


Significance of the Angiographic Morphology of Localized Coronary Stenoses: Histopathologic Correlations

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SUMMARY Postmortem coronary angiographic morphology was correlated with histologic sections of 73 localized subtotal coronary artery stenoses (50-99% reduction of luminal diameter) to determine whether complicated or uncomplicated atherosclerotic lesions could be detected angiographically. Lesions were divided into two types, according to angiographic morphology: Type I stenoses had smooth borders, an hourglass configuration, and no intraluminal lucencies; type II stenoses had irregular borders or intraluminal lucencies. Histologic sections were also divided into two types: "Uncomplicated" stenoses had fatty or fibrous plaques with intact intimal surfaces and no superimposed thrombus; "complicated" stenoses manifested plaque rupture, plaque hemorrhage, superimposed partially occluding thrombus, or recanalized thrombus.

Among 35 lesions with type I angiographic morphology, four (11.4%) were complicated lesions histologically. Among the 38 stenoses showing type II angiographic morphology, 30 (78.9%) were complicated lesions. Postmortem angiography thus had a sensitivity of 88% and specificity of 79% for detecting complicated stenoses on the basis of irregular borders or intraluminal lucencies.

Pathologic studies have shown that acute occlusive thrombosis of a coronary artery is usually associated with complicated atherosclerotic stenoses. Thus, complicated lesions represent a greater risk factor for acute myocardial infarction or sudden death than do uncomplicated lesions. This study suggests that coronary stenoses characterized angiographically by irregular borders or intraluminal lucencies are probably the clinically more dangerous "complicated" type.

IN REVIEWING and interpreting coronary angiograms, it is customary for the angiographer to describe a focal lesion only in terms of the percent luminal diameter or area narrowing it produces. This practice is uniformly adhered to both in published series and in the dictation, coding and scoring of individual angiographic reports. Virtually no attempt has been made to characterize the morphology of coronary lesions by their arteriographic appearance.

Atherosclerotic coronary artery narrowing is a complex and dynamic process. According to Roberts, these lesions can be classified into fatty, fibrous and complicated types. Complicated lesions are often characterized by superimposed thrombosis or ulceration and are most commonly associated with acute myocardial infarction (MI). Friedman has pointed out that hemorrhage or acute thrombosis in recanalized coronary artery thrombi is also frequently associated with acute MI. Other pathologic studies have confirmed the fact that atherosclerotic plaques complicated by rupture, ulceration, subintimal hemorrhage, and partially occluding or recanalized thrombi are more dangerous than uncomplicated fatty or fibrous coronary lesions in that they are more likely to become acutely occluded and precipitate MI.

Because complicated atherosclerotic plaques are more dangerous, it would be of great value if the angiographer could identify them in patients undergoing coronary arteriography. This study represents an initial attempt to predict the presence of complicated atherosclerotic lesions on the basis of angiographic morphology.

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Methods

Postmortem coronary angiograms and histologic sections of the coronary arteries were reviewed in 39 patients who had died of complications of MI or at the time of coronary artery bypass surgery. Seventy-three localized coronary artery stenoses were studied. Angiographically, each lesion appeared to produce 50–99% narrowing of the luminal diameter. Completely obstructing lesions were excluded, as were lesions within 2 cm of a bypass graft anastomosis or a perfusion cannula.

Postmortem arteriograms were performed by perfusing the right and left coronary arteries or bypass grafts with a barium-gelatin mixture at 150 mm Hg for 20 minutes. The heart was then fixed and the major coronary arteries dissected en bloc away from the epicardial surface. The right and left coronary arteries were carefully laid flat on a sheet of nonscreen, type M x-ray film (Eastman Kodak) and radiographed in a Faxitron unit. The vessels were sectioned at 2-mm intervals, laid out on another sheet of film in exactly the same configuration, and radiographed again. Histologic sections were obtained of each coronary artery cross section and could be matched precisely with each area of narrowing using the second set of radiographs.

The radiographs of the intact right and left coronary arterial tree were examined by one of the authors who had no knowledge of the clinical or histologic findings. The lesions were divided into two groups, according to their angiographic morphology. Type I stenoses had smooth borders, an “hourglass” configuration, and no intraluminal lucencies. Type II stenoses had irregular borders or intraluminal lucencies. The corresponding histologic section was classified as showing uncomplicated or complicated atherosclerotic stenosis. Uncomplicated lesions included fatty or fibrous plaques with intact intimal surfaces and no superimposed thrombus. Complicated lesions had plaque rupture, plaque hemorrhage, superimposed partially occluding thrombus or recanalized thrombus. The angiographic morphology and histologic appearance of each lesion were compared.

