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CLINICAL STUDIES

Coronary Angiographic Morphology in Myocardial Infarction: A Link Between the Pathogenesis of Unstable Angina and Myocardial Infarction

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It has previously been shown that analysis of coronary morphology can separate unstable from stable angina. An eccentric stenosis with a narrow neck or irregular borders, or both, is very common in patients who present with acute unstable angina, whereas it is rare in patients with stable angina. To extend these observations to myocardial infarction, the coronary morphology of 41 patients with acute or recent infarction and nontotally occluded infarct vessels was studied. For all patients, 27 (66%) of 41 infarct vessels contained this eccentric narrowing, whereas only 2 (11%) of 18 noninfarct vessels with narrowing of 50 to less than 100% had this lesion ($p < 0.001$). In addition, a separate group of patients with acute myocardial infarction who underwent intracoronary streptokinase infusion were also analyzed in similar fashion. Fourteen (61%) of 23 infarct vessels contained this lesion after streptokinase infusion compared with 1 (9%) of 11 noninfarct vessels with narrowing of 50 to less than 100% ($p < 0.01$).

Therefore, an eccentric coronary stenosis with a narrow neck or irregular borders, or both, is the most common morphologic feature on angiography in both acute and recent infarction as well as unstable angina. This lesion probably represents either a disrupted atherosclerotic plaque or a partially occlusive or lysed thrombus, or both. The predominance of this morphology in both unstable angina and acute infarction suggests a possible link between these two conditions. Unstable angina and myocardial infarction may form a continuous spectrum with the clinical outcome dependent on the subsequent change in coronary supply relative to myocardial demand.

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Acute coronary occlusion is the usual cause of transmural myocardial infarction. Angiography at the time of infarction has demonstrated thrombotic occlusion of a stenotic artery in 70 to 90% of infarct vessels, whereas in the remaining cases a severely stenotic artery without total occlusion is found (1,2). Pathologic studies (3,4) in patients whose death was due to infarction or sudden, or both, have shown that a thrombus is usually superimposed on a ruptured atherosclerotic plaque. Although the appearance of these complicated atherosclerotic lesions has been described by Levin and Fallon (5) at postmortem angiography, the qualitative appearance of coronary lesions at routine angiography in patients with acute myocardial infarction has not been reported.

We have previously shown (6) in a consecutive series of patients evaluated because of angina that patients presenting with acute unstable angina often have a characteristic coronary lesion. An eccentric stenosis with a narrow neck due to one or more overhanging edges or irregular borders, or both, was found in the majority of these patients. In patients whose presumed "angina-producing" vessel could be identified, this lesion was found in 71% of vessels in patients with unstable angina, compared with only 16% of vessels in patients with stable angina ($p < 0.001$). Not only was this lesion a sensitive indicator of unstable angina, it was infrequent in obstructed arteries that were not "angina-producing" vessels. It was postulated that these lesions possibly

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represent disrupted plaques or partially occlusive or lysed thrombi, or both. Unstable angina is often a precursor of myocardial infarction and both conditions may present acutely and suddenly. Therefore, morphologic analysis of coronary lesions in myocardial infarction may show similarities to the coronary lesions in unstable angina.

Methods

Patients. Angiographic data were reviewed in all patients with acute or recent (< 3 months) infarction referred for cardiac catheterization to Mount Sinai Hospital between September 1981 and April 1984. In all patients myocardial infarction was documented by a characteristic history of prolonged chest pain, by diagnostic electrocardiographic changes and by elevated serum cardiac enzymes. Only patients in whom characteristic electrocardiographic changes or wall motion abnormalities, or both, could confidently localize a nontotally occluded infarct vessel at angiography were studied. Totally occluded infarct vessels were eliminated because of inability to assess morphology.

Series 1. Of the 50 angiograms that fulfilled these criteria, seven were eliminated because of inadequate visualization of the coronary lesion in the infarct vessel and two because of inability to characterize the lesion. The remaining 41 films represent approximately 33% of all patients with acute or recent infarction who underwent catheterization at this institution. The remaining patients either had an infarct vessel that was totally occluded at the time of angiography or were part of an ongoing randomized trial on the effects of intracoronary streptokinase and were therefore not included in the analysis.

