

CLINICAL STUDIES

A Comprehensive Analysis of Myocardial Infarction Due to Left Circumflex Artery Occlusion: Comparison With Infarction Due to Right Coronary Artery and Left Anterior Descending Artery Occlusion

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Forty consecutive patients with creatine kinase-MB confirmed myocardial infarction due to circumflex artery occlusion (Group 1) were prospectively evaluated and compared with 107 patients with infarction due to right coronary artery occlusion (Group 2) and 94 with left anterior descending artery occlusion (Group 3). All 241 patients underwent exercise thallium-201 scintigraphy, radionuclide ventriculography, 24 h Holter electrocardiographic (ECG) monitoring and coronary arteriography before hospital discharge and were followed up for 39 ± 18 months. There were no significant differences among the three infarct groups in age, gender, number of risk factors, prevalence and type of prior infarction, Norris index, Killip class and frequency of in-hospital complications. Acute ST segment elevation was present in only 48% of patients in Group 1 versus 71 and 72% in Groups 2 and 3, respectively ($p = 0.012$), and 38% of patients with a circumflex artery-related infarct had no significant ST changes (that is, elevation or depression) on admission (versus 21 and 20% for patients in Groups 2 and 3, respectively) ($p = 0.001$). Abnormal R waves in lead V_1 were more common in Group 1 than in Group 2 ($p < 0.003$) as was ST elevation in leads I, aVL and V_4 to V_6 ($p \leq 0.048$). These differences in ECG findings between Group 1 and 2 patients correlated with a significantly higher prevalence of posterior and lateral wall asynergy in the group with a circumflex artery-related infarct. Infarct size based on peak creatine kinase levels and multiple radionuclide variables was intermediate in Group 1 compared with that in Group 2 (smallest) and Group 3 (largest). During long-term fol-

low-up, the probability of recurrent cardiac events was similar in the three infarct groups.

When patients with a circumflex artery-related infarct were stratified according to the presence or absence of abnormal R waves in lead V_1 or V_2 , the abnormal R wave group had more admission ST elevation ($p = 0.025$), a larger infarct ($p < 0.05$) and more extensive coronary artery disease ($p = 0.027$). In fact, all patients with a circumflex artery-related infarct and an abnormal R wave in lead V_1 had multivessel disease. An abnormal R wave in lead V_1 had a 96% specificity for circumflex versus right coronary artery-related infarction but a sensitivity of only 21%. Discriminate function analysis of all admission historical and ECG variables identified inferior and lateral ST elevation as independent predictors of circumflex artery-related infarction.

It is concluded that 1) the clinical characteristics and prognosis after circumflex artery-related infarction are no different from those occurring after right coronary or left anterior descending artery-related infarction; 2) circumflex artery-related infarction is less likely to result in acute ECG changes because of its posterior location; 3) in patients with admission ST elevation, only ST elevation in the lateral lead is helpful in distinguishing circumflex from right coronary artery-related infarction; and 4) an abnormal R wave in lead V_1 on serial ECG is a specific but insensitive marker for circumflex artery-related infarction. In addition, this finding indicates a large infarction and correlates with more extensive coronary artery disease.

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Acute myocardial infarction due to left circumflex coronary artery occlusion is an infrequent and poorly characterized event (1,2). Whereas several recent retrospective studies (3-6) have focused on selected aspects of circumflex artery-related or posterior infarction, we know of no comprehensive study limited to a consecutive series of patients with

arteriographically identified circumflex artery-related infarction. To more fully characterize this group of patients, we reviewed data from an ongoing prospective study of acute myocardial infarction and identified all patients whose circumflex artery was the vessel responsible for infarction. This report describes the clinical, electrocardiographic (ECG), scintigraphic, angiographic and follow-up findings in these patients and compares them with findings in patients with right coronary artery and left anterior descending artery-related infarction.

Methods

Patient selection criteria. The study cohort was selected from 273 consecutive patients admitted to our coronary intensive care unit who met the following criteria: 1) acute myocardial infarction diagnosed by a typical history of chest pain and a diagnostic increase and decrease of the serum creatine kinase MB isoenzyme; 2) age ≤ 65 years; 3) absence of significant valvular, congenital or cardiomyopathic heart disease or history of coronary bypass surgery; 4) absence of cardiogenic shock, ventricular septal defect or papillary muscle rupture; 5) absence of left bundle branch block by standard ECG criteria; 6) absence of serious noncoronary disease that might limit long-term follow-up; and 7) willingness to undergo predischARGE coronary angiography, quantitative thallium-201 exercise scintigraphy and rest radionuclide ventriculography.

All 273 patients who gave written informed consent were considered candidates for treadmill exercise testing before hospital discharge. However, rest or effort angina in the antecedent 4 days, persistent congestive heart failure, poorly controlled arrhythmias or musculoskeletal handicap precluded performing the stress examination in 32 (12%). Each of the remaining 241 patients met criteria for an uncomplicated infarction by the 5th hospital day (7) and none received thrombolytic therapy or coronary angioplasty in the acute period.

Clinical evaluation. All patients were evaluated on admission and daily thereafter by a staff cardiologist and a research nurse for the duration of their hospitalization. Serum creatine kinase levels were measured on admission and at 4 h intervals for the next 24 h, then daily until a normal value was obtained. Each patient was assigned by clinical criteria to Killip classes I to III (8); for further characterization the Norris coronary prognostic index was calculated (9).

