Diagnostic Accuracy of Selective Coronary Cinearteriography

By Harvey G. Kemp, M.D., Hilary Evans, M.D., William C. Elliott, M.D., and Richard Gorlin, M.D.

SUMMARY

The premortem selective coronary cinearteriograms of 29 patients who subsequently died of their underlying disease have been compared to findings at postmortem examination. Only three errors of functional significance were found. Possible sources of these errors were analyzed. The most important single factor in determining the accuracy was the radiographic quality of the arteriogram. The data support the conclusion that selective coronary cinearteriography is a highly accurate means of evaluating the morphology of both normal and diseased coronary vessels, but high quality arteriograms and experienced interpreters are required.

Additional Indexing Words:
Collateral circulation in heart Coronary artery disease

Although coronary angiography had been successfully achieved by a variety of methods, it was not until the development of the selective technique that visualization of the coronary vessels became a reliable and sound clinical procedure. Mortality and morbidity have proved to be low, and the procedure has gained widespread acceptance and availability. It has become essential for the objective morphological diagnosis of coronary atherosclerosis. Furthermore, a large number of studies are beginning to appear correlating the results of selective coronary cinearteriography (SCCA) with the more conventional means of evaluating patients believed to have coronary artery disease. The value of SCCA depends upon the accuracy of information which it reveals. How accurately does the interpretation of SCCA reflect the actual anatomic state of the coronary vessels as might be determined by gross and microscopic examination of the heart?

To date, available literature comparing premortem angiography with postmortem examination is almost nonexistent. Hale and Jefferson studied four patients who died within 6 months of coronary arteriography. Only one case was reported in detail, and in this instance, actual disease at necropsy had been grossly underestimated by coronary arteriography.

The purpose of this investigation is to compare the interpretation of coronary angiograms with findings at postmortem examination. What questions might be answered by such a study? The primary question concerns the accuracy of the arteriography. It is realized that this cannot be determined absolutely, that apparent discrepancies may be due to

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CORONARY CINEARTERIOGRAPHY

Table 1

Evaluation of Radiographic Technique of Angiography

<table>
<thead>
<tr>
<th>Diagnostic quality</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>D 1. Study of exceptional quality</td>
<td>D 2. Good quality: can identify and describe all vessels including tertiary branches</td>
</tr>
<tr>
<td>D 3. Borderline quality: can identify and describe 4 major vessels: right coronary artery, left coronary artery (main), left anterior descending, and left circumflex</td>
<td></td>
</tr>
<tr>
<td>Nondiagnostic</td>
<td>4. Can identify but not describe major branches</td>
</tr>
<tr>
<td></td>
<td>5. Unsuitable (nonselective, poor contrast)</td>
</tr>
</tbody>
</table>

actual progression of disease between the time of premortem examination and death, and that quantification of coronary atherosclerosis even at necropsy is difficult. Second, what factors contributed to the introduction of error? Finally, what is the minimum vessel size beyond which visualization by SCCA is currently impossible? Is there disease in small arteries beyond the range of SCCA?

Methods

Twenty-nine patients studied by selective coronary cinearteriography subsequently died of their underlying disease and were examined post mortem. The interval between coronary arteriography and the time of death varied from 1 day to 22 months (average, 4 months). The data were accumulated over the period 1964 to 1966, as follows: 10 cases in 1964, 13 in 1965, and six in 1966. Coronary arteriographic studies were reviewed by a panel of three members of the laboratory who, prior to any knowledge of necropsy findings, rendered a composite interpretation. After critical evaluation, a rating was assigned each right and left coronary arteriogram depending on the radiographic quality (table 1). Arteriograms of nondiagnostic quality were excluded from the study; all grades of diagnostic studies were included. Angiographic estimate of degree of stenosis was based on decrease in diameter as judged in two projections to estimate reduction in lumen in terms of loss of area of cross section. The gross dissection of each heart was reexamined and each coronary vessel was dissected by the bread-loafing technique. In those instances in which postmortem angiography was available (17 patients), it supported the findings on gross dissection of the main coronary vessels and secondary branches. A final anatomic description was prepared by the pathologist independent of the angiographic results, and it was compared with the previous description of the coronary arteriograms.

Table 2 presents the code used to quantify the degree of agreement or nonagreement between postmortem findings and premortem angiography. A designation "0" was assigned only when there was perfect agreement; a +1 or −1 was assigned only when the degree of nonagreement was of the most minor degree. The remainder of the table is self-explanatory.