Three groups of patients were identified in the 41 study patients. Group I comprised 13 patients who underwent angiography within 12 hours of acute infarction. Although all patients in Group I received intracoronary streptokinase, only the preintervention angiograms were analyzed. These patients were part of a completed pilot trial at Mount Sinai Hospital on the effects of intracoronary streptokinase in acute myocardial infarction and the final report of this study has been published (7). Group II comprised 11 patients studied 1 to 2 weeks after infarction, all of whom had been treated with full dose anticoagulation therapy. This group included patients in the medically treated control group of this same pilot trial who underwent routine catheterization 1 to 2 weeks after infarction. Group III comprised 17 patients with recent infarction (2 to 10 weeks) referred for catheterization because of postinfarction chest pain, young age or a positive exercise test. The mean age of patients was 53 years and there were no significant differences among the three groups. Of the 28 patients in Groups II and III, 23 had severe hypokinesia or akinesia in the distribution of the infarct vessel as assessed by left ventricular angiography.

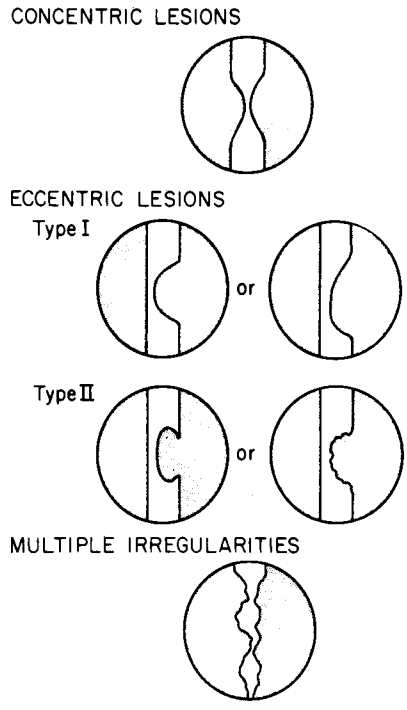

Figure 1. Schematic drawings of the morphologic findings in coronary artery disease. Concentric lesions were symmetric and usually smooth. Type I eccentric lesions were asymmetric and smooth. Most type I lesions were like those depicted on the **right side** of the diagram. Type II eccentric lesions either were smooth with a narrow neck (**left side**) or had irregular borders (**right side**). Multiple irregularities included vessels with serial lesions or severe diffuse disease.

Series 2. After the initial analysis of these data, a second series of angiograms was analyzed. The data on 36 patients with acute infarction and intracoronary streptokinase infusion were reviewed. All films were analyzed as described by the same angiographers who reviewed the first set of films. These patients represented a consecutive series of

Table 1. Coronary Morphology of the Infarct Vessel in Acute or Recent Myocardial Infarction (Series 1, 41 Cases)

	Coronary Morphology			Stenosis (%)*
	Type II	Conc	Other	
Group I (n = 13)	8	4	1	83 ± 8
Group II (n = 11)	7	4	0	84 ± 10
Group III (n = 17)	12	1	4	87 ± 9
Total	27 (66%)	9 (22%)	5 (12%)	

*Mean ± 1 SD. Conc = concentric lesions; Other = other morphologies; Type II = type II eccentric lesions.

patients with acute infarction admitted to a single hospital (St. Michael's Hospital) who underwent angiography within 12 hours of the onset of chest pain. From the group of 36 patients, 4 were eliminated because of inadequate films. In all patients the infarct vessel was localized at angiography and a loading dose of 10,000 U of streptokinase was directly infused into the coronary artery followed by a continuous infusion of 4,000 U/min for a total of 35 to 120 minutes. In 26 of the 32 patients, the infarct vessel was initially totally occluded and 17 of these arteries were reperfused (Group I SK). In the other six patients the infarct vessel was not totally occluded before streptokinase infusion (Group II SK). The mean dose of streptokinase was 308,000 U (range 135,000 to 500,000) and dosages were similar among patient groups.

Coronary arteriography. All coronary angiographic studies were performed from either the brachial or femoral approach using standard catheters and techniques. All coronary obstructions greater than 50% occlusive were traced on transparent paper in two views by the same angiographer and each obstruction was measured with a millimeter rule and compared with the "normal" proximal juxtaposed segment. Coronary lesions were morphologically classified by a consensus of three angiographers based on qualitative analysis of each lesion (Fig. 1). The details of the quantitative and qualitative analyses have been previously described (6).