Electrocardiographic evaluation. Twelve lead ECGs were obtained on admission (day 1), and on days 2, 3 and 10 at a paper speed of 25 mm/s and at a calibration of 1 cm = 1 mV. All four ECGs from each patient were interpreted without knowledge of other patient data by two independent investigators as previously described (10). When disagreement occurred with reference to the type of infarction (Q wave versus non-Q wave) or ST segment quantification, a third

observer interpreted the tracing in question and the majority reading prevailed.

ST segment elevation and depression on the admission ECG were measured with calipers 40 ms after the J point using the preceding TP segment as a baseline. An ST elevation and depression score was calculated by summing the amount of ST deviation from all leads with ≥ 1 mm ST elevation or depression. For the purpose of this study, posterior infarction was defined by the presence of an initial R wave of ≥ 40 ms in lead V_1 or V_2 or an R to S wave amplitude ratio ≥ 1 mm in lead V_1 or V_2 in the absence of Wolff-Parkinson-White syndrome, right ventricular hypertrophy or right bundle branch block. Eleven patients with right bundle branch block (two with circumflex, two with right coronary and seven with left anterior descending artery-related infarction) were excluded from analyses involving the R/S ratio in lead V_1 or V_2 . A Q wave infarction was designated if new Q waves of ≥ 30 ms appeared on serial ECGs in two or more contiguous leads. Patients with an abnormal R wave in lead V_1 (as previously defined) were included in the Q wave group. A non-Q wave infarction was designated if the aforementioned criteria were not met and there was active evolution of ST segment or T wave changes, or both, on serial ECGs. In all patients with a history of prior infarction, old ECGs were reviewed to ensure correct group assignment for those manifesting Q waves on the admission ECG.

PredischARGE exercise testing. An intravenous cannula was inserted before the test, and baseline 12 lead ECGs were recorded with patients in the supine, sitting and standing positions and after 30 s of hyperventilation. All patients exercised on a treadmill a mean of 10 ± 3 days after onset of infarction using previously described methods (10). Before the exercise test no attempt was made to alter medical therapy that was to be continued on a long-term basis. An intravenous dose of 1.8 to 2.1 mCi of thallium-201 was administered followed by a 10 ml saline flush as the patient approached either the target heart rate or work load or limiting symptoms and the exercise was continued as tolerated for an additional 60 s.

Quantitative thallium-201 perfusion scintigraphy. The techniques for myocardial thallium-201 scintigraphy, computer processing of the early postexercise and redistribution images and quantification of segmental thallium uptake and washout in six standard scan segments have been previously described (11). Briefly, after image acquisition, each segment was classified as normal or abnormal on the basis of relative quantitative evaluation of both the early (10 min) and late (2 to 3 h) postexercise scintigrams. To be considered normal, a scintigram had to have uniform thallium uptake on the initial image, with subsequent washout of the radiotracer over the 2 to 3 h imaging period (i.e., a decline in the time-activity curve). A myocardial segment was designated abnormal if thallium uptake was reduced by $\geq 25\%$ in the

anterolateral, anteroseptal, apical, posterolateral or inferoapical/low posterolateral segments and by $\geq 35\%$ in the inferior segment relative to the myocardial region of most intense uptake on the initial images. The delayed images were used to characterize initial perfusion abnormalities as either persistent or showing redistribution (11,12). A persistent defect was designated if no redistribution was documented on numerical analysis and regional myocardial thallium activity remained persistently reduced during the imaging period.

Radionuclide ventriculography. After the delayed thallium-201 scintigrams were obtained, technetium-99m equilibrium-gated blood pool imaging was performed at rest using standard count volume techniques to determine left ventricular ejection fraction and segmental wall motion patterns. Ejection fraction was calculated from the 45° left anterior oblique projection without caudal angulation by an accepted count-volume method. Wall motion was assessed qualitatively by dividing the left ventricle into 11 segments as previously described (13,14). Left ventricular wall motion was graded using a five point scale: -1 = hyperkinetic, 0 = segment not seen, 1 = normal, 2 = hypokinetic, 3 = akinetic and 4 = dyskinetic. A regional wall motion score was derived by summing the scores of individual segments. The wall motion index was then calculated as the total wall motion score divided by the number of segments analyzed (13,14).

Coronary angiography. Selective coronary angiography in multiple oblique projections was performed in all patients within 24 to 72 h of exercise testing. Our methodology for interpreting the angiographic findings has been previously described (15). Briefly, the location of significant stenoses, i.e., $\geq 50\%$ luminal narrowing, was recorded with use of the 15 segment model recommended by the American Heart Association (16). Multivessel disease was defined as a $\geq 50\%$ luminal narrowing in two or more of the major epicardial vessels. Only the most severe stenosis of the coronary artery segment was recorded and each patient was classified as having one, two or three vessel disease. Significant narrowings in large diagonal or marginal branches were considered lesions of the left anterior descending or left circumflex coronary artery, respectively. Narrowing of the left main coronary artery was recorded as disease in both the left anterior descending and left circumflex arteries.

