Discrepancies Between Cineangiographic and Postmortem Findings in Patients with Coronary Artery Disease and Recent Myocardial Revascularization

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SUMMARY
In 28 consecutive patients who died following coronary artery grafting and within 30 days of a previous coronary cineangiogram, a study was undertaken to compare the findings at autopsy and those at angiography. In five instances, such a comparison could not be made: in one instance, no postmortem examination was obtained, and in four additional cases, the quality of the cineangiographic document (three instances) or the pathological specimen (one instance) did not permit a reliable comparison. In the remaining 23 cases, there were nine specimens in which an appreciable difference (≥25%) was noted in the severity of the coronary artery lesions. In four of these nine cases, failure of cineangiography to assess the degree of coronary arterial narrowing led to incomplete myocardial revascularization and contributed, in retrospect, to the surgical failure. Most discrepancies occurred in the left coronary artery system, despite the fact that in all instances, four projections had been obtained of the left coronary artery in the transverse plane. Because of the particular orientation of the initial portion of the left coronary artery and its major divisions, it is recommended that additional projections in the sagittal plane be included to eliminate angiographic superimposition of multiple branches, which often cannot be properly separated in the standard transverse plane.

Additional Indexing Words:
Cinecoronary arteriography
Early postoperative mortality in coronary artery grafting
Technique of cinecoronary arteriography

CORONARY ARTERIOGRAPHY remains the most accurate method of detecting the presence and severity of coronary artery disease. Its value in the study of the natural history of ischemic heart disease has been established in recent reports.1–3 Authors disagree, however, on the correlations between the lesions described at angiography and those found at autopsy.4–7 Several of these studies compare the accuracy of anatomical dissection to that of postmortem angiography,8,9 while others, dealing with in vivo coronary arteriography,4–6 show a delay of months or years between the angiographic study and the postmortem examination. Little information is available concerning the incidence, severity or consequences of discrepancy between the findings at autopsy and those on a recent coronary cineangiogram.

The purpose of the present communication is 1) to compare findings at coronary arteriography and at autopsy in a consecutive series of patients who, following coronary artery grafting, died less than one month after a cineangiographic study, and 2) to comment on the incidence and clinical consequences of discrepancies between angiography and pathological examination and on recent technical refinements in coronary angiography which may help minimize these discrepancies.

Clinical Material
Thirty-six of the first 500 patients (7.2%)* who

*The 7.2% operative mortality is for all patients who underwent coronary artery grafting, including those with stable angina, impending infarction, left ventricular aneurysm, and valvular disease.
underwent coronary artery grafting at the Montreal Heart Institute died in the early postoperative period or at operation. In 28 of these 36 patients, a coronary cinearteriogram had been obtained less than one month before death. A postmortem examination was conducted in all but one patient. The average time elapsed between angiography and autopsy was 11 days. The surgical technique utilized varied to some extent during that period (1969 to 1972),\textsuperscript{10} while that of coronary arteriography did not,\textsuperscript{11} although several important changes were made recently in the light of the present study.\textsuperscript{12}

### Angiographic Technique

The technique of cinearteriography utilized during the present study consisted essentially of manual injection of contrast medium via a special catheter* introduced percutaneously through the femoral artery. A 35 mm camera (60 frames/sec) was mounted on the C-Arm of a Picker Saturn apparatus that could rotate 180° about the thoracic cage in the transverse plane. Four views were obtained of the left coronary artery (LCA): the frontal, lateral, left anterior oblique (LAO, 45° to 60°) and right anterior oblique (RAO, 30°) projections. For the right coronary artery (RCA), the lateral projection was not obtained routinely throughout this study, while the other three projections were.

