Clinical significance of the coronary arteriogram¹

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A method is described of scoring the degree of obstruction of all three coronary arteries as revealed by coronary arteriography so that the disease process as a whole can be assessed.

This score has been correlated with the clinical details of 107 patients having ischaemic heart disease, rheumatic heart disease, or both.

Of those patients with a clinical history of myocardial infarction, 87 per cent were found to have complete, or almost complete, obstruction in one of the coronary arteries.

The level of serum cholesterol was related to the severity of the obstructive disease in the whole group even when the level remained within normal limits. There was no correlation between the total score and the length of history of angina pectoris or the number of cigarettes smoked. Those patients with a history of congestive cardiac failure had a higher score than those without.

We were unable to find a close relation between the particular artery diseased and the area of myocardial damage as predicted from the electrocardiogram either at rest or on exercise.

Neither the electrocardiographic nor clinical diagnosis of myocardial infarction, alone or together, correlated with complete obstruction on the arteriogram.

We believe that our method of scoring coronary arterial disease is a practical objective means of assessing the clinical significance of the coronary arteriogram.

Selective coronary arteriography is now accepted as a relatively safe procedure which is indicated mainly in the selection of patients for coronary arterial surgery but also for the evaluation of chest pain of doubtful causation when exact diagnosis is mandatory (Sones, 1968). We have devised a method of scoring the degree of obstruction as revealed by the arteriogram and have reviewed a series of 118 coronary arteriograms performed on 107 patients between June 1966 and June 1969. The patients have been divided into those with and those without ischaemic heart disease as assessed clinically, including the electrocardiogram, and we have compared the clinical and angiographic findings. We have also attempted to correlate the degree of obstruction in the coronary arteries with the duration of angina, history of an infarct, electrocardiograms, and serum cholesterol.

Subjects and methods

The majority (66%) of the 107 patients investigated were diagnosed before arteriography as

suffering from ischaemic heart disease and most of the remainder (28%) from rheumatic heart disease. Three patients were thought to have both diseases and were included in both groups for this analysis; a further 3 patients were investigated as examples of congestive cardiomyopathy (Raftery, Banks, and Oram, 1969). Eleven of the group were investigated on two occasions so that the total number of investigations performed was 118.

The first 74 investigations were performed using the Sones' technique (Sones and Shirey, 1962), but the Judkins' percutaneous technique (Judkins, 1967) was used exclusively for the remaining patients.

Clinical assessment The following parameters were noted.

1 *Clinical diagnosis* was that made when the patient was admitted to hospital for the investigation and has been used throughout this analysis unless otherwise stated.

2 *Myocardial infarction* was diagnosed if the patient had a history of prolonged chest pain requiring admission to hospital for a period of several weeks, or had the typical electrocardiographic changes described below, and raised serum aspartate aminotransferase (SGOT) and lactic dehydrogenase (LDH).

3 *Angina pectoris* was diagnosed when there was a history of retrosternal chest pain related to exertion. The duration of this symptom was re-

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corded in months from the time of onset to the date of the investigation.

4 *Heart failure* was diagnosed if the patient had at some time required treatment with digitalis and diuretics, or had a history of pulmonary oedema.

5 *Smoking habits*: patients were divided into six groups, namely non-smokers, those who had given up smoking, those with a daily consumption of 1-9 cigarettes, 10-19 cigarettes, 20-29 cigarettes, and those smoking more than 29 cigarettes a day.

This allowed a correlation of their smoking habits with the other recorded clinical details. There were a few pipe smokers and these were placed in the group which seemed appropriate, for example $\frac{1}{2}$ oz daily being considered equivalent to 1-9 cigarettes.

6 *Serum cholesterol* levels were taken as those recorded when the patient was first seen, unless treatment had been started, in which case the highest levels recorded in King's College Hospital were taken.

7 The *electrocardiograms* recorded at the time of admission for arteriography were reviewed by two observers independently. In all patients these were taken at rest, and in 43 patients there were also recordings after exercise. Disagreement was resolved by reviewing the electrocardiograms together, but this was necessary in only four instances. The tracings were classified as follows. (a) Normal; (b) myocardial infarction, a Q wave wider than 0.4 sec and greater than 2 mm in depth, in any lead; (c) myocardial ischaemia, depression of the ST segment greater than 1 mm or flattening or inversion of the T wave in any left ventricular lead; (d) other findings, for example left ventricular hypertrophy.