Figure 2. Selected angiographic images from two patients with a type II lesion. **Top,** The **arrow** points to the type II lesion in the proximal left anterior descending artery as seen in the right anterior oblique projection. **Bottom,** The **arrow** points to the type II lesion in the midright coronary artery as seen in the left anterior oblique projection.

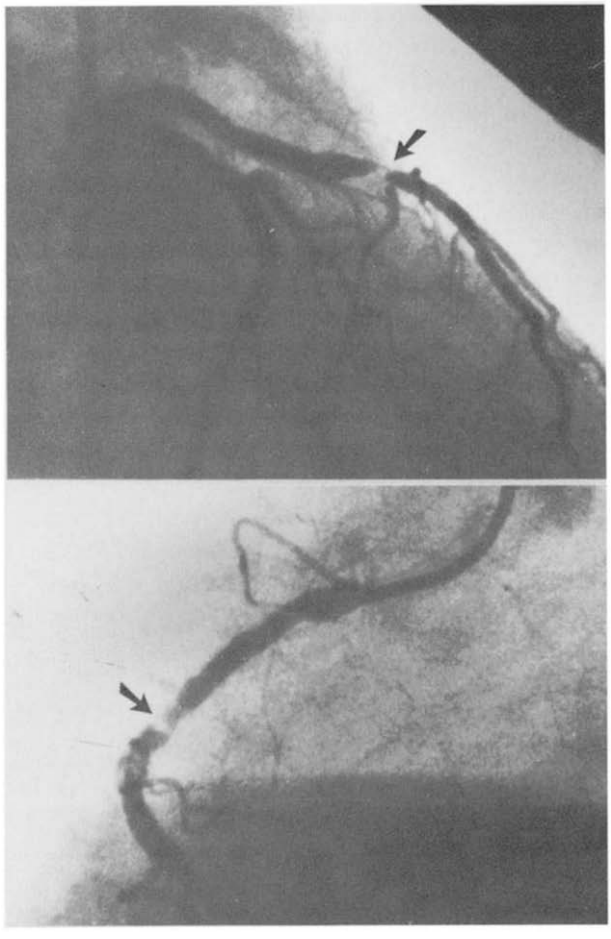

Table 2. Coronary Morphology of the Infarct Vessel in Myocardial Infarction Before and After Reperfusion With Streptokinase (Series 2, 23 Cases)

	Prestreptokinase Coronary Morphology			Poststreptokinase Coronary Morphology			Stenosis
	Type II	Conc	Other	Type II	Conc	Other	(%)
Group I SK (n = 17)				10	4	3	83 ± 11
Group II SK (n = 6)	4	1	1	4	1	1	83 ± 8
Total				14 (61%)	5 (22%)	4 (17%)	

Abbreviations as in Table 1.

Lesions were classified into one of four categories: 1) concentric stenosis—symmetric and smooth narrowing of the coronary artery; 2,3) eccentric stenosis—asymmetric narrowing of the coronary artery, with two subgroups categorized: type I eccentric lesion (asymmetric stenosis with smooth borders and a broad neck) and type II eccentric lesion (asymmetric stenosis in the form of a convex intraluminal obstruction with a narrow base due to one or more overhanging edges or extremely irregular or scalloped borders, or both); 4) multiple irregularities—three or more serial and closely spaced severe obstructions or severe diffuse irregularities in a coronary artery. Intra- and interobserver variability for categorizing a lesion into its morphologic subset was 95 and 88%, respectively. All quantitative and qualitative analyses in patients given streptokinase were performed at the end of the streptokinase infusion. In patients given streptokinase whose infarct vessel was not totally occluded, lesions were compared before and at the end of the infusion.

Statistical analyses. All analyses between groups were performed using the two-tailed Student's *t* test or the chi-square test. Significance was defined as a probability (p) value less than 0.05.

Results

In the 41 patients with acute or recent infarction analyzed in the first part of this study, the infarct vessel was the left

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anterior descending artery in 18, the right coronary artery in 13 and the left circumflex artery in 10. One vessel disease was present in 26 patients, and 15 had multivessel disease.

