Location of Coronary Arterial Occlusions and Their Relation to the Arterial Pattern

By Bertram Pitt, M.D., Paul M. Zoll, M.D., Herrman L. Blumgart, M.D., and David G. Freiman, M.D.

THE INCIDENCE and localization of coronary artery occlusion have assumed increasing importance because of the current exploration of cardiac lesions in patients by angiography and surgery. We wish to report the results of a large series that extends the previous studies by Schlesinger and Zoll on anatomic variations in coronary arterial patterns and on the incidence and localization of coronary arterial occlusions.1,2

Methods

The injection plus dissection method of Schlesinger was employed.4 Briefly, this method consists of (1) injecting radiopaque lead-agar mass of different colors into the coronary arteries; (2) unrolling the heart so that the entire coronary tree lies in one plane; (3) taking a roentgenogram of the unrolled heart; and (4) carefully dissecting the coronary arteries with use of the film as a guide. This technic discloses all narrowings and occlusions, larger anastomoses, and the anatomic pattern of the coronary arterial tree.

In this study angina pectoris was defined in accordance with the usual criteria, and myocardial infarction was defined as a grossly visible scar or lesion confirmed by histologic examination. This definition, it should be stressed, does not include microscopic necrosis or grossly visible scattered areas of fibrosis that may be ischemic in origin. The term coronary occlusion refers to complete occlusion and does not include arterial narrowing, no matter how marked. The presence or absence of atherosclerosis was determined after dissection of the coronary arteries, and the degree of involvement was based on an estimation of the over-all extent of arterial narrowing and obstruction. The extent of the atherosclerotic process was graded as absent (0), slight (+), moderate (+++), or marked (+++).

The results of 1,576 necropsies in which the hearts were injected at the Beth Israel Hospital, in an unselected and almost consecutive series from 1936 to 1949, were analyzed. This series includes the smaller group of cases previously reported by Schlesinger.1,2

Incidence and Localization of Coronary Artery Occlusions

Of the 1,576 hearts in the present study 378 were found to have coronary arterial occlusions; the total number of occlusions, both old and recent, was 969. This incidence is similar to the previous finding of an average of 2.5 occlusions per heart in cases with occlusion.5

In our present study, of all 378 hearts with complete occlusions, 62 per cent had more than one occlusion per heart (table 1), and 48 per cent of the hearts had occlusion of at least two of the three main coronary arteries. Multiple occlusions were present in one of the coronary arteries in one third of the cases (table 1).

In many previous investigations the left anterior descending coronary artery was found to be the most frequent site of occlusion.6 Schlesinger and Zoll3 found 38 per cent of occlusions in the left anterior descending, 26 per cent in the left circumflex, and 35 per cent in the right coronary artery. Our present series of 969 occlusions, both old and recent, confirms their observations and the findings of Horne et al.7 in emphasizing the frequency of occlusion in the right coronary artery.

All of the cases with complete coronary occlusions (in which an adequate history was available) were subdivided into those with angina pectoris, those with congestive heart failure, and those without clinical symptoms of coronary artery disease (table 2). This analysis re-emphasizes the severity of the occlusive process in patients with angina pec-
toris, 60 per cent having two or more occlusions; conversely, there was a relatively large percentage of patients, 30 per cent, with coronary occlusions not having clinical manifestations.

The Coronary Arterial Pattern

Schlesinger differentiated three main variations in pattern of the right and left circumflex coronary arteries.\textsuperscript{1,2} The first and most common group (48 per cent) showed right "coronary artery predominance" with the right coronary artery extending beyond the posterior descending branch and supplying the right ventricle, the posterior half of the interventricular septum, and part of the left ventricle. The second group (34 per cent) was found to have a "balanced circulation" with each of the two ventricles receiving its blood supply from the corresponding coronary artery: the right coronary artery extends as far as the crux of the heart to give off the posterior descending branch so that it supplies the right ventricle plus the posterior half of the interventricular septum, and the left coronary artery supplies the whole left ventricle plus the anterior half of the interventricular septum. The third pattern (18 per cent) was "left coronary artery preponderant," the left coronary artery giving off the posterior descending branch so as to supply the whole left ventricle, the entire interventricular septum, and in some cases part of the right ventricle. The coronary artery pattern is fixed throughout life and is unchanged even with hypertrophy.\textsuperscript{8,9} The amount of blood normally supplied to any one part of the myocardium is independent of the coronary artery pattern.