Results

Table 3 shows the relative quality of selective coronary arteriograms of the 29 patients. Only one study of each vessel was judged to be of the highest radiographic quality (D1). Twenty and 10 studies of the right and left coronaries, respectively, were of good quality (D2), while six of the right coronary and 15 of the left were considered to be of borderline radiographic quality (D3). For purposes of comparison, the coronary arterial tree was divided into five major divisions: right, left main, left anterior descending, diagonal branches of the left anterior descending, and left circumflex (fig. 1).

Table 1

<table>
<thead>
<tr>
<th>Agreement Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Perfect agreement between angiography and postmortem examination</td>
</tr>
<tr>
<td>1</td>
<td>Minor difference, that is, variation in amount of stenosis &lt; 25%</td>
</tr>
<tr>
<td>2</td>
<td>Major difference, correct functional evaluation</td>
</tr>
<tr>
<td>3</td>
<td>Major difference, incorrect functional evaluation</td>
</tr>
<tr>
<td>4</td>
<td>Overestimation of disease by angiography</td>
</tr>
<tr>
<td>5</td>
<td>Underestimation of disease by angiography</td>
</tr>
</tbody>
</table>

Table 3

Twenty-nine Patients with Premortem Selective Coronary Cinearteriography

<table>
<thead>
<tr>
<th>Radiographic quality</th>
<th>RCA</th>
<th>LCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnostic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>D2</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>D3</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>Nondiagnostic</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>29</td>
<td>29</td>
</tr>
</tbody>
</table>
Right Coronary Artery

Ten of the 27 diagnostic studies of the right coronary artery disclosed a normal artery. There was complete agreement in 22 of the total group. Four instances of minor underestimation of disease occurred (fig. 2). One of these occurred in evaluating a 53-year-old man being studied for possible aortic valve replacement because of severe aortic regurgitation. The lumen of the right coronary artery was large, smooth, and on cinearteriography appeared to move in a supple fashion. Blood flow appeared to be pulsatile—a characteristic seen almost exclusively in normal vessels. At postmortem examination, however, there was an approximate 25% decrease in the area of the lumen due to coronary atherosclerosis, which was constant throughout its length. The lumen nevertheless was quite large as seen on premortem angiography. Thus, while atherosclerosis was overlooked, appraisal of size of the lumen was accurate and the “functional” assessment of the vessel was correct. Other instances of minor underestimation of disease were as follows: (1) a 90% mid-stenosis at angiography was found

Figure 1

(Upper) Normal left coronary arteriogram (LCA); left anterior oblique projection. (Lower) Normal right coronary arteriogram (RCA); left anterior oblique projection. LAD = left anterior descending artery; Diag. = diagonal branches of left anterior descending artery.
to be a complete occlusion at postmortem examination 8 months later, (2) a second small marginal branch of the right coronary artery with an 80% discrete stenosis in its proximal portion at postmortem examination was not visualized by SCCA, and (3) a 50% proximal stenosis at angiography proved to be 75% at postmortem examination 22 months later.

Only one significant error occurred. In this instance, a short 80% proximal stenosis was found by dissection whereas interpretation of coronary angiography 10 days premortem was intraluminal disease, but no single area of stenosis greater than 50%. The vessel was seen in the right anterior oblique projection only, and in this projection, the proximal portion of the right coronary artery extends directly toward the viewer. This makes possible superimposition of a proximal or distal portion of dye-filled lumen of normal caliber on a short area of stenosis and was the probable source of interpretive error in this instance.

**Main Left Coronary Artery**

Of 26 diagnostic studies of the main left coronary artery, 25 were in complete agreement (fig. 3). Only one instance of minor...
underestimation of disease occurred. A possible source of this error is discussed below.

**Left Anterior Descending Coronary Artery**

The left anterior descending coronary artery was normal in seven of 26 vessels studied. There was complete agreement in 19 and only a minor degree of underestimation of disease in six (fig. 4). The source of minor error in four of the six patients was the presence of a “crescentic” as opposed to a concentric, stenosis. Figure 5 is a schematic representation illustrating how crescentic stenosis may cause a vessel to appear of normal caliber when seen in one plane only. In the one instance of underestimation of disease of the main left coronary artery, such a crescentic stenosis was the source of error.