Series 1. Coronary anatomy and morphology. Quantitative and qualitative analyses of the coronary lesions in the infarct vessel are contained in Table 1. In each group the type II eccentric lesion was the most common coronary morphology and its prevalence in the various subgroups was similar. Therefore, the time from infarction to angiography did not influence the prevalence of the type II lesion. Two type II lesions from different patients are shown in Figure 2. For all patients, 27 (66%) of 41 infarct vessels contained a type II lesion, whereas only 2 (11%) of 18 noninfarct vessels with obstruction of 50 to less than 100% had a type II lesion ($p < 0.001$). The percent stenosis of infarct vessels was similar among the three groups.

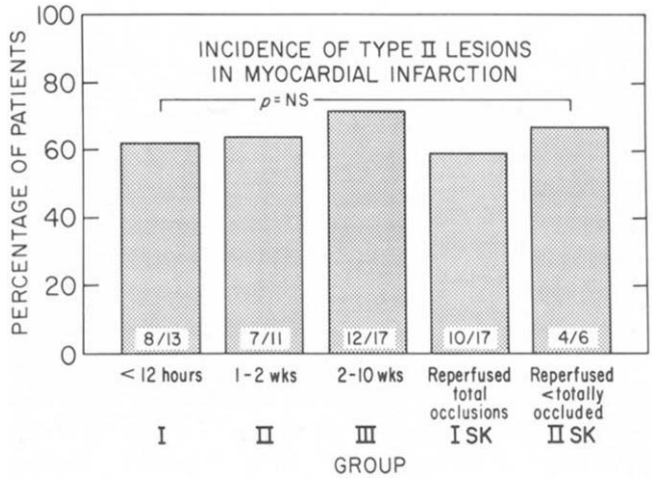
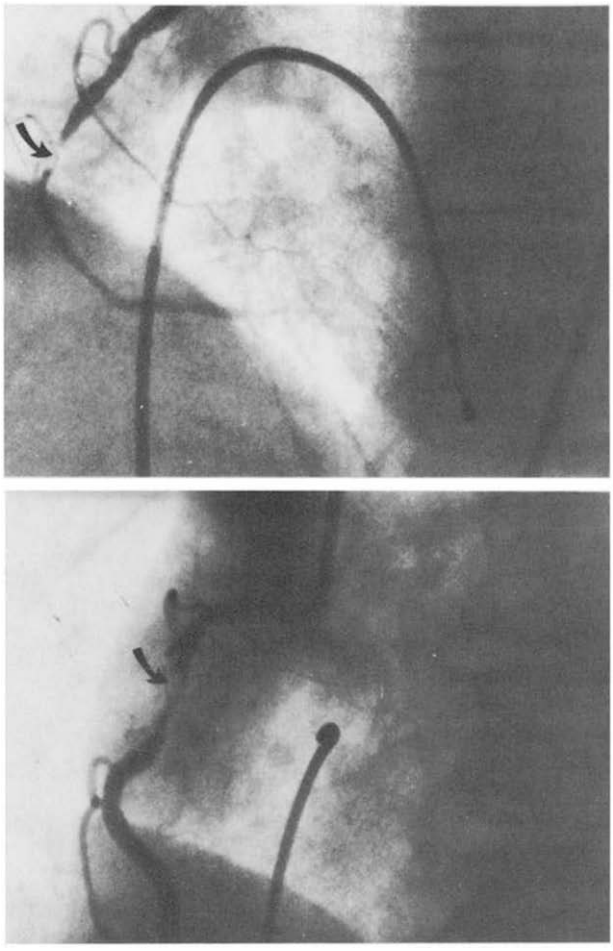


Figure 4. Bar diagram depicting the incidence of type II lesions within the five different subgroups from both parts of the study (Series 1 and 2).

Figure 3. Selected angiographic frames from two patients with a type II lesion after infusion of streptokinase. **Top,** The **arrow** points to the type II lesion in the midright coronary artery of a patient from Group I SK. **Bottom,** The **arrow** points to the type II lesion in the proximal right coronary artery of a patient from Group II SK. Both frames were filmed in the left anterior oblique projection. See text for definition of Groups I SK and II SK.