An attempt to predict the anatomical area of myocardial damage from the distribution of electrocardiogram changes was made (Table 1).

8 The *coronary arteriograms* were reviewed by two observers independently. To allow comparisons to be made, the degree of obstruction of each of the three major arteries was assessed by awarding a score from 1 to 4 (Fig. 1). The minimum score (i.e. normal) for each vessel was 1, and the maximum score (i.e. complete obstruction) 4. These three scores were then added together to give a total score which represented the overall obstructive disease for all three arteries of that heart. Thus, the minimum possible total score for each patient was 3 and the maximum was 12.

9 *Complications* resulting from the arteriogram were noted, and in those patients who were investigated using the Sones' technique (Sones and Shirey, 1962) the radial pulse was examined when the patient attended the clinic after several weeks.

In most cases Student's *t* test was used to determine the significance of the results. However, when the coronary arterial score was used, the mean score was calculated and the χ^2 test used to see if the distribution of scores in the groups differed significantly.

TABLE 1 *Anatomical area of myocardial damage as predicted by electrocardiogram*

	I	II	III	VR	VL	VF	VI	V2	V3	V4	V5	V6
Anterior	x				x			x	x			
Septal	x						x	x	x			
Apical										x	x	
Lateral	x				x						x	x
Posterior		x	x			x						

Results

The group consisted of 86 men and 21 women. The mean age was 47 years, with a range of 17 to 74. Sixty-nine of the investigations were on men and 11 on women with ischaemic heart disease, and 26 on men and 12 on women with other heart diseases. There were no differences between the men and women in any of the analyses, and we were unable to show any correlation between the age of the patients and the other variables. Fifty-seven patients subsequently had heart operations, 33 for ischaemic heart disease and 24 for valve lesions. The operations on the ischaemic group included unilateral or bilateral mammary arterial implantation (Vine-

FIG. 1 *Schematic representation of the degree of obstruction required for scores 1-4 to each coronary artery.*

TABLE 2 Smoking habits of whole group and those patients with ischaemic heart disease

	<i>Non-smokers</i>	<i>Given up</i>	<i>Daily number of cigarettes</i>				
			<i>1-9</i>	<i>10-19</i>	<i>20-29</i>	<i>30 +</i>	<i>Unknown</i>
<i>Men</i>							
Non-ischaemic heart disease	3	6	3	2	4	3	6
Ischaemic heart disease	3	15	3	19	13	0	6
<i>Women</i>							
Non-ischaemic heart disease	4	1	0	1	1	0	5
Ischaemic heart disease	3	1	2	0	2	0	1

berg, 1962), plication of the left ventricle, and in one patient cardiac transplantation.

A history of myocardial infarction was not associated in this analysis with an increased cigarette consumption, serum cholesterol, or any other distinguishing features. Twenty of the patients who had such a history had the changes of infarction on the electrocardiogram; of the others, 8 were classified as showing ischaemic changes, one electrocardiogram was lost, and 2 were normal. One of these 2 was a woman who had been admitted to another hospital with severe chest pain lasting several hours and had had electrocardiographic changes suggestive of myocardial infarction; no cardiac enzymes were estimated. The other patient was a man who had been in hospital on several occasions with severe pain and raised enzymes. On one occasion his cardiogram showed the changes of infarction but this had returned to normal by the time he was investigated.

Smoking habits The smoking habits of those with and without ischaemic heart disease are presented in Table 2. More of the ischaemic group (64%) were smokers though all the heavy smokers were in the non-ischaemic group.

TABLE 3 Mean total score in coronary arteries and mean total score for men and women in whole group

	Male		Female	
	No.*	Mean	No.	Mean
Anterior descending artery	90	2.5	21	1.9
Right coronary artery	93	2.2	22	1.2
Circumflex artery	89	1.9	21	1.5
Total score	89	6.7	19	4.6

* No. = the number of measurements used to obtain the mean value.

We were unable to demonstrate any relation between smoking habits and the other clinical features.

Serum cholesterol In those patients with a diagnosis of ischaemic heart disease the mean value was 280 mg/100 ml (S.E.M. ± 12.8 mg), compared with 217 mg/100 ml (S.E.M. ± 12.6 mg) in the non-ischaemic group. This difference was statistically significant ($P < 0.01$).

