The Significance of Coronary Calcification Detected by Fluoroscopy

A Report of 360 Patients

By Alan G. Bartel, M.D., James T. Chen, M.D., Robert H. Peter, M.D., Victor S. Behar, M.D., Yihong Kong, M.D., and Richard G. Lester, M.D.

SUMMARY
Cardiac fluoroscopy to detect coronary calcification was performed on 360 patients before undergoing coronary arteriography for proven or suspected coronary artery disease. Among the 154 patients in whom coronary calcification was identified, 97% had significant coronary disease angiographically (≥70% stenosis). In this group, the distribution of one, two, and three vessel coronary disease was 9%, 25%, and 66% respectively. The prevalence of coronary calcification increased with age and severity of coronary disease, but no difference in males versus females was demonstrable. The angiographic severity of coronary disease increased with multiple vessel calcification; three vessel disease occurred in 45%, 66%, and 82% of patients with one, two, and three vessel calcification, respectively. Patients with hyperlipidemia or hypertension had no significant difference in the prevalence of coronary calcification. Among the 267 patients with significant coronary lesions, 56% had calcification detected by fluoroscopy.

Five of the 93 patients with no significant coronary disease angiographically had coronary calcification fluoroscopically. Four of the five had a prior history of myocardial infarction, and two showed asynergy on left ventriculography.

This study demonstrates that cardiac fluoroscopy is a valuable procedure for detecting significant coronary artery disease since this highly specific test is easily performed, inexpensive, noninvasive, and widely applicable for screening large patient populations.

Additional Indexing Words:
Coronary artery disease  Ischemic heart disease  Coronary arteriography
Hypertension  Hyperlipidemia  Radiologic studies

CORONARY CALCIFICATION occurs in the intima and reflects advanced atheromatous disease.2 Radiographic analysis of large series of living and autopsied patients have demonstrated that coronary calcification is easily detected, occurs frequently, increases with age, and indicates severe underlying lesions. There are no large series which correlate the results obtained at cardiac fluoroscopy with the findings at coronary angiography.

The present study indicates that detection of coronary calcification by the noninvasive technique of cardiac fluoroscopy in a largely symptomatic population identifies severe coronary artery disease in 97% of patients, most of whom have three vessel disease.

Methods
The population studied is composed of 360 consecutive patients undergoing routine fluoroscopy prior to cardiac catheterization and coronary cineangiography. All patients were studied between September 1969, and November 1972, because of suspected or proven coronary artery disease, and many were undergoing evaluation for coronary vein bypass surgery.

Cardiac fluoroscopy was performed within five days prior to cineangiography, image intensification was routinely
used, and at times, videotape recordings were made for further analysis. Most of the patients were studied in both erect and recumbent positions in at least four different views. The average examining time was 3.5 min. All studies were performed by one fluoroscopist (J.C.) without knowledge of the patient’s clinical status.

Technique of Fluoroscopy

The advent of image intensification has made modern fluoroscopy the most powerful tool for the diagnosis of coronary artery calcifications. It is the recorded motion of small densities that makes their visualization possible. However, even this technique may fail to register any number of small calcific spots if the examination is only casually done, or if certain important factors are disregarded.

1. Fluoroscopy of the heart is ideally performed in four different views with the patient erect and holding his breath in full inspiration. These views include the postero-anterior, left lateral, and right anterior oblique at 20° and left anterior oblique at 45°. No barium meal should be given until the search for intracardiac calcification is completed.

Also of importance is a recognition of the relative sensitivity of different views for visualization of different coronary arteries. For example, one may miss a small calcification in the right coronary artery completely if a true lateral view is not used. The right anterior oblique and lateral views are ideal for detection of calcifications in the anterior descending coronary artery. However, calcifications in the same vessel may be completely invisible in the left anterior oblique view. The left anterior oblique view, on the other hand, is advantageous for separating calcifications in the circumflex from those in the anterior descending, as well as for detecting densities in the posterior descending branch. Sometimes, recumbency may help visualize small calcifications in the large or obese patient.