### Pathological Examination

The grading of atherosclerotic narrowing of coronary arteries was performed according to the following method: at postmortem examination, the coronary arteries were transected at 2 mm intervals and the encroachment upon the lumen by atherosclerotic material was graded from 0 to IV; grade 0 meant no lesion; grade I, 25% narrowing of the lumen; grade II, 50%; grade III, 75%; and grade IV, complete occlusion. The same grading was utilized subsequently when reviewing the cineangiographic films, although in the formal angiographic report narrowings are usually expressed to the nearest 5%. For a more precise evaluation, the standard grades were halved so that I+ meant 37% narrowing, II+ 62% narrowing and III+ 87% narrowing. The percentage of narrowing of the arterial lumen was assessed as follows: at angiography, the diameter of the artery was measured at the site of maximal narrowing on one of the multiple projections obtained. This diameter was compared to the diameter of the artery distal to the stenosis in that particular view. A percentage was thus arrived at and the figure nearest to the grades described above was used. At autopsy, the percentage of the arterial lumen occupied by atheromatous material was first visually assessed, and the diameter of the residual lumen at its narrowest point was measured with graded probes and was compared to the diameter of the lumen of the artery distal to the narrowing. The two figures usually coincided except for narrowings with slit-like lumen, where the percentage utilized was that obtained with the probe technique.

The angiograms were reviewed by one of us (JL) without prior knowledge of discrepancy. This final assessment did not differ appreciably from the original reading of the film. In three instances, where appreciable differences were found in coronary arterial lesions at postmortem examination, the quality of the angiographic study was deemed unsatisfactory, either because of nonelective injections, especially of the right coronary artery, or because of the insufficient number of projections obtained. Likewise, in one additional instance the state of preservation of the autopsy specimen did not permit reliable comparison between anatomical and angiographic findings. These four cases were therefore rejected.

### Results

In the 23 cases where the quality of the coronary arteriogram and postmortem specimen allowed comparison of findings, there were 9 instances of significant disagreement or discrepancy between these two methods of investigation. In general, the arterial lesions appeared more severe and more extensive or diffuse at postmortem examination than at angiography. The postsurgical changes often rendered dissection and analysis of small vessels (external diameter ≤ 1.5 mm) difficult; angiography therefore proved more valuable and more accurate in assessing lesions in these peripheral branches (≤1.0 mm internal diameter at angiography). This study, however, was designed to compare the accuracy of the two methods vis-à-vis lesions of the proximal portion of major coronary divisions since only the latter are amenable to surgical therapy. In no instances did the angiogram overestimate the severity or the length of anatomical narrowing in the major divisions.

Discrepancy of less than one grade (< 25%) was frequent and was discarded. A difference of one grade (25%) was taken into account only when it occurred in lesions which at angiography caused a narrowing of at least 50% of the lumen. Such a discrepancy indeed converted a nonsurgical narrowing (50% or grade II) into a surgical narrowing (75% or grade III). On the other hand, anatomical narrowing of 50% of the lumen of the artery was accepted—although not a surgical lesion by present standards—when the angiogram showed no appreciable narrowing (grade 0).

### Arteries Involved and Sites of Involvement

In the nine specimens mentioned above, there was a total of 11 arteries in which there was a discrepancy between the findings at angiography and those at autopsy. As outlined on table 1, the right coronary artery (RCA) was involved in three instances, the left coronary artery (LCA) in eight cases. In two of the three cases where the RCA was

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*Bourassa Catheters, United States Catheter and Instrument Corporation, Billerica, Mass.*
Table 1
Possible Influence of Discrepancies on Outcome of Patients