Electrocardiogram Twenty-nine patients had electrocardiographic evidence of myocardial infarction; of these, 20 had a history of infarction, 8 did not, and in 1 case no history was available. An electrocardiogram showing ischaemia was not associated with any other clinical features, and patients with a history of angina plus an ischaemic electrocardiogram were no different from the remainder.

Correlation with coronary arteriogram Analysis of the total coronary arterial score, and the scores for individual arteries, showed that the mean score in all three arteries was higher in the men compared with the women

FIG. 2 The distribution of the patients according to the diagnosis with respect to the total coronary arterial score ($\chi^2 48.45$; degrees of freedom 2, $P < 0.0005$).

(Table 3). These scores were also higher and the distribution of scores significantly different ($P < 0.0005$) in those with a diagnosis of ischaemic heart disease compared with those without that diagnosis. The distribution of these groups with respect to the total coronary score is shown in Fig. 2.

History of myocardial infarction This was associated with a higher score in all the coronary arteries, the distribution of the scores being significantly different from the remainder for all the arteries ($P < 0.01$). Of the 31 patients who had a history of cardiac infarction, 18 were classified as having complete obstruction of a major vessel on the arteriogram, and 9 had a score of 3 in a major vessel, but 5 scored less than 3 in each major vessel. Of these 5 patients, 3 had apparently normal arteries; one was a patient who had two arteriograms separated by an interval of one year and who died 6 months later of acute pancreatitis. Necropsy confirmed the angiographic findings of mild disease in the coronary arteries. The second was a man with aortic stenosis who suffered prolonged chest pain which had the characteristic features of angina pectoris, but had neither electrocardiographic nor enzyme changes. The third was a youth of 17 who showed unequivocal electrocardiographic and enzyme changes of myocardial infarction.

Angina pectoris There was no relation between the length of time the patients had suffered angina and the degree of obstruction in any of the arteries or in the total score.

Cardiac failure Patients with a clinical diagnosis of ischaemic heart disease and rheumatic heart disease, who had congestive cardiac failure, had a higher mean total score (8.7 and 4.6) than those without congestive cardiac failure (7.1 and 3.3), though the distribution of the scores in the two groups was not significantly different.

Smoking habits There was no correlation between the number of cigarettes smoked and the amount of disease in any of the arteries. Even the total coronary arterial score did not bear any significant relation to the tobacco consumption (Fig. 3).

Mean serum cholesterol This rose with increase in the score in the individual arteries (right coronary artery, $P < 0.05$; anterior descending artery, $P < 0.001$; circumflex artery $P < 0.01$) and with increase in the total score ($P < 0.001$, Fig. 4).

FIG. 3 Cigarette consumption of patients related to the total coronary arterial score. The bars show the calculated standard deviation and are given as an indicator of the scatter of the scores.

FIG. 4 The serum cholesterol as related to the total coronary arterial score. The regression line is that calculated from all the data. For simplicity the scores have been grouped together as indicated on the abscissa, and the mean standard deviation is given.

Electrocardiogram Initial analysis of the resting electrocardiogram showed that the mean total score in those with a diagnosis of infarction was 7.8 and the distribution was significantly different ($P < 0.05$) from those with a diagnosis of ischaemia (mean score 5.9) and the patients with valve disease (mean score 5.7). A similar analysis of the cardiogram after exercise showed that those with ischaemia (mean score 7.9) did not differ significantly in distribution from the patients with valve disease (mean score 5.1).

Since there was no difference in coronary score between those patients with an ischaemic resting cardiogram and those with a normal resting cardiogram, the results were reanalysed, all the patients with evidence of infarction or ischaemia being grouped together. This reanalysis failed to show a significant difference between the group with either infarction or ischaemia on the electrocardiogram, at rest or on exercise, and the 'normals'.

Further analysis showed that those patients with a history of angina and an ischaemic electrocardiogram had higher scores in all the major coronary arteries (Table 4) and a significantly different distribution of scores ($P < 0.0005$) from those with electrocardiographic changes only.

Of the 29 patients who were diagnosed as having a myocardial infarct on the electrocardiogram, 15 had complete obstruction in one of the coronary arteries, 9 had incomplete obstruction with a score of 3, and 5 scored less than 3. The patients who had both a clinical diagnosis of myocardial infarction and electrocardiographic changes of infarction were analysed as a group to see if this improved the diagnostic accuracy. There were 20 patients in this group and 12 of them had complete obstruction on the arteriogram, 5 had incomplete obstruction, and 3 patients scored less than 3 on all arteries.