2. Technical factors crucial for visualization of small densities include proper selection of mA, kV, and shutter opening. Unnecessarily high kV tends to reduce the contrast and details of the images, and excessive mA tends to blur off a small image into a globe of fluffy lights. All patients included in this study were examined using a General Electric X-ray generator with a six inch Vidicon image intensifier tube and a Sony television monitor. The tube gain was at least 5,000. The mA varied between 1.5 and 3.5 and the kV between 70 and 110 depending on the size of the patient. The X-ray unit was also equipped with an automatic brightness control which maintained optimal kV utilizing a photoelectric cell at the level of the output phosphor. Additional clarity of the fluoroscopic image was achieved by the use of a shutter mechanism which delimited the field size to include only the primary area of interest.

In each of the four views mentioned above, one should readjust the exposure factors and shutter size briefly in order to see the calcific vessels to better advantage.

Detailed knowledge of the coronary anatomy and relationships to adjacent cardiovascular, pulmonary, and mediastinal structures aids in differentiation of coronary calcification from calcified deposits in the mitral valve leaflets, mitral valve anulus, aortic valve, ascending aorta, pericardium, left ventricular aneurysm, lymph nodes, etc.

Right and left heart catheterization, Fick cardiac output, and left ventricular cineangiography were performed. Selective coronary cinearteriography at 60 frames/sec with multiple views in single or biplane modes was performed using Judkins or Sones techniques. A significant lesion was defined as 70% or greater stenosis in a major coronary artery or branch and was agreed upon by at least three angiographers. Significant lesions were divided into total occlusion or subtotal lesions (70–99% stenosis). Significant stenosis of the main left coronary was considered equivalent to combined stenosis of the left anterior descending and circumflex coronary arteries. All data were collected prospectively and stored in a Sigma V computer for subsequent statistical analysis.

In order to determine whether stenotic lesions occurred in the site of calcification, 40 consecutive cases with coronary calcification heavy enough to be detected during cineangiography were studied. The presence or absence of a significant coronary lesion in the exact site of calcification was recorded along with the frequency of occlusive disease in the vessels without apparent calcification.

Results

Coronary calcification was detected fluoroscopically in 154 of the 360 patients examined (43%). Among the 154 patients, 149 (97%) had significant coronary artery disease demonstrated by coronary cineangiography, while five (3%) had no significant coronary disease. Among those patients with significant coronary disease and coronary calcification, 9% had significant stenosis of one coronary artery, 25% had stenosis of two vessels, and 66% had three vessel involvement. The left anterior descending coronary artery was most frequently calcified (75% of the patients); however, the left circumflex and right coronary arteries were also frequently calcified (67% and 53% respectively). Calcification of the left main coronary was found in 4% of the cases.

The prevalence of coronary calcification generally increased with age (fig. 1). This trend was more evident for males. However, there was no significant difference in the prevalence of calcification in males or females either subdivided by decade or comparing the entire group. The prevalence of coronary calcification was related to the severity of angiographically demonstrable coronary disease, increasing from 5% in patients without significant coronary stenosis to 66% in patients with three vessel occlusive coronary disease (fig. 2). Among the entire population of 267 patients having significant coronary disease angiographically, 149 (56%) had coronary calcification demonstrable by fluoroscopy.

The 154 patients with coronary calcification were subdivided into three groups based on the extent of
calcification. Fifty-three patients were found to have calcification limited to a single coronary artery. Fifty-six patients had calcification of two coronary arteries, and 45 patients had three vessel calcification. The severity of coronary disease demonstrated angiographically increased progressively with the extent of fluoroscopically demonstrable calcification (fig. 3). Among those patients with three vessel calcification, all had significant occlusive coronary disease by angiography and 82% had three vessel coronary disease. The number of vessels calcified usually underestimates the number of vessels with significant stenosis: 76% of the patients with single vessel calcification had significant stenosis of two or three coronary arteries.