The only significant error in evaluating the left anterior descending coronary artery occurred in a 35-year-old man with severe three-vessel coronary artery disease. The left anterior descending artery was severely involved with intraluminal disease, narrowing the lumen to 25% or less of its normal dimension. Six days after study, he was taken to surgery for internal mammary artery implantation. During induction of anesthesia, blood pressure dropped to 70 mm Hg and was allowed to remain at that level. Postoperatively, the patient was in shock and developed pulmonary edema. A previously normal electrocardiogram now showed changes suggesting acute anterior infarction. The patient died within 2 hours. Postmortem examination revealed occlusion of the left anterior descending coronary artery, which on microscopic examination did not appear to be acute. Although subsequent repeated viewing of the cineangiogram has failed to allow for a revised inter-

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**Figure 6**

Distribution of errors in the diagonal branches of the left anterior descending artery.

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**Figure 7**

Postmortem angiogram showing calcified and totally occluded A-V branch of the left circumflex coronary artery with filling of enlarged atrial branch which fills collaterals to marginal branch of the left circumflex and posterior left ventricular wall.
pretation, this has been tabulated as an error of grade 3 significance.

**First Diagonal Branch, Left Anterior Descending Artery**

The first diagonal branch of the left anterior descending coronary artery was normal in nine of 26 studies (fig. 6). In 21 instances there was complete agreement, while in two there was minor underestimation, and in three, minor overestimation of disease. The instances involving overestimation of disease were of interest. In each case, the vessel was small, but this was a normal variant and was not due to coronary atherosclerosis. Because of the presence of severe disease in the other coronary vessels, it was erroneously assumed that the same process was responsible for the narrow caliber of the first diagonal branch.

**Left Circumflex Artery**

A major error occurred in assessment of the left circumflex in one patient. In this instance, postmortem angiography (fig. 7) revealed a totally occluded, calcific left circumflex artery without a stump or blunting at the parent vessel. Superimposed upon this artery and following alongside its path over a distance of 3 to 4 cm was a large patent, fully developed atrial branch of the left circumflex system. Assessing function in terms of radiopacification, this vessel appeared to be supplying the myocardial distribution of the occluded left circumflex artery. Accordingly, this atrial branch was mistaken for the left circumflex artery.

Overestimation of disease was seen with the left circumflex system as with the left diagonal system (fig. 8). The error resulted from having implicated this vessel on the basis of "guilt by association." This source of error was unique to the diagonal and left circumflex arteries which may normally vary greatly in size and distribution.

**Discussion**

Although the progression of disease may distort correlation between premortem arteriographic and postmortem findings, such a comparison is still the most objective means of assessing the accuracy of selective arteriography. Despite innumerable opportunities for error in assessing 145 coronary arteries individually, only 23 errors were made and of these only three were of functional significance. The frequency and extent of error bore no clear-cut relationship to the year of study in this small series.

Recently, Robbins and Rodriguez emphasized the difficulty of quantification of coronary atherosclerosis even at postmortem examination. Using three different techniques in the same hearts, these authors found a surprising variance in estimates of intraluminal stenosis assessed by different observers. Nevertheless, it was necessary to use the postmortem data as some sort of base line for comparison with the arteriographic interpretation. In this way, one may well overestimate the "correctness" of the postmortem evaluation and underestimate the accuracy of coronary arteriography. It was this difficulty in quantification that inclined the authors not to overemphasize absolute members of errors, except when these errors were of functional significance, but rather to attempt to find particular anatomic situations which made interpretation of arteriography difficult.

Several particular hazards to correct interpretation were evident. If the cross-sectional shape of a discrete stenosis is crescentic rather than concentric, the diameter of that area can appear normal if seen in only one
projection. As emphasized by Osborn, among others, atheromas are much more frequently eccentric than they are circumferential. Two arteries, the diagonal branch of the left anterior descending and the left circumflex, vary greatly in size and distribution in normal hearts. If they are small in the presence of severe coronary artery disease elsewhere, they may be incorrectly interpreted as being atherosclerotic as well. In patients with a highly dominant right coronary artery, the virtual absence of the left circumflex in the posterior atrioventricular sulcus may be normal. This problem arose in interpreting one of the arteriograms in this series. After extensive reviewing of the film, it was felt that a "stump" of the left circumflex could be seen, and the correct interpretation of an occlusion was made.