All vessels were classified as patent or occluded. Patency was designated only if prompt and complete antegrade filling of the distal vessel was demonstrated during selective coronary injection. Vessels showing no antegrade flow beyond the point of occlusion were recorded as occluded, as were those with perceptibly slow antegrade flow and only minimal or incomplete filling of the vessel past the obstruction. With reference to the 15 segment model (16), a proximal vessel stenosis or occlusion was designated if it was located in segment 1 in the right, 5 or 6 in the left anterior

descending or 11 in the circumflex coronary artery. Any obstruction distal to these segments in the main epicardial vessel was designated as a distal lesion.

The vessel considered responsible for the infarction was identified as the coronary artery supplying the area of maximal asynergy seen on the radionuclide ventriculogram and consistent with the ECG-determined site of acute infarction. Data derived from the admission ECG and the predischARGE radionuclide and angiographic evaluation permitted us to identify the infarct-related vessel in all but 4 (1.7%) of the 241 patients. These four patients had comparably severe occlusions of both the left circumflex and right coronary arteries and similar ECG and ventriculographic abnormalities. To maintain as much purity as possible in the circumflex artery group, the infarction in all four was designated as right coronary artery-related infarction.

Clinical follow-up. After hospital discharge, patients were managed by their primary physicians and no attempt was made to standardize medical therapy or regulate rehabilitation strategy. All patients were asked to return to the Post-Myocardial Infarction Clinic for evaluation of clinical status by the principal investigator (R.S.G.) 3 months after discharge and yearly thereafter. For the 3% of eligible patients who did not return, follow-up information was collected by telephone interview. During follow-up, the incidence of cardiac death, recurrent myocardial infarction, rapidly progressive New York Heart Association class III or IV angina pectoris and aortocoronary bypass surgery or percutaneous transluminal coronary angioplasty was tabulated. To avoid classifying noncardiac chest pain as an ischemic event, recurrent chest pain was recorded as an event only if it was designated as class III or IV angina and required rehospitalization for management. Because we anticipated that results of predischARGE testing might contribute to the decision to perform coronary surgery or angioplasty, the specific reason for revascularization was sought.

The functional class of patients with stable exertional angina after discharge was also recorded. The diagnosis of recurrent myocardial infarction was established as described. Cardiac death was defined if the death was sudden, occurring within 1 h of onset of symptoms, or if it was associated with other cardiac complications for which the patient had been hospitalized. For purposes of analysis, only one event, the most serious, was tabulated for each patient. Follow-up was terminated with the occurrence of death, bypass surgery or angioplasty.

Data interpretation and statistical analyses. All test results were interpreted by two experienced investigators without knowledge of patient identity or results of other tests. In cases of discordant readings, a consensus interpretation with a third blinded observer was used. Individual test data were compiled prospectively and stored in a computerized data bank using a Vax 11/750. Commercially available

software (Statistical Analysis System) was used for statistical computations.

Continuous data are recorded as mean values \pm SD except when indicated for graphic purposes, in which case mean values \pm SEM are employed. To determine differences between means of independent observations, *t* statistics were employed to delineate the significance of any observed differences. Discrete variables were analyzed with contingency tables with either a chi-square or two-tailed Fisher's exact test. Comparisons among group means were done by analysis of variance (ANOVA). Stepwise discriminant function analysis was employed to identify clinical and ECG predictors of circumflex artery-related infarction.

Comparative event rates, including cardiac death, recurrent infarction, unstable angina pectoris requiring hospitalization and coronary artery bypass surgery or angioplasty among the three groups based on infarct-related vessel identity, were initially evaluated as simple differences between proportions. To further examine differences in outcome, separate life tables (Kaplan-Meier) based on individual survival time were calculated for patients with left circumflex, right coronary and left anterior descending artery-related infarction. Plots were constructed to show the cumulative event rates from testing after myocardial infarction to the conclusion of follow-up; follow-up was terminated in the case of death or if the patient underwent either coronary bypass surgery or angioplasty in this analysis. Equality of event probability between groups of patients based on the vessel responsible for infarction was evaluated using the log rank statistic.

Results

Of the 241 patients, 40 (17%) had left circumflex, 167 (44%) had right coronary and 94 (39%) had left anterior descending artery-related infarction. There were no significant differences among the three groups in baseline clinical characteristics or prevalence of Lown grade ≥ 3 ventricular arrhythmias (Table 1).

Type and magnitude of electrocardiographic changes. Table 2 shows the admission and serial ECG data stratified by infarct-related vessel. Acute ST segment elevation was found in only 48% of patients with circumflex artery-related infarction versus 71 and 72% of patients with right coronary and left anterior descending artery-related infarction, respectively ($p = 0.012$ [ANOVA]). The magnitude of ST elevation in patients who had ≥ 1 mm of ST elevation was no different between the circumflex and right coronary groups. Although the proportion of patients with ST depression was similar in the circumflex and right coronary groups (45 versus 55%, $p = \text{NS}$), the number of leads with ST depression was significantly greater in the right coronary group (2.2 ± 2.4 versus 1.4 ± 1.9 leads, $p = 0.05$). Fifteen patients (38%) in the circumflex group had no ST change (elevation or

Table 1. Baseline Clinical Characteristics of 241 Patients Stratified by Infarct-Related Coronary Vessel