Results

There were 35 type I stenoses and 38 type II stenoses in the study. Among the 35 type I stenoses, only four (11.4%) proved to be complicated lesions. Two contained areas of plaque hemorrhage and two contained small plaque ruptures. The remaining 31 stenoses had intact intimal surfaces and were without rupture, hemorrhage or thrombosis. Figure 1 shows a postmortem angiogram of a type I lesion and the histologic section of the same lesion.

Among the 38 type II stenoses, 30 (78.9%) were complicated lesions and eight were uncomplicated. The 30 complicated lesions included eight instances of partially occluding acute or organizing thrombi superimposed on atheromatous plaques, six instances of partially occluding thrombi superimposed on atheromatous plaques that contained areas of rupture or hemorrhage, 10 instances of plaque rupture or hemorrhage without thrombosis, and six instances of recanalized thrombi. Figures 2 and 3 show postmortem angiograms of type II lesions and the corresponding histologic sections of the complicated atherosclerotic stenoses.

In detecting complicated atherosclerotic lesions from irregular borders or intraluminal lucencies, the postmortem angiogram therefore had a sensitivity (true positive ÷ [true positives + false negatives]) of 88% and a specificity (true negatives ÷ [true negatives + false positives]) of 79%.

Discussion

Pathologic studies in atherosclerotic human coronary artery disease (CAD) have provided strong, but not incontrovertible, evidence that complicated atherosclerotic stenoses represent the major predisposing factor in the genesis of acute occlusive thrombosis. Chapman1 examined 19 coronary artery segments obstructed by recent thrombi and found in every case that the thrombi had adhered to a rupture of the intimal surface of an atheromatous plaque. Intramural hemorrhage and organizing, nonocclusive thrombi were also

Figure 1. (A) Postmortem angiogram of a type I stenosis of the main left coronary artery (arrow). There is an hourglass narrowing with smooth borders and no intraluminal filling defects. (B) The corresponding histologic section reveals an eccentric lumen (L) resulting from the presence of fibrous, fatty atherosclerotic plaque (P) and is typical of uncomplicated lesions. Hematoxylin-eosin stain; original magnification × 30.
of occluding coronary thrombi formed at sites of ruptured atheromatous plaques.

The aforementioned studies suggest that a complicated atherosclerotic plaque is usually the precursor of thrombotic coronary occlusion. However, the thrombus itself may contribute to further development of the complicated atherosclerotic plaque, providing an indication of the vicious circle by which coronary atherosclerosis proceeds. Thus, Ridolfi and Hutchins⁶ and Roberts and Buja⁸ showed that as older coronary thrombi undergo organization or recanalization, they may develop pathologic features indistinguishable from nonoccluding plaques. Recanalization can result in one large or several small lumens; in the former situation it may not be possible to differentiate histologically or angiographically between preocclusive atherosclerotic stenosis and postocclusive recanalized thrombus. The dangerous aspect of recanalized thrombi is apparent from the study of Friedman.² Among 75 patients who died of CAD, he found recanal-

Figure 2. (A) Postmortem angiogram of a type II stenosis of the proximal left anterior descending artery (arrow). The borders of the lesion are markedly irregular and there are numerous intraluminal lucencies in the area of and distal to the narrowing. (B) The corresponding histologic section shows a complicated atherosclerotic plaque with plaque rupture (arrows), intraplaque hemorrhage (H), and an intraluminal thrombus (T) that occludes the lumen almost totally. Hematoxylin-eosin stain; original magnification × 30.

frequently present in or on the plaques. Forty coronary artery segments containing occluding thrombi were examined by Friedman and Van den Bovenkamp.⁴ In 39 segments they found the thrombus overlying a rupture in the lining of the plaque, which in turn communicated with a necrotic “atheromatous abscess” usually located deeper within the plaque wall. Hemorrhage was almost always present in these “abscesses,” and in approximately one-third, there was some degree of recanalization of atherosclerotic tissue. Ridolfi and Hutchins⁶ studied 69 zones of MI less than 2 weeks old that were associated with atherosclerotic lesions of the major epicardial branches of the coronary arteries (excluding infarcts related to embolization, clinical episodes of hypoperfusion or cardiac catheterization accidents). Sixty-seven of these coronary arteries (97%) contained partially or totally occluding thrombi, and in all but three, endothelial ulcers, erosions or ruptures underlay the thrombus and were considered to be nidus for thrombus deposition. Horie et al.⁷ found that 91%