In another study, a unique problem arose in which one vessel appeared to "substitute" for another. The left circumflex artery was completely occluded and calcified. An atrial branch which arose just proximal to the occlusion had dilated to such an extent that its diameter was as large as that of the left circumflex artery. It ran parallel just above the atrioventricular sulcus and gave off collateral vessels to the marginal branch of the left circumflex with good flow and distribution as determined arteriographically.

Several potential problems in interpretation were carefully sought but not found in this study. If spasm occurs in a coronary artery during arteriography, an incorrect interpretation of stenosis might be made. Although in most instances arteriography was performed before and after administration of nitroglycerin, no instances of spasm were seen which were not clearly at the tip of the catheter and relieved by a change in catheter position. The only instances of overestimation of disease were in the diagonal system and left circumflex arteries, as discussed above. Because of the variation normally encountered in the anatomy of the coronary arterial tree, occlusion of a tertiary or even secondary branch flush with the parent vessel might be missed, particularly in the absence of atherosclerosis in the other coronary arteries. Though this continues to seem a likely source of error, it accounted for only one instance of minor underinterpretation in this study.

In one of the selective left coronary arteriograms, sino-atrial node artery arose from the proximal left circumflex artery and could be followed for a distance of 4 cm or more through its course in the atrium. By carefully dissecting this artery at postmortem examination, an estimate was made of the vessel size which can be seen arteriographically. On projected still frames, the artery could be seen clearly when its internal diameter was 0.5 mm, and when viewed in motion, it could be seen easily when it had narrowed to half that size. In studies of excellent quality, smaller vessels can be seen. It should be borne in mind, however, that this represents the current limits within which the presence or absence of a vessel can be recognized, but accurate description of luminal irregularities in these small vessels is not feasible. Although the hearts in this series were not exhaustively examined for small vessel disease beyond routine histological section, other investigators have found that coronary atherosclerosis is a disease of the large epicardial vessels and rarely, if ever, is limited to vessels too small to be well visualized by coronary arteriography.

A direct relation existed between the quality of the arteriogram and the accuracy of the interpretation (fig. 9). The better the quality of the film, the fewer errors were made. The only studies in which significant errors were made were those of borderline radiographic
quality. The converse would appear to be equally true: that if a study is of excellent quality, a high degree of accuracy is possible. In the interpretation of the single best right and left coronary arteriograms in the study, seven discrete lesions were interpreted exactly as they appeared at postmortem examination.

A number of factors contribute to radiographic quality. Certain of these are technical and relate to the cine and image intensification system; these will be mentioned only categorically here. Focus and contrast must be capable of a high degree of resolution. Magnification must be adequate for viewing the proximal portions of the major arteries. The equipment must produce consistent results from day to day with patients of varying sizes. Finally, all of the factors which might be included under the general term "projection"—including film handling, processing, actual projection equipment and projection room—contribute to the final quality. The skill of the arteriographer is of equally great importance. A high quality arteriogram usually will not result from this technique unless the dye injection is made selectively into the coronary ostium. Proper framing and panning, appropriate use of magnification and multiple projections all add to the quality of the study.

The final step involves the human process of interpretation. Experience is required to distinguish normal variants from disease, to recognize different degrees of intraluminal stenosis, to appreciate differences in the motion of a vessel when it is restricted by intramural disease, and to look for the common pathways of collateral flow. An example of an interesting normal variant was found in this series. The coronary arteries appeared normal except that they became extremely tortuous in the distal two thirds of their course. Tortuosity of arteries in other organs may suggest atherosclerosis. Because of the absence of any other indication of disease, the correct interpretation was made that these were normal vessels. Collateral flow is particularly well seen by the selective technique. In several instances, collateral channels could be seen arteriographically that were also demonstrated by postmortem angiography but were impossible to trace on gross dissection.

Occasionally, the angiographer may decide to limit his goal in a particular patient in order to shorten the procedure. One of the patients in the study was a man with severe aortic stenosis, being evaluated for valve replacement. Selective coronary catheterization proved to be difficult, and it was elected to settle for a nonselective study of lesser quality. This was with the realization that accurate interpretation would be possible only regarding disease of his major vessels; the information which was clinically important. At postmortem examination, the interpretation of the arteriography was correct with regard to the major arteries, but coronary atherosclerosis was also present in the distal portions of the coronary vessels which could not be seen at premortem angiography. Therefore, while selective coronary cinearteriography is highly accurate, the angiographer must constantly bear in mind the quality of each individual study when evaluating the probable accuracy of the interpretation.

References

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