Series 2. Coronary anatomy and morphology after streptokinase. Quantitative and qualitative analyses of the patients receiving streptokinase infusion in the second part of this study are contained in Table 2. The left anterior descending coronary artery was involved in nine patients, whereas the left circumflex and right coronary arteries were the infarct vessels in six and eight patients, respectively. Eleven patients had one vessel disease and the remainder had multivessel disease. The angiographic findings after streptokinase infusion from a typical patient in Group I SK (total occlusion and reperfusion) and another from Group II SK (nontotal occlusion) are shown in Figure 3. In Group I SK, 10 (59%) of 17 reperfused arteries contained a type II lesion compared with 4 (67%) of 6 in Group II SK (p = NS). For both groups, 14 (61%) of 23 infarct vessels contained a type II lesion, whereas only 1 (9%) of 11 noninfarct vessels with obstruction of 50 to less than 100% had a type II lesion ($p < 0.01$). After streptokinase, no Group II SK lesion had a changed morphology. The percent stenosis of the infarct vessel before and after streptokinase infusion in Group II SK did not change significantly, but in three patients distal flow in the obstructed vessel visually improved after streptokinase. In addition, the percent stenosis of infarct vessels in Group I SK and Group II SK was also similar.

Discussion

Type II eccentric coronary lesion. Quantitative analysis of the degree of obstructive coronary artery disease often shows no difference among the various clinical coronary artery syndromes (8–10). Qualitative analysis of coronary morphology may provide a foundation for the angio-

graphic stratification of patients with various clinical presentations in coronary artery disease. The type II eccentric lesion (smooth with narrow neck or irregular borders) is found in the majority of patients with an acute presentation of unstable angina but is infrequent in stable angina pectoris (6). The present study also indicates that a similar appearing lesion is found in the majority of patients with acute or recent myocardial infarction and nontotally occluded vessels. The type II lesion is also the most frequent morphologic finding in infarct vessels after reperfusion with streptokinase (Fig. 4). Though the pathologic significance of the type II lesion is unknown, eccentric and irregular lesions on postmortem angiography have been shown to manifest plaque rupture, plaque hemorrhage, superimposed partially occlusive thrombus or recanalized thrombus (5). The acute presentation of unstable angina with the type II lesion, the angiographic appearance of this lesion and the postmortem angiographic data of Levin and Fallon (5) suggest that the type II lesion may represent a disrupted atherosclerotic plaque or a partially occlusive or lysed thrombus, or both. Recently the appearance of intracoronary thrombus has been described at angiography in patients with unstable angina and nontotally occluded vessels (11–14). Such thrombus has been visualized as a filling defect usually noted just distal to the obstruction in a region of diminished flow. A similar appearance was noted in six patients from our entire study.

Spectrum of unstable angina and myocardial infarction. Both unstable angina and acute myocardial infarction often present acutely and suddenly. This suggests that an acute process within the coronary artery is causing a decrease in coronary blood flow relative to oxygen demand. The predominance of the type II lesion in both conditions implies that unstable angina and acute infarction may form a continuous spectrum. If plaque disruption occurs within an artery, a superimposed thrombus may form. The degree of anterograde obstruction, the time course of development of this obstruction as well as the collateral flow and myocardial oxygen demand determine whether unstable angina or myocardial infarction ensues. Therefore, the presence of this lesion may warrant special consideration. When found in patients with unstable angina, a type II lesion may represent a coronary plaque in evolution and it could be the precursor of impending infarction. This change, if it occurs, probably involves additional thrombus formation or vasospasm, or both (15,16).

Study limitations. Our analysis of coronary morphology is purely descriptive. Although we believe that the type II lesion represents a ruptured plaque or a partially lysed thrombus, or both, we have no definite pathologic confirmation of this finding and we do not know the pathologic significance of the other coronary lesions. However, the postmortem angiographic data of Levin and Fallon (5) support our hypothesis concerning the pathologic significance of the type II lesion. Additionally, approximately one-third of infarct patients did not have this lesion. Whether patients without a type II lesion have a different mechanism for infarction is also unknown. Conceivably, a minute area of plaque disruption could also be present. This could serve as a nidus for thrombus formation, yet the irregularities of this lesion may not be visible because of the limited resolution of the X-ray equipment. Pathologic analysis of coronary lesions in patients who died suddenly has shown that small areas of plaque disruption with superimposed thrombi are frequently present (4).