<table>
<thead>
<tr>
<th>Patient</th>
<th>Influence</th>
<th>Artery with discrepancy</th>
<th>Could have been bypassed</th>
<th>Bypassed</th>
<th>Angiogr. diagnosis</th>
<th>Pathol. diagnosis</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>Post. desc.</td>
<td>No</td>
<td>No</td>
<td>0</td>
<td>II</td>
<td>Postoperative brain damage. Died on 3rd day</td>
</tr>
<tr>
<td>2</td>
<td>Likely</td>
<td>Left marginal</td>
<td>Yes</td>
<td>No</td>
<td>I+</td>
<td>III+</td>
<td>Ventricular fibrillation in OR and 12 hrs PO</td>
</tr>
<tr>
<td>3</td>
<td>None</td>
<td>Diagonal</td>
<td>Yes</td>
<td>Pre-stenosis</td>
<td>I</td>
<td>III</td>
<td>Died 48 hrs PO of retrograde dissecting aneurysm of aorta</td>
</tr>
<tr>
<td>4</td>
<td>None</td>
<td>LAD</td>
<td>Yes</td>
<td>Yes</td>
<td>II+</td>
<td>III+</td>
<td>Died 48 hrs PO of MI and shock</td>
</tr>
<tr>
<td>5</td>
<td>Likely</td>
<td>RCA</td>
<td>Yes</td>
<td>Yes</td>
<td>I</td>
<td>III</td>
<td>Died in OR, unable to come off bypass</td>
</tr>
<tr>
<td>6</td>
<td>Likely</td>
<td>Cx (dominant)</td>
<td>Yes</td>
<td>No</td>
<td>0</td>
<td>III</td>
<td>Died in OR, unable to come off bypass</td>
</tr>
<tr>
<td>7</td>
<td>Likely</td>
<td>Post. lat. br. of Cx.</td>
<td>Yes</td>
<td>No</td>
<td>I</td>
<td>III</td>
<td>Died in OR, unable to come off bypass</td>
</tr>
<tr>
<td>8</td>
<td>None</td>
<td>Cx proximal</td>
<td>Yes</td>
<td>No</td>
<td>II</td>
<td>III+</td>
<td>Died 48 hrs PO of MI and shock</td>
</tr>
<tr>
<td>9</td>
<td>None</td>
<td>LAD</td>
<td>Yes</td>
<td>No</td>
<td>II+</td>
<td>III+</td>
<td>Died in OR. Had severe muscular subaortic stenosis</td>
</tr>
</tbody>
</table>

Abbreviations: Post. desc. = Posterior descending branch of RCA; RCA = Right coronary artery; LAD = Left anterior descending artery; Cx = Circumflex artery; Pre-stenosis = the graft was inserted proximal to a stenosis; OR = Operating room; PO = Post-operatively; MI = Myocardial infarction.

involved (fig. 1, cases 1 and 2), the lesion on which the two methods of investigation disagreed consisted of a short stenosis at the take-off of the posterior descending branch. In one of the two cases, the injection of contrast medium was not selective on all standard views. This case would have been rejected, had it not been for the additional discrepancy noted in a lesion of the circumflex coronary artery for which an adequate angiographic document had been obtained. In the second instance, the posterior descending branch and the distal portion of the RCA ran a parallel course. Overlapping of these two branches was probably responsible for angiographic underestimation of the degree of stenosis in this case. The third case of discrepancy over a lesion of the RCA consisted of a tubular narrowing of the initial portion of the artery, estimated to be grade I at angiography and grade III at postmortem examination. The lesion was diffuse in this case so that the comparison with the normal size artery was not possible (fig. 1, case 4).

Of the eight cases of discrepancy in the LCA, there were two involving the origin of the first diagonal branch (fig. 1, cases 3 and 7). In both cases, the difference was of 2 grades (50%). Overlapping of the diagonal and of the left anterior descending (LAD) was believed responsible for the discrepancy in both instances. In two cases (fig. 1, cases 4 and 9), a grade III+ (87%) narrowing of the proximal portion of the LAD was misdiagnosed angiographically as grade II+ (62%) narrowing. In retrospect, in these two cases, additional projections in the sagittal axis (see comments) would probably have assessed with greater accuracy the degree of narrowing located in the very proximal portion of the LAD. In the remaining four cases, lesions for which there was a major difference of opinion were located in the proximal portion of either the circumflex artery (fig. 1, cases 5 and 8) or of one of its branches (1 posterolateral branch, 1 marginal branch) (fig. 1, cases 2 and 6). In both instances of involvement of the proximal circumflex, the narrowing was diffuse. In the other two cases, discrepancy was due either to insufficient number of oblique views—although four were obtained—or to the inherent deficiency of cinearteriography vis-à-vis certain types of lesions in specific areas, e.g., short stenoses at take-off of branches.