	LCx (n = 40)	RCA (n = 107)	LAD (n = 94)
Age (yr)	52 \pm 8	51 \pm 8	51 \pm 9
Gender (male)	88%	85%	84%
No. risk factors*	2.4 \pm 0.8	2.2 \pm 1.1	2.3 \pm 1.2
Prior angina	40%	36%	51%
Previous MI	18%	18%	17%
Norris index	2.8 \pm 1.9	2.6 \pm 1.9	2.9 \pm 2.2
Duration of chest pain before CCU admission (h)	5.2 \pm 5.6	5.1 \pm 7.1	4.1 \pm 9.4
Admission Killip class	1.4 \pm 0.1	1.3 \pm 0.5	1.4 \pm 0.6
Maximal Killip class	1.5 \pm 0.6	1.5 \pm 0.6	1.6 \pm 0.6
Time to peak CK (h)	21.7 \pm 8.1	21.1 \pm 8.7	18.6 \pm 9.1
In-hospital complications†	1.2 \pm 1.1	1.4 \pm 1.3	1.3 \pm 1.1
Lown grade ≥ 3 PVCs‡	20%	19%	19%

*Hypertension, smoking, hypercholesterolemia, family history of coronary disease at ≤ 60 years of age, diabetes mellitus and obesity. †Angina pectoris, infarct extension, congestive heart failure, hypotension, ventricular tachycardia or fibrillation, heart block requiring pacemaker insertion, pericarditis or right ventricular infarction syndrome. ‡24 h Holter (Avionics Model 650 or Cardiodata MK3 system) recording during routine hospital activities 8 ± 3 days after onset of infarction. CCU = coronary care unit; CK = creatine kinase; LAD = left anterior descending coronary artery; LCx = left circumflex coronary artery; MI = myocardial infarction; PVC = premature ventricular complexes; RCA = right coronary artery.

depression) on the admission ECG, compared with only 21% in the right coronary and 20% in the left anterior descending group ($p = 0.001$ [ANOVA]). When the 40 patients with a circumflex artery-related infarct were stratified on the basis of presence ($n = 25$) or absence ($n = 15$) of admission ST changes, no significant differences were found with respect to any clinical or angiographic variable or enzymatic or scintigraphic measure of infarct size.

Although no between-group differences were found in the type of infarction (that is, Q versus non-Q wave), an abnormal R wave in lead V_1 was five times more frequent with circumflex than with right coronary artery-related infarction (8 [21%] of 38 versus 4 [3.9%] of 105; $p = 0.0028$). An abnormal R wave in lead V_2 , however, was equally common in the two infarct groups (42 versus 33%, $p = \text{NS}$).

Location of electrocardiographic changes. The location of admission and serial ECG changes stratified by infarct-related vessel is shown in Table 3. In the circumflex group, ST segment elevation was found most frequently in leads II, III and aVF followed by leads V_5 and V_6 . Although the proportion of patients with ST elevation in each of the inferior leads (II, III, aVF) was similar for the circumflex and right coronary groups, ST elevation in each of the four lateral leads (I, aVL, V_5 , V_6) as well as lead V_4 was significantly more common in patients with a circumflex compared with a right coronary artery-related infarct (p values between 0.048 and 0.0004 for individual lead comparisons).

Table 2. Admission and Serial Electrocardiographic Data on 241 Patients Stratified by Infarct Vessel

	LCx (n = 40)	RCA (n = 107)	LAD (n = 94)
Admission electrocardiogram			
ST elev. ≥ 1 mm* (pts)	19 (48%) ^{†,‡}	76 (71%)	68 (72%)
Magnitude of ST seg elev (mm)			
1.0 to 1.9	10 (53%)	34 (45%)	22 (32%)
2.0 to 2.9	5 (26%)	26 (34%)	15 (22%)
≥ 3.0	4 (21%)	16 (21%)	31 (46%)
Leads with ≥ 1 mm ST seg elev	1.9 \pm 2.5 [‡]	2.1 \pm 1.7 [‡]	2.9 \pm 2.5
ST seg elev score (mm)	3.9 \pm 7.2 [‡]	4.9 \pm 5.6 [‡]	7.1 \pm 8.3
ST seg dep ≥ 1 mm* (pts)	18 (45%)	59 (55%) [§]	30 (32%)
Leads with ≥ 1 mm ST seg dep	1.4 \pm 1.9 [‡]	2.2 \pm 2.4 [‡]	0.9 \pm 1.4
ST seg dep score (mm)	2.7 \pm 5.0	3.9 \pm 5.5 [‡]	1.2 \pm 2.2
No ST seg elev or dep ≥ 1 mm* (pts)	15 (38%) ^{†,‡}	22 (21%)	19 (20%)
Serial electrocardiogram			
Non-Q wave infarction (pts)	20 (50%)	35 (33%)	32 (34%)
Abnormal R waves (pts)			
Lead V ₁	8 (21%) ^{†,‡}	4 (3.9%)	1 (1.2%)
Lead V ₂	16 (42%) [‡]	35 (33%) [§]	1 (1.2%)
Lead V ₁ or V ₂	19 (50%) [‡]	35 (33%) [§]	2 (2.3%)

Unless otherwise indicated, p = NS for comparisons between the three infarct vessels. * = $n \geq 1$ lead; † = $p \leq 0.05$ between the left circumflex coronary artery and right coronary artery groups; ‡ = $p \leq 0.05$ between the left circumflex coronary artery and left anterior descending artery groups; § = $p \leq 0.05$ between the right coronary artery and left anterior descending artery groups; || = 11 patients not included because of the presence of right bundle branch block; dep = depression; elev = elevation; pts = patients; seg = segment; other abbreviations as in Table 1.

