que le explication del plus effeace anastomoses in le cordes bantu jace possibilemente in le plus alte incidentia de anemia megaloblastic e anemia a carentia de ferro in le infantes bantu.

Le studio ha confirmate le lasse incidentia de sever grado de atherosclerosis coronari e de su complicaciones in le cordes del bantu.

References


Circulation, Volume XXII, July 1960

On Cardiac Murmurs

By AUSTIN FLINT, M.D.

The practiced auscultator, by listening to the murmurs alone, is able to tell whether lesions are situated at the mitral, or at the aortic, or at the pulmonic orifice, and he is able to say, in certain cases, that the valves which are to protect these orifices against a regurgitant current of blood, have been rendered by disease inadequate to their office.—Am. J. M. Sc. n.s. 44: 29, 1862.
Interarterial Coronary Anastomoses and Coronary Arterial Pattern: A Comparative Study of South African Bantu and European Hearts

W. J. PEPLER and B. J. MEYER

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