Comments
The surgical treatment of ischemic heart disease...
Diagrammatic portrayal of coronary arterial lesions for which a discrepancy existed between findings at autopsy and at cineangiography. The roman numbers in the squares indicate the degree of narrowing as seen at angiography (A) and at pathological (P) examination. Narrowings are graded from 0 to IV (0% to 100%). Vein grafts to various arteries can be recognized by the hash marks. Order of patients is same as in table 1 and in arabic numbers in lower right hand corner. In cases 2, 5, 6 and 7, angiographic underestimation of the severity of coronary arterial lesions led to incomplete revascularization and contributed to the surgical failure. PDB = posterior descending branch; LAD = left anterior descending artery; Cx = circumflex artery; MARG = marginal branch of Cx; PL = posterolateral branch of Cx; DIAG = diagonal artery; IHSS = idiopathic hypertrophic subaortic stenosis.

relies heavily on the accuracy of coronary arteriograms. In several centers, the simple angiographic demonstration of a severe narrowing in a specific area, for instance the left main or the high anterior descending coronary artery, constitutes a sufficient criterion for surgical intervention even in the absence of clinical symptoms. Angiography must neither fail to demonstrate significant coronary artery disease nor overestimate the severity of a lesion. Most authors agree that coronary arteriograms tend to underestimate coronary arterial lesions. Despite great interest in this field, studies comparing angiographic and anatomical findings are relatively few in the English literature. Most of the early reports compared in vitro angiography and anatomical dissection. The accuracy of postmortem angiograms has been seriously questioned. On the other hand, in most studies published so far concerning in vivo cineangiography, a delay of months to years occurred between the angiographic study and the pathological examination. It is indeed surprising that little discrepancy could be found in a large series where the average delay was one and a half years. In a more recent study by Vlodaver and his co-workers of 10 specimens, the interval varied from 3 to 13 weeks except in one case in which it was 3 years.

Rapid progression of coronary artery disease, as demonstrated by angiography, is not infrequent. Several reports have been published recently on the natural history of coronary atherosclerosis as seen angiographically. However, there are problems inherent in studies concerned with angiographic progression of coronary artery disease, as these studies require long period of follow-up during which the quality of arteriographic documents is bound to improve. As stated by Kemp and co-workers, the single most important factor in determining the accuracy of selective coronary arteriography in the radiographic quality of the study.

The present study covers a period of three years

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beginning at the end of 1969, at a time when the technique of selective cineangiography had been standardized at this institution and multiple projections in the transverse plane were available. Cases in which the quality of the angiographic study was questionable were rejected. Moreover, the short interval—less than one month—between angiographic and postmortem examinations virtually eliminates progression of coronary artery disease as a factor responsible for the discrepancy noted between these two methods of investigation. Other factors which may explain the variance in findings include 1) postmortem alterations, 2) the different behavior of the atheromatous lesions in vivo and in vitro, and 3) the inadequacy of present techniques of cineangiography.

It has been suggested that changes due to postmortem shrinkage and fixation techniques may lead to overestimation of obstructive lesions. There is little evidence, however, that the ratio diameter of lesion-to-residual lumen can be significantly altered by postmortem changes. For this ratio to change, one would have to assume that following fixation the arterial wall shrinks while the atheromatous material remains unchanged. On the other hand, atheromatous deposits are often eccentric and are not necessarily rigid or calcified. Early lipid-containing lesions may be compressed and may obey changes in pressure and motion. Distension of the artery in vitro or in vivo by injection of contrast medium or in vivo by the blood pressure itself may mask luminal narrowing to some degree, and thus contribute to “underestimation” of lesions. This point was also stressed by Vladauer and associates who were of the opinion, however, that multiple angiographic projections would considerably reduce discrepancies between angiography and postmortem examination. Indeed, in most instances, only two projections had been obtained in the study conducted by these investigators through the biplane Schonander technique.