**Relationship Between Site of Calcification and Significant Coronary Lesions**

Table 1 demonstrates that in the presence of calcification of the left anterior descending, left circumflex, and right coronary arteries, significant occlusive lesions were found at similar sites on arteriography in 89%, 79%, and 95%, respectively. The frequency of subtotal and total lesions in the calcified vessel was approximately the same for the left anterior descending and right coronary arteries. However, in the circumflex branch, subtotal stenosis was almost three times as frequent as total occlusion. Among 53 patients with single vessel calcification (table 2), 25 had calcification limited to the left anterior descending distribution. Among these, 11 had subtotal left anterior descending lesions angiographically and nine had total occlusions. Five had "insignificantly narrowed" vessels. Thus, 20 of 25 patients with isolated calcification of the left anterior descending coronary had significant lesions demonstrated in that vessel by angiography. Twenty-four of the 25 patients (96%) had significant coronary lesions demonstrated in at least one coronary artery. A similar analysis revealed that among 14 patients with isolated calcification of the left circumflex coronary, 57% had significant lesions in the circumflex system and 86% had significant coronary atherosclerosis angiographically. Among 14 patients with calcification limited to the right coronary artery, 93% had significant stenosis of the right coronary artery, and all had significant coronary disease angiographically.

**Correlation of Area of Calcification With Exact Site of Stenosis**

Among the 40 consecutive patients having calcification which was detected during...
cineangiography, all had significant coronary disease, and 8%, 20%, and 72% had one, two, and three vessel disease respectively. The stenotic vessel was in the exact site of calcification in 91% of the 34 left anterior descending calcifications, 93% of the 15 circumflex calcifications, 83% of the 12 right coronary calcifications, and four of the five calcified main left coronary arteries. Only 10% of the 66 calcified vessels had no significant stenosis demonstrated angiographically in the exact site of calcification.

Table 1

The Relationship Between the Site of Calcification and Significant Stenosis in the Calcified Vessel

<table>
<thead>
<tr>
<th></th>
<th>Calcification left anterior descending coronary artery (116 patients)</th>
<th>Calcification left circumflex coronary artery (103 patients)</th>
<th>Calcification right coronary artery (81 patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significant stenosis of calcified vessel</td>
<td>89%</td>
<td>79%</td>
<td>95%</td>
</tr>
<tr>
<td>Subtotal stenosis of calcified vessel</td>
<td>48%</td>
<td>57%</td>
<td>41%</td>
</tr>
<tr>
<td>Total occlusion of calcified vessel</td>
<td>41%</td>
<td>22%</td>
<td>54%</td>
</tr>
<tr>
<td>Significant coronary disease</td>
<td>97%</td>
<td>97%</td>
<td>91%</td>
</tr>
</tbody>
</table>

The total group included 154 patients (subtotal stenosis: 70–99%).

False Positives

Five patients had coronary calcification demonstrated at cardiac fluoroscopy, but had no coronary stenosis considered significant on coronary angiography. It should be emphasized that "significant" coronary disease was arbitrarily defined as ≥70% stenosis. Therefore lesser degrees of narrowing were considered "insignificant." Two of the five patients were females, aged 61 and 62, and the three males were between 44 and 50 years old. There were no false positives among the 93 patients aged 43 or less. It is interesting that four of the five patients had a previous history of myocardial infarction, and two of them had definite ventricular asynchrony on ventriculography. The other two patients had normally contracting ventricles and no significant coronary disease. The fifth patient had narrowing of all three coronary arteries by angiography, but none was considered significant (all <30%).

Discussion

The results of the present study contradict the widely held view that coronary calcification is of less importance in older (55) than in younger patients.1, 4, 5 Although many patients in the present report with significant coronary stenosis demonstrated by cineangiography had no detectable coronary calcification by fluoroscopy (false negatives 44%), the

Table 2

The Relationship Between Site of Isolated Calcification and Significant Stenosis of the Calcified Vessel

<table>
<thead>
<tr>
<th></th>
<th>Isolated calcification left anterior descending coronary artery (21 patients)</th>
<th>Isolated calcification left circumflex coronary artery (14 patients)</th>
<th>Isolated calcification right coronary artery (14 patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significant stenosis of calcified vessel</td>
<td>80%</td>
<td>57%</td>
<td>93%</td>
</tr>
<tr>
<td>Subtotal stenosis of calcified vessel</td>
<td>44%</td>
<td>45%</td>
<td>43%</td>
</tr>
<tr>
<td>Total occlusion of calcified vessel</td>
<td>36%</td>
<td>14%</td>
<td>50%</td>
</tr>
<tr>
<td>Significant coronary disease</td>
<td>96%</td>
<td>80%</td>
<td>100%</td>
</tr>
</tbody>
</table>