In the circumflex group, ST segment depression was found most frequently in leads V₂ to V₄ and aVL. However, the proportion of patients with ST segment depression in each of the four anterior precordial leads (V₁ to V₄) was

similar in the circumflex and the right coronary group. The only leads with ST segment depression that discriminated between these two groups were leads I and aVL; ST segment depression in both of these leads was more common with right coronary infarction ($p = 0.007$ and 0.016 , respectively).

New Q waves in leads III and aVF were more common in the right coronary group ($p = 0.0026$ compared with the circumflex group) whereas Q waves in leads I, aVL and V₆ were more common in the circumflex group ($p \leq 0.018$ compared with the right coronary group). As with ST elevation, the prevalence of Q waves in leads I, aVL and V₅ was similar in the circumflex and left anterior descending groups but was greater in lead V₆ among patients with a circumflex artery-related infarct.

Measures of infarct size (Fig. 1). The size of infarction as assessed by peak creatine kinase levels, ejection fraction, the number of akinetic left ventricular segments, infarct zone asynergy scores and the number of persistent thallium defects within the infarct region was intermediate in the circumflex group when compared with the right coronary group (smallest infarcts) and the left anterior descending group (largest infarcts). Whereas left anterior descending artery-related infarcts were significantly larger than right coronary artery-related infarcts by all techniques used to measure infarct size, only radionuclide ventriculography identified significant differences between circumflex and left anterior descending artery-related infarcts (left ventricular ejection fraction $49 \pm 10\%$ versus $44 \pm 13\%$, $p = 0.017$) and between circumflex and right coronary infarcts (infarct zone asynergy score 2.0 ± 0.6 versus 1.7 ± 0.5 , $p = 0.025$).

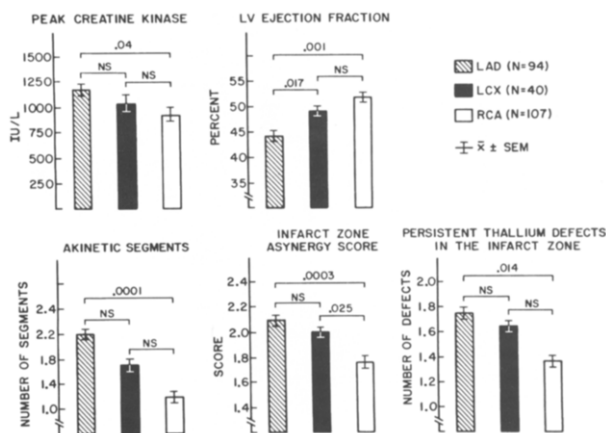
Location of left ventricular asynergy and thallium-201 perfusion abnormalities. Figure 2 shows the location of scintigraphic abnormalities in patients with single vessel circumflex artery-related infarction versus single vessel right coronary artery-related infarction. In the circumflex group, left ventricular wall motion abnormalities were found most

Table 3. Location of Electrocardiographic Changes Stratified by Infarct Vessel

n (%)	Inferior Leads			Lateral Leads				Anterior Leads			
	II	III	aVF	I	aVL	V ₅	V ₆	V ₁	V ₂	V ₃	V ₄
ST seg elev											
LCx (n = 19)	11 (58%)	12 (63%)	12 (63%)	4 (32%)	3 (16%)	8 (42%)	9 (47%)	1 (5)	3 (16%)	4 (21%)	4 (21%)
RCA (n = 76)	51 (67%)	63 (83%)	59 (78%)	2 (3%)	1 (1%)	5 (7%)	7 (9%)	2 (3%)	9 (12%)	9 (12%)	4 (5%)
LAD (n = 68)	3 (4%)	5 (7%)	3 (4%)	18 (26%)	19 (28%)	29 (43%)	11 (16%)	18 (26%)	62 (91%)	56 (82%)	44 (65%)
ST seg dep											
LCx (n = 18)	0 (0%)	2 (11%)	1 (6%)	4 (22%)	8 (44%)	4 (22%)	5 (28%)	5 (28%)	11 (61%)	9 (50%)	8 (44%)
RCA (n = 59)	1 (2%)	2 (3%)	2 (3%)	35 (59%)	46 (78%)	21 (36%)	17 (29%)	12 (20%)	38 (64%)	37(63%)	30 (51%)
LAD (n = 30)	16 (53%)	20 (67%)	18 (60%)	3 (10%)	2 (7%)	8 (27%)	5 (17%)	0 (0%)	0 (0%)	3 (10%)	7 (23%)
New Q waves											
LCx (n = 26)	8 (31%)	16 (62%)	14 (54%)	5 (19%)	4 (15%)	1 (4%)	5 (19%)	2 (8%)	2 (8%)	1 (4%)	1 (4%)
RCA (n = 83)	30 (36%)	79 (95%)	70 (84%)	1 (1%)	0 (0%)	3 (4%)	3 (4%)	2 (2%)	2 (2%)	3 (4%)	1 (1%)
LAD (n = 75)	4 (5%)	12 (16%)	7 (9%)	9 (12%)	22 (29%)	15 (20%)	4 (5%)	38 (51%)	57 (76%)	51 (68%)	38 (51%)

Symbols and abbreviations as in Table 2.