In the present study, despite the fact that three or four projections—frontal, lateral, LAO, and RAO—were obtained in all instances, discrepancies were not infrequent. The number of projections obtained with the present technique of cinearteriography is, therefore, probably insufficient especially for the left coronary artery system. Because of the particular transverse orientation of the initial portion of the branches of the left coronary artery, there is frequent overlapping of these branches in the transverse plane. Accordingly, following the present study, the technique of angiography was modified so as to minimize this overlapping. This technique, which has been described in greater detail elsewhere, consists of sagittal angulation of the X-ray tube in order to obtain—in addition to the present rotational views in the transverse plane—a rotation in the sagittal cephalo-caudal axis (fig. 2). Coning is also used to increase contrast in the critical area of the LCA and its major divisions. These additional projections, which require increased manipulations and injections, are reserved for the left coronary artery since angiographic underestimation of lesions on the right side stems mainly from nonselective injection or from superimposition of the diaphragm rather than from overlapping of coronary artery branches. The sagittal angulation allows for separation of the LAD, the diagonal, the circumflex and the left marginal arteries which, in their initial portion, often tend to run a course parallel to the transverse axis of the X-ray beam and, consequently, may be seen end-on or tangentially in the standard transverse plane.

Of additional interest in the present study were the incidence of discrepancy between cineangiography and postmortem examination and the probable influence such discrepancies exerted on operative mortality. In 23 postmortem examinations of patients who succumbed shortly after coronary artery grafting and within 30 days of a previous coronary arteriogram, there were 9 specimens in which significant differences were noted in the coronary artery lesions as estimated by these two methods of investigation. The over-all incidence of discrepancy was lower when the total number of lesions is considered. Out of a total of 145 angiographically significant lesions of the coronary arteries in these 23 cases, only 11 lesions (7.5%) proved at autopsy to have been grossly underestimated at angiography. As shown in the table 1, in four of the nine cases, underestimation of the severity of the lesion by angiography and the subsequent decision not to bypass the arteries involved resulted in incomplete myocardial revascularization and contributed, in retrospect, to the surgical failure. In three of these four instances, it was not possible to wean the patient from cardiopulmonary bypass. The fourth patient developed ventricular fibrillation in the operating room and had cardiac arrest 12 hours postoperatively. In none of the remaining five patients did the underestimation of the arterial narrowing by angiography appear to influence survival of the patient. Only one of these five patients succumbed.
in the operating room. This patient had severe muscular subaortic stenosis.

It may be argued that similar discrepancies were present but undetected in patients who did well after coronary grafting or that no discrepancies were noted in 14 of the 23 patients who comprise the present study. There were, however, only two operative deaths in these 14 patients and only one operative death in the group of five patients in whom autopsy revealed discrepancies which were not believed to have influenced the surgical result. Myocardial failure secondary to inadequate intraoperative myocardial protection or to incomplete revascularization remains the major cause of operative deaths in coronary artery grafting. Failure of cineangiography to assess the severity of coronary artery disease may lead to incomplete revascularization. Occasionally, a patient may be denied treatment of significant coronary artery disease which has either not been detected angiographically or has been underestimated.

It must be recognized however that the quality of cineangiographic documents has improved considerably in very recent years due to major technological advances. These include the use of cesium iodide image intensifiers, optimal over-frame lensing, magnification or coning of critical areas and, most important in our opinion, the multiple angulations or projections obtained not only in the transverse plane—which provides the conventional frontal, lateral and oblique views—but also in the sagittal plane. It is hoped that these technical refinements will help minimize discrepancies between, in essence, the image and the reality.

References


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