Although there are some minor differences, the results in the present, larger series (table 3) confirm the relative frequencies of the three patterns found by Schlesinger.\textsuperscript{1,2} The incidence of these three patterns is similar to that noted recently by James in 106 hearts,\textsuperscript{10} but his suggestion of a significant variation in pattern with sex is not confirmed in our larger series.

In his original small series Schlesinger\textsuperscript{1,2}
found hearts with left coronary artery preponderance to have the greatest incidence of myocardial infarction and the worst prognosis after infarction: there were no cases of healed infarction with this pattern. The hearts with a balanced circulation were stated to have the lowest incidence of myocardial infarction and the best prognosis. The right coronary artery preponderant hearts were intermediate. Our results in this larger series show that the differences in proportion of healed and recent infarction in the three groups are not significant ($p = 0.339$) (table 4). Consequently, it now appears that the pattern of the coronary tree does not influence the prognosis of myocardial infarction. Furthermore, there were no significant differences in the three groups in the severity of atherosclerosis (table 5) nor in the relative incidence of occlusions (table 6). An analysis

Table 2

Relation of Coronary Artery Occlusions to Clinical Disease

<table>
<thead>
<tr>
<th>Number of main coronary arteries with old complete occlusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Artery No.</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>Angina pectoris</td>
</tr>
<tr>
<td>Congestive heart failure</td>
</tr>
<tr>
<td>Asymptomatic</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Table 3

Incidence of Anatomic Pattern of the Coronary Arteries

<table>
<thead>
<tr>
<th>Men</th>
<th>Women</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. %</td>
<td>No. %</td>
<td>No. %</td>
</tr>
<tr>
<td>Group I (Right)</td>
<td>506 (58)</td>
<td>425 (42)</td>
</tr>
<tr>
<td>Group II (Balanced)</td>
<td>199 (59)</td>
<td>138 (41)</td>
</tr>
<tr>
<td>Group III (Left)</td>
<td>128 (58)</td>
<td>90 (41)</td>
</tr>
<tr>
<td>Total</td>
<td>922 (58.5)</td>
<td>654 (41.5)</td>
</tr>
</tbody>
</table>

Table 4

Relation of the Coronary Artery Pattern to the Incidence and Prognosis of Myocardial Infarction

<table>
<thead>
<tr>
<th>Total no. hearts</th>
<th>Hearts with infarcts No. %</th>
<th>Total no. of infarcts</th>
<th>Healed No. %</th>
<th>Recent No. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I (Right)</td>
<td>1,021</td>
<td>210 (21)</td>
<td>235</td>
<td>113 (48)</td>
</tr>
<tr>
<td>Group II (Balanced)</td>
<td>337</td>
<td>54 (16)</td>
<td>59</td>
<td>26 (44)</td>
</tr>
<tr>
<td>Group III (Left)</td>
<td>218</td>
<td>34 (15.5)</td>
<td>38</td>
<td>15 (40)</td>
</tr>
<tr>
<td>Total</td>
<td>1,576</td>
<td>298 (19)</td>
<td>332</td>
<td>154 (46.5)</td>
</tr>
</tbody>
</table>

Table 5

Incidence of Atherosclerosis in the Three Groups

<table>
<thead>
<tr>
<th>No. hearts</th>
<th>Slight (0 to +)</th>
<th>Moderate and marked (+ + to +++)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I (Right)</td>
<td>1021</td>
<td>709 (70%)</td>
</tr>
<tr>
<td>Group II (Balanced)</td>
<td>337</td>
<td>245 (73%)</td>
</tr>
<tr>
<td>Group III (Left)</td>
<td>218</td>
<td>163 (75%)</td>
</tr>
</tbody>
</table>

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of cases in which there was only one complete occlusion failed to reveal any correlation between the location of the occlusion and the three groups (table 7). There was, however, a slightly higher incidence of infarction in group-I hearts (table 4). In a recent study Smol'ianikov and Naddachina\(^\text{11}\) suggested that a further subdivision of the coronary artery patterns into right coronary artery, right medial, left, left medial, and balanced groups would reveal differences in occurrence of coronary artery disease. This study was based on a relatively smaller number of cases and is, as yet, unconfirmed.