TABLE 4 Mean coronary arterial scores and mean total score for patients with electrocardiographic changes of ischaemia

	History of ischaemic heart disease		No history of ischaemic heart disease	
	No.	Mean	No.	Mean
Anterior descending artery	41	2.9	18	1.4
Right coronary artery	40	2.7	22	1.3
Circumflex artery	40	2.3	18	1.2
Total score	39	7.9	17	4.1

TABLE 5 Mean scores in coronary arteries, and mean total score for different areas of damage as predicted from electrocardiogram

	Anterior (No. = 23 19.5%) Mean	Septal (No. = 10 8.5%) Mean	Apical (No. = 13 11%) Mean	Lateral (No. = 12 10%) Mean	Posterior (No. = 23 19.5%) Mean
Anterior descending artery	2.2	3.7	2.6	2.3	2.6
Right coronary artery	1.7	3.0	2.5	1.8	2.4
Circumflex artery	1.7	2.0	1.8	1.9	2.3
Total score	5.7	8.9	7.3	6.0	7.5

The mean scores in the 3 arteries with respect to the area of damage predicted from the electrocardiogram is given in Table 5. In all instances the anterior descending artery was the most severely affected, especially when there was a septal infarct (mean score from 10 patients = 3.7, when the maximum was 4). This was probably a reflection of the fact that the anterior descending is the artery most often obstructed in patients with ischaemic heart disease. The right coronary artery was also severely damaged when the infarct was posterior, apical, or septal, whereas the circumflex artery was only obstructed to a comparable degree when the infarct was posterior.

Analysis of coronary arteriogram with respect to number of arteries damaged

Only those patients who scored 3 or 4 in any of their arteries are considered in this section. The patients were grouped into those with disease of one, two, or three arteries. We were unable to show any increase in the number

FIG. 5 Comparison of the duration of angina pectoris with the degree of arterial obstruction.

of arteries diseased, with the duration of angina or with the serum cholesterol, though there were fewer patients with one artery disease who had suffered angina for more than 3 years (Fig. 5).

Complete obstruction Thirty-three patients had 43 complete obstructions, i.e. 1.3 per patient. The majority (21) were in the anterior descending artery, most of the remainder (17) in the right coronary artery, and the rest (5) in the circumflex artery. Ten patients had complete obstruction in two arteries but none had it in all three. Forty-six per cent of these patients had an electrocardiographic diagnosis of myocardial infarction, 36 per cent had ischaemia, and 12 per cent were normal. The remaining 6 per cent were no longer available for analysis. Eighteen of these patients had a history of myocardial infarction; 14 did not have such a history, and in one case the records were incomplete.

Incomplete obstruction There were 30 of the remaining patients who had a score of 3 in one of their arteries but did not score 4 in any of them. These patients might have had a complete obstruction which had recanalized. Fifty-seven arteries scored 3, an incidence of 1.9 such lesions per patient. The anterior descending artery was the most often affected (26), but the number of lesions in the circumflex (14) was about the same as in the right coronary artery (17), unlike the findings with complete obstruction when the circumflex was far less often affected. Seventeen per cent of the patients had an electrocardiographic diagnosis of myocardial infarction, 60 per cent of ischaemia, 10 per cent were normal, and 13 per cent were unknown. Six patients had a history of infarction, 21 did not, and 3 were not definite.

Morbidity One patient developed a fatal arrhythmia while being investigated. This was during the first few months of the series, and the patient was suffering continuous angina accompanied by severe electrocardiographic changes. One patient developed a myocardial infarct immediately after the investigation for no other apparent reason. Of the 74 patients who were investigated using the Sones' technique (Sones and Shirey, 1962), 12 were considered to have a reduced pulse and 2 lost the radial pulse. One of the patients with a reduced pulse, and another without a pulse, suffered intermittent claudication of the right hand but this improved without therapy. The other patient without a pulse had no symptoms. In one instance it

was necessary to explore the brachial artery because of the formation of a false aneurysm 10 days after the investigation.