Figure 1. Measures of infarct size based on identity of infarct-related coronary artery in 241 patients. LAD = left anterior descending coronary artery; LCX = left circumflex coronary artery; LV = left ventricular; RCA = right coronary artery.



often in the posterobasal segment (80%) followed by the low posterolateral (36%) and anterolateral segments (36%). Asynergy in each of these three segments as well as the high posterolateral segment was significantly more frequent in the circumflex than in the right coronary group. In contrast, inferior left ventricular asynergy was more common in the right coronary group.

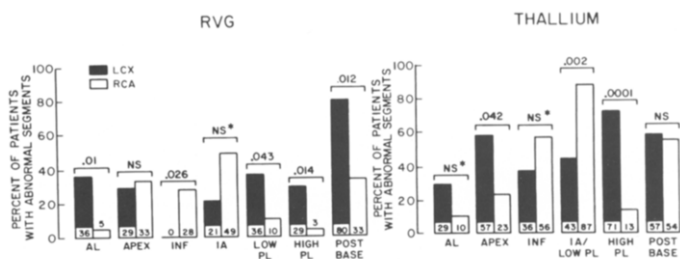
Thallium scintigraphy in the circumflex group revealed perfusion defects most commonly in the high posterolateral segment (71%) followed by the posterobasal (57%) and apical (57%) segments. Defects in the high posterolateral and apical segments were more common with circumflex than with right coronary artery-related infarction. Scintigraphic findings in patients with multivessel disease are shown in Figure 3.

Sensitivity of abnormal R waves in leads V_1 and V_2 for posterior asynergy. Because an abnormal R wave in lead V_1 or V_2 is thought to be a marker for posterior infarction, we examined the relation between abnormal R waves and wall

motion abnormalities of the posterior and posterolateral walls. Abnormal R waves in lead V_1 or V_2 were found in 15 (75%) of 20 patients with low posterolateral asynergy, in 9 (64%) of 14 patients with high posterolateral asynergy, in 7 (77%) of 9 patients with distal posterior asynergy (as assessed from the 70° left anterior oblique projection) and in 11 (50%) of 22 patients with posterobasal asynergy. When the analysis was restricted to an abnormal R wave in lead V_1 , the frequency of associated asynergy was 40, 21, 55 and 23% for the four segments, respectively. Thus, although an abnormal R wave in lead V_1 or V_2 was frequently associated with posterior asynergy, the presence of an abnormal R wave in lead V_1 was a relatively insensitive marker.

Coronary angiographic data. In the circumflex group, 26 (65%) of 40 patients had two or three vessel disease. By comparison, 68 (64%) of 107 patients in the right coronary group and 44 (47%) of 94 patients in the left anterior descending group had multivessel disease ($p = 0.06$ [ANOVA]). The proximal segment of the infarct-related

Figure 2. Location of scintigraphic defects in 53 of the 103 patients with single vessel disease (patients with disease of the left anterior descending artery are excluded). Numbers at the bottom of each column equal percent. * $p \leq 0.005$ when patients with multivessel disease are included. AL = anterolateral; IA = inferoapical; INF = inferior; LCX = left circumflex coronary artery; PL = posterolateral; POST BASE = posterobasal; RCA = right coronary artery; RVG = radionuclide ventriculogram.



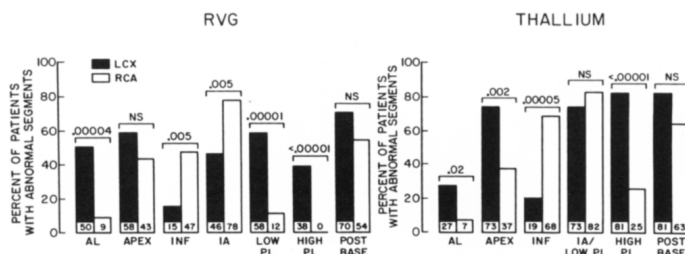


Figure 3. Location of scintigraphic defects in 94 of the 138 patients with multivessel disease (patients with disease affecting the left anterior descending artery are not included). Numbers at the bottom of each column equal percent. Abbreviations as in Figure 2.

artery contained the most severe stenosis in 75, 60 and 57% of patients in the three infarct groups, respectively ($p = \text{NS}$). Complete occlusion of the infarct-related vessel was found in 60% of the circumflex group versus 75% of the right coronary group and 56% of left anterior descending group ($p = 0.018$ [ANOVA]).

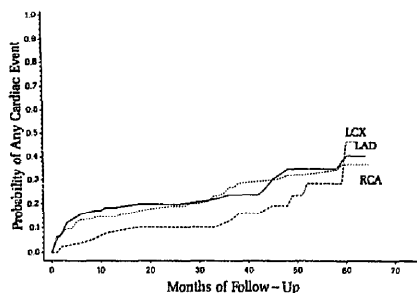
Clinical outcome. During a mean follow-up period of 39 months, there were three deaths (7.5%) in the circumflex group, and six cases (15%) of reinfarction and six cases (15%) of unstable angina that subsequently required either coronary bypass surgery or angioplasty for control of symptoms. There were no differences in these event rates (individually or combined) when the patients with a circumflex artery-related infarct were compared with those with right coronary or left anterior descending artery-related infarcts. Figure 4 illustrates the similar cumulative event rates among the three groups subsequent to hospital discharge.