Another potential limitation involves patient selection. The patients analyzed in this study represent only a fraction of those catheterized with acute infarction. However, because the same predominant morphology was present in all groups of patients analyzed, this sample is probably representative of the majority of patients with acute infarction.

Clinical implications. In conclusion, the type II lesion is the predominant obstructive coronary morphology in acute myocardial infarction as well as in unstable angina. However, the clinical significance of this finding is unclear. The anatomy and morphology of coronary lesions before the onset of unstable angina or infarction are unknown, as is the clinical outcome of the type II eccentric lesion in unstable angina. If it can be shown that the type II lesion in a patient with unstable angina is likely to progress and cause myocardial infarction, then aggressive therapy would be indicated when this lesion is demonstrated. The predominance of this lesion in both unstable angina and myocardial infarction suggests a link between these two disorders. However, further study will be necessary to validate this association.

References

1. Rentrop P, Blanke H, Karsch KR, Kaiser H, Kostering H, Leitz K. Selective intracoronary thrombolysis in acute myocardial infarction and unstable angina pectoris. Circulation 1981;63:307–17.
2. Merx W, Dorr R, Rentrop P, et al. Evaluation of the effectiveness of intracoronary streptokinase infusion in acute myocardial infarction: postprocedure management and hospital course in 204 patients. Am Heart J 1981;102:1181–7.
3. Chapman I. Morphogenesis of occluding coronary artery thrombosis. Arch Pathol 1965;80:256–61.
4. Davies MJ, Thomas A. Thrombosis and acute coronary artery lesions in sudden cardiac ischemic death. N Engl J Med 1984;310:1137–40.
5. Levin DC, Fallon JT. Significance of the angiographic morphology of localized coronary stenoses. Histopathologic correlations. Circulation 1982;66:316–20.
6. Ambrose JA, Winters SL, Stern A, et al. Angiographic morphology and the pathogenesis of unstable angina pectoris. J Am Coll Cardiol 1985;5:609–16.
7. Rentrop KP, Feit F, Blanke H, et al. Effects of intracoronary streptokinase and intracoronary nitroglycerine infusion on coronary angiographic patterns and mortality in patients with acute myocardial infarction. N Engl J Med 1984;311:1457–63.

8. Alison HW, Russell RO Jr, Mantle JA, Kouchoukos NT, Moraski RE, Rackley CE. Coronary anatomy and arteriography in patients with unstable angina pectoris. Am J Cardiol 1978;41:204–9.

9. Rafflenbeul W, Smith LR, Rogers WT, Mantle JA, Rackley CE, Russell RO. Qualitative coronary arteriography. Coronary anatomy of patients with unstable angina pectoris reexamined 1 year after optimal medical therapy. Am J Cardiol 1979;43:699–707.

10. Fuster V, Frye RL, Connolly DC, Danielson MA, Elveback LR, Kurkland LT. Arteriographic patterns early in the onset of the coronary syndromes. Br Heart J 1975;37:1250–5.

11. Vetrovec GW, Cowley MJ, Overton H, Richardson DW. Intracoronary thrombus in syndromes of unstable myocardial ischemia. Am Heart J 1981;102:1202–8.

12. Holmes DR Jr, Hartzler GO, Smith HC, Fuster V. Coronary artery thrombus in patients with unstable angina. Br Heart J 1981;45:411–6.

13. Mandelkorn JB, Wolf MN, Singh S, et al. Intracoronary thrombus in nontransmural myocardial infarction and in unstable angina pectoris. Am J Cardiol 1983;52:1–6.

14. Capone GT, Meyer BB, Wolf NM, Meister SG. Incidence of intracoronary thrombi in patients with active unstable angina pectoris. Circulation 1984;70(suppl II):II-415.

15. Fuster V, Chesebro JH. Current concepts of thrombogenesis. Role of platelets. Mayo Clin Proc 1981;56:102–8.

16. Hirsh PD, Hillis LD, Campbell WB, Firth BG, Willerson JT. Release of prostaglandins and thromboxane into the coronary circulation in patients with ischemic heart disease. N Engl J Med 1981;304:685–91.