The group included 53 patients. Note that even isolated coronary calcification accurately identified patients with significant coronary disease (94%), and 77% had significant stenosis of the calcified vessel.
presence of coronary calcification was highly specific (false positives 3%). Patients with coronary calcification had more extensive coronary disease than those with no detectable calcification, and multiple vessel calcification signified more severe involvement and fewer false positives.

A review of the pertinent literature reveals a paucity of data relative to the frequency of coronary calcification in living patients, and the significance of this finding in terms of underlying coronary atherosclerosis. It should be emphasized that the data obtained from this study were derived from a largely asymptomatic population, many with previously documented coronary heart disease. Although many patients were studied for diagnostic reasons, data regarding the frequency of coronary calcification in an asymptomatic or outpatient population may not be comparable. With this bias in mind, however, it is significant that almost half of the patients in this study had fluoroscopically demonstrable coronary calcification.

In a study reported by Oliver et al., 4 250 patients with ischemic heart disease had a 46% frequency of coronary calcification compared with 24% of the control group (250 patients matched for age and sex). McGuire et al., 8 described 544 consecutive patients examined fluoroscopically for noncardiovascular conditions. The overall frequency of coronary calcification was 20% and the symptoms of ischemic heart disease were twice as prevalent compared to a control group. In a series of 200 human hearts obtained at random from autopsies on patients 30 years or older, postmortem roentgenograms revealed coronary calcification in 69% of the hearts. 2 These differences may be related to the more optimal radiographic technique that one may employ for the postmortem specimen. Eight postmortem hearts from patients in the present series were studied similarly, and all of the coronary artery calcifications identified at fluoroscopy were seen on the postmortem X-rays. There were additional smaller areas of calcification visualized only on the latter study which used 25-28 kV, 3 mA, and a 3 min exposure time.

Although tomography, cinematography, and fluoroscopic spot filming can all register the relatively large calcifications in the coronary arteries, the simplest and the most sensitive test seems to be a properly executed fluoroscopy aided by image intensification and videotape recording.

Demonstration of coronary artery calcifications in the conventional PA and lateral radiograph is difficult unless the calcium deposits are exceptionally heavy. Radiographic examination in multiple views (e.g., four views cardiac series) improves the prospect of detecting calcium in the coronary arteries. Tomography and fluoroscopic spot filming are not very useful because the relatively long exposure usually fails to catch swiftly moving small images.

The fluoroscopy in this series was performed by a highly trained radiologist, and the time required for the examination was minimal. Fluoroscopy can be performed in outpatients, is painless, without risk, and requires only moderately sophisticated equipment. In terms of practicality, the authors suggest that radiologists performing upper gastrointestinal series might examine the heart fluoroscopically before or after examination of the esophagus and proximal intestine. This concept may be particularly applicable to multiphasic screening examinations which include radiographic examinations of the GI tract.

Several studies have demonstrated an increasing prevalence of coronary calcification with age, 1-8 and the importance of a finding of coronary calcification in younger patients has been emphasized. 1, 8 Data from the present study reveals a general increase in the frequency of coronary calcification with age, which is not as impressive for females as it is for males. There was no age predilection among the false positive patients, although there were no false positives among the 16 patients with calcification below age 44. None of these age differences were statistically significant and probably reflects the well-known tendency for coronary atherosclerosis to increase both in frequency and severity with increasing age.

The data published by Lieber 2 revealed that coronary calcification demonstrated by cinefluorography had a much more direct relationship between signs and symptoms of ischemic heart disease when multiple coronary arteries were calcified. Approximately two-thirds of the patients in the present study had multiple vessel calcification. The frequency of false positives was much lower in this group as was the occurrence of single vessel disease. The relationship of multiple vessel coronary calcification to increasingly severe coronary disease is substantiated by data from this study; 82% of patients with three vessel coronary calcification had three vessel coronary disease and 98% had two or three vessel disease (fig. 3).