Subgroup analysis based on electrocardiographic type of infarction (Q wave versus non-Q wave). All 241 patients were subclassified on the basis of presence or absence of new pathologic Q waves on serial ECGs. In both the right coronary and left anterior descending groups, the absence of

Q waves (that is, presence of non-Q wave infarction) was associated with significantly lower peak creatine kinase levels, a higher left ventricular ejection fraction, more residual infarct zone ischemia by thallium-201 criteria and a higher incidence of recurrent ischemic events during long-term follow-up compared with Q wave infarction. However, these differences were not found consistently when patients with a circumflex artery-related infarct were stratified into Q wave and non-Q wave subgroups. Only thallium scintigraphy identified differences between the Q wave and non-Q wave subgroup of patients in the left circumflex group; compared with patients with a Q wave infarct, those with a non-Q wave infarct had fewer persistent thallium defects (2.2 ± 1.0 versus 1.0 ± 1.0 , $p \leq 0.01$) but more redistribution defects within the infarct zone (0.3 ± 0.6 versus 1.1 ± 1.1 , $p \leq 0.01$).

Patients with a circumflex artery-related infarct were also subgrouped according to the presence or absence of abnormal R waves in leads V_1 or V_2 . In this analysis, 2 of the 40 patients with circumflex artery-related infarction were censored because of the presence of right bundle branch block. Among the remaining 38 patients, 19 (50%) had an abnormal R wave in lead V_1 or V_2 and 19 (50%) did not. When these two groups were compared, a number of significant differences emerged. Although the proportion of patients with ST elevation in each group was similar, the magnitude of ST elevation was greater in the abnormal R wave group compared with the normal R wave group (for example, number of leads with ST elevation 2.7 ± 3.0 versus 0.9 ± 1.3 , $p = 0.025$ and Σ ST elevation score 6.7 ± 9.7 versus 1.3 ± 1.7 mm, $p = 0.027$). Also, several measurements of infarct size indicated more necrosis in the group with an abnormal R wave including: left ventricular ejection fraction (45 ± 10 versus $53 \pm 10\%$, $p = 0.03$); the number of akinetic segments (2.3 ± 1.9 versus 1.2 ± 1.2 , $p = 0.047$) and the number of persistent thallium defects in the infarct zone (2.1 ± 1.0 versus 1.2 ± 1.1 , $p = 0.019$). The coronary angiographic data revealed that although the number of diseased vessels in the two groups was similar (2.1 ± 0.7 versus 1.7 ± 0.9 , $p = \text{NS}$), the number of jeopardized angiographic segments and the number of proximal segments with significant stenoses were

Figure 4. Probability of any cardiac event (death, reinfarction or unstable angina requiring bypass surgery or angioplasty) in 241 patients stratified by infarct-related vessel (Kaplan-Meier plots) (see text). Abbreviations as in Figure 1.



greater in the abnormal R wave group compared with the normal R wave group (8.0 ± 2.8 versus 5.7 ± 3.2 jeopardized segments, $p = 0.027$, and 1.5 ± 0.7 versus 0.95 ± 0.7 proximal segments, $p = 0.027$, respectively). Furthermore, all eight patients in the circumflex group who had an abnormal R wave in lead V_1 had multivessel disease. No patient with single vessel circumflex artery-related infarction developed an abnormal R wave in lead V_1 ($p = 0.022$). Most of these findings were not observed when patients with right coronary artery-related infarction were stratified by the presence or absence of an abnormal R wave in lead V_1 or V_2 .

Predicting circumflex artery-related infarction. An abnormal R wave in lead V_1 was found to be very specific (96%) for circumflex artery-related infarction. However, because only 8 of the 38 patients in this group had this ECG finding, the sensitivity was quite low (21%). Including abnormal R waves in lead V_2 increased sensitivity to 50% but decreased both specificity and predictive accuracy to 67 and 62%, respectively.

When all historical and ECG data available at the time of hospital admission were evaluated with stepwise discriminant function analysis, only inferior and lateral ST elevation were found to be independent predictors of circumflex versus right coronary artery-related infarction. Isolated inferior ST elevation predicted right coronary infarction, whereas three patterns predicted circumflex artery-related infarction. These included 1) the presence of both inferior and lateral ST elevation (best predictor); 2) the absence of both inferior and lateral ST elevation; and 3) isolated lateral ST elevation. With one of these independent variables, the infarct-related vessel was calculated for each patient and the calculations were examined for accuracy. Overall, 93 (63%) of the 147 infarct-related vessels were correctly predicted: 34 (85%) in the circumflex group and 59 (55%) in the right coronary group. Table 4 shows the patterns of ST elevation in the 40 patients in the circumflex group and the 107 patients in the right coronary group.