Discussion

Our method of scoring the degree of obstruction in the major coronary arteries as revealed by selective coronary arteriography, and then summing the scores, has not been previously used, though Mitchell and Schwartz (1965) used a similar technique with necropsy material. They were able to measure the degree of obstruction in much smaller vessels than is reasonable from arteriograms.

This method of scoring was adopted as we felt that by giving a percentage of obstruction, as used by other workers (Herman, Elliott, and Gorlin, 1967; Proudfit, Shirey, and Sones, 1967; Gensini and Buonanno, 1968), a greater degree of accuracy is suggested than is possible; the amount of obstruction seen depends closely on the projection in which the arteriogram is performed, and varies greatly according to the radiological view taken. We have found that our score is reproducible by the same observer and with good agreement by a second observer. The total score also allows more complete analysis to be carried out.

Some of the results produced by our method were different from those produced by the percentage method of scoring. This is illustrated with respect to the length of time the patients had had angina pectoris. Our method of scoring did not show any relation between the length of angina and the amount of arterial disease, whereas analysis using the number of arteries severely damaged showed that the more arteries were damaged the longer the patient had had angina, as was found by Elliott and Gorlin (1966).

The patients who form the groups we have analysed were similar in age range and in sex ratio to those described by Hale *et al.* (1966) and Gensini and Buonanno (1968). This in part reflects the common policy of taking the age of 60 as the upper limit for cardiac surgical procedures.

The finding that 58 per cent of the patients with a history of myocardial infarction had complete obstruction in one of the major coronary vessels, and that a further 29 per cent had almost complete obstruction (score of 3), agrees with that of Proudfit, Shirey, and Sones (1966). Their finding of 1.1 per cent normal arteriograms in patients who had had an undoubted clinical myocardial infarct compares with our finding of 2.5 per cent. The most reasonable explanation for this is that

in some patients recanalization takes place restoring a smooth lumen to the vessel. A less likely explanation is that severe and prolonged arterial spasm may lead to transient but virtually complete obstruction of a coronary artery.

A history of cardiac failure was associated with a higher total score in all patients, even when an obvious mechanical lesion such as mitral valve disease was present. This suggests that impairment of coronary arterial flow may be important in the production of heart failure in patients with rheumatic heart disease, and that a coronary arteriogram may be as informative prognostically in valvar surgery as the demonstration of severe mechanical lesions.

The finding that the amount of tobacco consumed did not relate to the score in any of the arteries, nor to the total score, was surprising. This might be because the association between cigarette smoking and the degree of coronary arterial obstruction is based on necropsy material (Auerbach, Hammond, and Garfinkel, 1965). Smoking causes dilatation of the coronary arteries (Oram and Sowton, 1963), and it may be associated with sudden death and not progressive coronary arterial diseases (U.S. Department of Health, Education and Welfare, 1967).

We were unable to show any close correlation between the area of damage suggested by the electrocardiogram and the degree of obstruction revealed by the coronary arteriogram. The only positive correlation was between the electrocardiographic diagnosis of septal infarction and the presence of complete obstruction of the anterior descending artery. This finding was not unexpected, since most authors agree that the degree of obstruction found at arteriography is greater than expected from the clinical findings, but is in contrast with the findings of Gensini and Buonanno (1968) who found a close correlation.

We have shown not only a relation between the level of the serum cholesterol and the severity of obstructive disease of the coronary arteries, but also that this relation is not confined to patients with cholesterol levels in excess of the normal values. This is important supportive evidence of the predictive value of the serum cholesterol, even if within normal limits, in the production of atheromatous lesions.

The incidence of 1.3 complete obstructions per patient agrees well with the findings of Gensini and Buonanno (1968) but is less than that reported by Zoll, Wessler, and Schlesinger (1951) and Mitchell and Schwartz (1965)

in necropsy material. However, Gensini and Buonanno (1968), and Rodriguez, Robbins, and Banasiewicz (1964) found that the right coronary artery was most frequently completely obstructed, whereas in the present series the anterior descending artery was the most often completely obstructed, as also found by Mitchell and Schwartz.

None of the clinical features alone, or in any combination, was completely reliable in predicting those patients who had a complete or almost complete obstruction in any of their coronary arteries, though the vast majority had angina of effort. Apart from the elderly, we feel that there must be strong reasons for not performing a coronary arteriogram on any patient with intractable cardiac pain, since this investigation carries only a small risk and may reveal a lesion which is amenable to surgical relief.

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