Figure 3. (A) Postmortem angiogram of a long, irregular type II stenosis in the left circumflex artery (arrow). (B) The corresponding histologic section shows a superficial organizing mural thrombus (arrows) overlying a fibrous atherosclerotic plaque and surrounding much of the lumen (L). Numerous vascular channels filled with dark-staining angiographic medium in the organizing thrombus probably account for some of the wall irregularity on the angiogram. Hematoxylin-eosin stain; original magnification × 30.
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Alized thrombi in 30 of the arteries thought to be responsible for the terminal coronary event. In 26 of these recanalized segments, fresh hemorrhage into the thrombus or recurrent thrombosis of one or more channels was found. In 23, these were the only discernible acute or subacute changes in the coronary vasculature preceding the patient’s death.

It is not clear why some atherosclerotic lesions rupture, ulcerate, hemorrhage or thrombose while others do not. However, these pathologic studies show that complicated lesions are considerably more dangerous to the patient than uncomplicated lesions because of their propensity to cause acute occlusive thromboses and MI. Thus, it would be of great help in the clinical management of patients with proved CAD to have reliable angiographic criteria for differentiating between uncomplicated and complicated atheromatous lesions. Patients with the latter would be candidates for surgery on a more urgent basis and perhaps also at an earlier stage of narrowing.

This study indicates that complicated coronary artery stenoses can be reliably predicted on a postmortem angiogram by the presence of irregular borders or intraluminal lucency at the site of stenosis. One major difficulty in applying this principle clinically is that postmortem angiography provides much finer detail than does in vivo coronary angiography. Subtle changes that can be seen on a postmortem angiogram might not be apparent on a coronary cineangiogram from a living patient. This problem increases the likelihood of false-negative results in attempting to diagnose complicated stenoses by in vivo coronary angiography. On the other hand, our postmortem angiograms

**Figure 4.** Left coronary arteriogram, right anterior oblique projection. A severe stenosis with irregular borders is seen in the proximal left anterior descending artery (arrow). A well-collateralized total occlusion of the right coronary artery was also present. The patient was a 54-year-old woman without evidence of previous myocardial infarction but with rapidly progressive chest pain on minimal exertion. She died suddenly 3 days after angiography, while awaiting surgery. Although a postmortem examination was not obtained, it seems likely that death resulted from acute occlusion of this complicated stenosis.

**Figure 5.** Right coronary arteriograms. (A) Left anterior oblique view. (B) Right anterior oblique view. A long segment of irregular narrowing in the proximal portion of the right coronary artery (arrows) suggests the presence of a complicated stenosis.
were filmed in only a single projection. In vivo angiograms are routinely obtained in multiple projections, which would tend to decrease the likelihood of a false-negative result. In any event, a meaningful attempt at morphologic evaluation of stenoses seen on coronary cinearteriograms demands advanced angiographic equipment capable of producing high-resolution, high-contrast images. In laboratories that have such equipment, grossly apparent border irregularities and intraluminal lucencies on cineangiograms of living patients should be suspected of being complicated atherosclerotic lesions. Figures 4 and 5 show in vivo angiographic lesion configurations that we consider suggestive of complicated plaques.

The angiographic morphology of coronary stenoses has been almost completely ignored in gathering data and in medical or surgical decision-making in patients with CAD. Scoring systems10–12 widely used for coronary angiography concentrate only on the location of a lesion and the degree of narrowing it produces. Even the more recent attempts at quantitative coronary angiography13,14 do not take into account the presence and possible significance of irregular borders and intraluminal lucencies. Our results suggest that when coronary angiography reveals a smooth, “hourglass” narrowing without intraluminal lucencies, the lesion is likely to be a fibrous or fatty plaque with an intact intimal lining. If the angiogram instead shows that the narrowed segment has irregular borders or intraluminal lucencies, the lesion is likely to be a ruptured or hemorrhagic plaque, a partially occluding or recanalized thrombus, or some combination thereof. The prognosis in such cases may be poorer and the need for surgical intervention more urgent. Further studies in living patients are needed to ascertain the clinical significance of these observations. If their validity is confirmed, morphologic characteristics of lesions should be incorporated into all coronary angiographic reports.

References
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