### Discussion

The advent of coronary angiography has led to renewed interest in the three variations of coronary artery pattern described by Schlesinger.\(^\text{1,2}\) This differentiation of coronary artery pattern into right preponderant, left preponderant, and balanced circulation was based on arbitrary anatomic criteria. Unfortunately, the previous correlation of coronary artery pattern with prognosis after myocardial infarction lends a physiologic connotation to the term “coronary artery preponderance” that was not intended. The mass of left ventricular myocardium is so much greater than the right that the left coronary artery is the physiologically preponderant artery in the majority of all normal human hearts.\(^\text{10}\) The present study shows that the coronary pattern is not related to the prognosis after infarction, nor can it be correlated with the incidence of occlusion or with the severity of atherosclerosis. The finding of a slightly higher but statistically significant incidence of infarction in right coronary preponderant hearts is unexplained.

Oclusions were rather uniformly distributed in the main coronary arteries except for their higher concentration (70 per cent) in the first 4 cm.\(^2\) One might have expected a somewhat higher incidence of occlusion in the right coronary artery in right coronary artery preponderant hearts (group I) than in the left coronary artery preponderant hearts (group III) because of the greater length of the right coronary artery in the group I hearts. The extra length of the peripheral portion of the right coronary artery in group-I hearts had relatively little influence on the frequency of occlusion in that artery.

The proper selection of patients for coronary artery surgery requires accurate angiography.\(^\text{12}\) The occurrence of multiple occlusion...
CORONARY ARTERIAL OCCLUSIONS

sions in a large number of cases points to certain difficulties in the interpretation of the angiograms. Although the angiogram may show only one occlusion in a main vessel, further occlusions will not be detected unless there is recanalization or retrograde flow through collateral vessels. It has been suggested that considerable pathologic change can be present in the coronary system without any abnormality appearing in the clinical arteriogram. Furthermore, the recognition of occlusions in the smaller branches of the coronary tree is extremely difficult because of the variable distribution and number of these vessels.

Studies in our laboratories have provided much of the pathologic and anatomic background necessary for the understanding of the clinical manifestations of coronary disease, in particular angina pectoris, and have been used as a basis for the consideration of a surgical approach to coronary artery disease. The characteristics of coronary arterial occlusions have been presented in detail and need only be summarized here. The vascular lesions in the coronary system are almost entirely atherosclerotic in nature; initially they are localized and segmental, but they may extend to involve most of the vascular walls. The atherosclerotic process may produce little or no narrowing of the lumen or total occlusion may result; the degree of obstruction may not be closely related to the extent of the atherosclerosis. The lesions occur almost entirely in the epicardial distribution of the main coronary arteries and their primary branches. The highest incidence of occlusion is not directly at the mouth of the vessel but a short distance distal to the mouth. One half are within 3 cm. and 70 per cent are within 4 cm. of the coronary ostia. In the 193 occlusions previously studied, 64 per cent were less than 5 mm. in length and 40 per cent were less than 3 mm. in length. Occlusions of the right coronary and left circumflex coronary arteries were almost as frequent as of the left anterior descending branch of the left coronary artery. Interarterial coronary anastomoses were markedly increased with coronary artery disease.

Our present data on coronary artery occlusions indicate the extremely limited role endarterectomy may be expected to play in the therapy of angina pectoris. These data do not include coronary artery narrowing, which often causes significant reduction in coronary flow and may affect the myocardium even more than do occlusions. Involvement of the coronary arteries with the atherosclerotic process may prevent surgical manipulation of the walls even in the absence of obstruction. The data on length of occlusion and distance of occlusion from the ostia, which had been used as a pathologic basis for endarterectomy, were obtained from an unselected group of postmortem cases with complete coronary occlusion. The present study reveals that about one half of the cases did not have angina pectoris or myocardial infarction, that in 30 per cent of the cases the occlusions were asymptomatic during life, and that 20 per cent of the cases had congestive heart failure only (table 2). Because the severity of the occlusive process in these patients is significantly less than in patients with angina pectoris, the earlier estimates of the applicability of endarterectomy for the therapy of angina pectoris should be revised downward. Once coronary artery disease becomes manifest as angina, the occlusive process is in most cases too widespread for surgical intervention. The patients with complete occlusions who were asymptomatic or who have only congestive heart failure, appear to be the ones in which we would expect the greatest technical success with endarterectomy. As the natural history of these patients is not, as yet, adequately known and the surgical mortality is high, it seems unwarranted to operate on such patients even if they could be detected. Until such a time as the operative mortality and secondary failure rate, due to restenosis, can be reduced through new surgical techniques, coronary endarterectomy should be considered an experimental procedure to be investigated vigorously in the laboratory, but not
to be applied for therapeutic purposes in man. These conclusions are in agreement with the recent findings of Swedlund et al.\textsuperscript{23}