Among the 93 patients with no significant coronary artery disease angiographically, only five had coronary calcification demonstrated by fluoroscopy. The historical evidence of myocardial infarction in four of these five patients and definite abnormal segments of myocardium, demonstrated by left ventricular cineangiogram in two of these four patients, indicate that their hearts were not completely normal. Limitations of angiography such as inability to visualize total occlusions of major branches,
recanalization of occluded vessels, eccentric lesions, among others, cannot be excluded as possible reasons for false positives.

The very low frequency of false positives in the present study has important implications in terms of the application of cardiac fluoroscopy as a screening procedure for the presence of coronary artery disease. Our data supports the conclusions of several other authors\(^4\) that calcification in the coronary arteries can be regarded as an index of advanced coronary atherosclerosis. In addition, the presence of coronary calcification provides some index of severity of the disease, even in noncalcified vessels.

The higher frequency of calcification of the left anterior descending coronary in the present study is similar to previously reported studies\(^4\) and probably reflects the tendency for this vessel to be involved in the atherosclerotic process. The association of the site of calcification with significant coronary lesions is demonstrated in table 1. Good correlation was found between calcification and a significant lesion in the left anterior descending and right coronary arteries (86% and 93% respectively), and a less significant correlation was present in the circumflex system (79%). This may be explained in part by the difficulty in separating very proximal calcification of the circumflex system from the proximal left anterior descending coronary system fluoroscopically. Even in patients with isolated calcification (table 2), there was an excellent correlation for the left anterior descending and right coronary arteries (80% and 93%) and a lower correlation for the circumflex system (57%). However, it should be emphasized that even isolated coronary calcification is associated with a high frequency of significant coronary atherosclerosis. The data is most dramatic for isolated calcification of the right coronary artery (14 patients), all of whom had significant coronary artery disease demonstrated angiographically.

An important aspect of this study involved the analysis of the correlation of the site of calcification with the exact site of stenosis found at cineangiography. As described above, cardiac fluoroscopy is a more sensitive technique than cineangiography for the detection of calcification. These data are, therefore, biased by the exclusion of smaller, less dense areas of calcification demonstrable fluoroscopically but not on cineangiography. There were no false positives in this group and 72% had three vessel coronary disease. The finding that 90% of calcifications identified significant obstructive lesions at that exact site further emphasizes the importance of detecting calcification and implies a critical physiological significance of coronary calcification.

Since many of the patients in this study were studied as candidates for coronary vein bypass surgery, and the presence of calcification may create technical difficulties at operation, the relationship of calcification to operative mortality was analyzed. One hundred patients underwent aorto-coronary bypass surgery, 54 of whom had at least one calcified artery fluoroscopically. The hospital mortality of 15% was not significantly different from patients without calcification (11%). This finding is not surprising since the vast majority of calcification (especially in the left anterior descending and circumflex coronaries) is found in the proximal vessels rather than the more distal coronary segments in which bypass grafts are more likely to be inserted.

The short-term prognosis of coronary calcification was also examined in the 127 patients who were followed at least six months but not operated upon. The mortality rate for the 66 patients with calcification was essentially the same at six months and one year when compared to the 61 patients without calcification (15% and 22% vs 13% and 14% respectively).

Data from the present study indicate that cardiac fluoroscopy is an important noninvasive method for the detection of significant coronary artery disease. Difficulties in detection of small flecks of calcification probably explain differences between the present study and postmortem X-ray studies of coronary calcification. The highly significant associations with coronary angiography in terms of stenosis both of the calcified vessel and of noncalcified vessels, and the low frequency of false positives imply that this procedure should be more widely utilized in the detection and evaluation of coronary atherosclerosis.

Acknowledgment

The authors gratefully acknowledge the secretarial assistance of Miss Salley Gantt.

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Circulation. 1974;49:1247-1253
doi: 10.1161/01.CIR.49.6.1247

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
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