The objection might be raised that our studies were based on postmortem data representing the end stage of the disease process, and that the extent of the obstructive coronary disease would be much less during life. Since the old occlusions found at autopsy existed prior to the patient’s terminal illness, and since many of our patients died of extracardiac disease, the postmortem data do seem to provide a fair representation of the pathology present for some time during life. In Thal’s clinical study of 50 patients with coronary angiography there were only two instances in which the obstructions were localized or segmental.\textsuperscript{24} Both of these patients were asymptomatic. Direct observation of the coronary arteries during endarterectomy\textsuperscript{21} has also demonstrated extensive involvement of the coronary main stems by occlusive disease during life and suggests that this objection may be discounted.

Summary

The present study shows that the coronary artery pattern is not related to the prognosis after infarction nor can it be correlated with the incidence of occlusion or with the severity of atherosclerosis. This analysis re-emphasizes the severity of the occlusive process in patients with angina pectoris and, conversely, the relatively large percentage of patients having coronary occlusion who had either congestive heart failure or who were asymptomatic.

The proper selection of patients for coronary artery surgery requires accurate angiography. The occurrence of multiple occlusions in a large number of cases points to certain difficulties in the interpretation of the coronary angiogram and also indicates the extremely limited role endarterectomy may be expected to play in the therapy of angina pectoris. Until such a time as the operative mortality and secondary failure rate, due to restenosis, can be reduced through new surgical techniques, coronary endarterectomy should be considered an experimental procedure to be investigated vigorously in the laboratory but not to be applied for therapeutic purposes in man.

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Inertia vs New Ideas

Apart from the happy few whose work has already great prestige or lies in fields that are being actively expanded at the moment, discoverers of new truths always find their ideas resisted. The consideration of this process is often obscured by two assumptions: first it is supposed that the most harmful resistance comes from obvious and noisy prejudice and that the more dangerous resistance of inertia and quasi-rational negation is unimportant; and secondly, it is supposed that workers in science are of course free from any resistive tendency but a rational conservatism. Each of these assumptions is an almost complete delusion.

The vociferous opposition met with by the ideas of Charles Darwin and of Lister probably did nothing to hinder the spread of these, and probably brought them within reach of a larger number of people capable of accepting them than would have been the case if the opposition had been well behaved. Again it was not noisy prejudice that caused the work of Mendel to lie dead for thirty years, but the sheer inability of contemporary opinion to distinguish between a new idea and nonsense. That his same inability may be shown even by the most eminent workers in science scarcely needs demonstration for anyone at all aware of the history of knowledge, but it may be illustrated by an anecdote which we owe to the third Lord Rayleigh and which is to be found in the delightful Life of that very great and wise man. J. J. Waterston was an engineer who interested himself in mathematical physics, and in 1845 wrote a paper on the molecular theory of gases which was ten or fifteen years in advance of his time and anticipated much of the work of physicists no less eminent than Joule, Clausius, and even Clerk Maxwell. The only contemporary judgement on this paper that survives is that of the referee of the Royal Society to whom it was submitted. He said, 'The paper is nothing but nonsense.' What Waterston might have accomplished if he had had the recognition and encouragement upon which this genius seems to have been unusually dependent, is beyond conjecture. He did not get them. His work lay in utter oblivion for forty-five years until it was exhumed by the pious efforts of Rayleigh. He himself lived on disappointed and obscure for many years, and then was overtaken by a yet deeper obscurity, for as the result of some strange accident or a long gathering impulse of despair, he disappeared and left no sign.—The Collected Papers of Wilfred Trotter, F.R.S. London, Oxford University Press, 1946, p. 26.
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