Discussion

Circumflex coronary artery-related infarction. We found that 17% of our 241 patients with creatine kinase MB isoenzyme-confirmed acute uncomplicated myocardial infarction had circumflex coronary artery-related infarction. This prevalence is slightly higher than the 8 to 16% reported in recent thrombolytic trials (1), possibly because ST elevation (an enrollment criterion for thrombolytic protocols) was not required for entry into our study. The clinical characteristics of our patients with a circumflex artery-related infarct were no different from those in patients with a right coronary or left anterior descending artery-related infarct. In addition, prognosis during a mean follow-up of 39 months was similar among the three infarct groups (Fig. 4). This finding is not surprising and can be explained by noting that left ventricu-

lar function was relatively well preserved in all three groups, that all patients had uncomplicated infarction and were eligible for predischARGE exercise testing and that no between-group differences existed in either the prevalence of Lown grade ≥ 3 arrhythmias or the extent of inducible myocardial ischemia as assessed by predischARGE quantitative thallium scintigraphic criteria, that is, redistribution defects ($p = 0.219$ [ANOVA]).

Electrocardiographic findings with circumflex artery-related infarction. Our data show that circumflex artery-related infarction is less likely to result in acute ECG changes because of its posterior location. Indeed, only 48% of our circumflex group had ST segment elevation on the admission ECG compared with 71% in the right coronary and 72% in the left anterior descending group (Table 2). This is similar to the data reported by Movahed and Becker (3), who found that only 12 (55%) of 22 patients with acute infarction limited to the lateral and posterolateral walls by thallium scintigraphy had ST segment elevation on admission.

ST segment elevation on the admission ECG was found most frequently in the inferior leads followed by leads V_5 and V_6 , and ST segment depression occurred most commonly in leads V_2 to V_4 and aVL. These findings agree with previously reported data (17,18) but, as noted by Fuchs et al. (18), the location of these acute ECG changes is not specific for either circumflex or right coronary artery-related infarction. Indeed, the frequency of inferior ST elevation and anterior ST depression was not different in the two infarct groups. Only the lateral leads separated these two groups: lateral ST elevation was more common in circumflex artery-related infarction and ST depression in lead I and lead aVL was more common with right coronary artery-related infarction. Our data also show that the magnitude of ST segment change in those patients who have acute ECG changes is similar in the two groups of patients (Table 2). Therefore, when ST elevation is present, only lateral ST segment elevation is helpful in distinguishing circumflex from right coronary artery-related infarction.

In addition to ST segment shifts in the lateral leads, an abnormal R wave in lead V_1 was also useful in distinguishing circumflex and right coronary artery-related infarction. An abnormal R wave in lead V_1 was five times more common in the former group compared with the latter group (21 versus 3.9%, $p = 0.0028$) (Table 2). A similar trend was found when abnormal R waves in lead V_1 or V_2 were included in the analysis, although the difference did not quite reach statistical significance ($p = 0.08$). This is because an abnormal R wave in lead V_2 was found in 33% of the right coronary group versus 42% of the circumflex group ($p = \text{NS}$). Thus, our data indicate that "true posterior" infarction is more likely due to circumflex artery-related infarction. Bough and Korr (4) reported no significant difference in the incidence of circumflex versus right coronary disease in ECG posterior

infarction; however, they included an isolated abnormal R wave in lead V_2 in their definition of posterior infarction for this selected retrospective study.

Comparisons between the circumflex and left anterior descending groups revealed no differences in the frequency of ST elevation or new Q waves in the lateral leads I, aVL and V_5 . As expected, anterior ST elevation was more frequent in left anterior descending artery-related infarcts; however, ST depression in the anterior leads V_1 to V_3 was more common in circumflex artery-related infarcts.

Only 5 (15%) of our 40 patients in the circumflex group presented with isolated ST depression. Five of these six patients had both anterior and lateral ST depression and one had ST depression confined to leads V_1 to V_4 . Boden et al. (19) recently reported that 23 of 56 patients in their study of non-Q wave infarction presented with isolated anterior ST depression but subsequently evolved criteria for posterior infarction (that is, posterior infarction presenting as anterior non-Q wave infarction). Our data indicate that this type of presentation for circumflex artery-related infarction is uncommon.

Correlation of electrocardiographic and radionuclide data.

Among patients with circumflex artery-related infarction and single vessel disease, radionuclide ventriculography showed asynergy most frequently in the posterobasal, low posterolateral and anterolateral segments (Fig. 2). Whereas asynergy of these three segments as well as the high posterolateral segment was more common in these patients compared with those with right coronary artery-related infarction, no patient in the single vessel circumflex group had inferior asynergy compared with 28% with in the right coronary group ($p = 0.026$). In addition, inferoapical asynergy was more frequent in the right coronary versus the circumflex group and this difference reached statistical significance when patients with multivessel disease were included (Fig. 3).

Thallium scintigraphy revealed perfusion defects in the infarct group with single vessel disease of the circumflex artery, most commonly in the high posterolateral, posterobasal and apical segments (Fig. 2). This finding agrees closely with previously reported data on patients with circumflex artery disease (17,20). In our group, an abnormal R wave in lead V_1 or V_2 was most often associated with asynergy of the low posterolateral (75%) and distal posterior (77%) segments, as assessed by radionuclide ventriculography. Bough et al. (5) found that similar R waves were most strongly associated with abnormalities of the basal lateral (our high posterolateral) segment, although asynergy of adjacent inferior and lateral segments was found frequently. We also found adjacent asynergy to be common because only 4 (10%) of 40 patients had asynergy in only one segment.

Our data show that the standard 12 lead scalar ECG is insensitive in detecting posterolateral or posterior asynergy. Other studies have found similar results. For example, Arkin

et al. (21) reported that an abnormal R wave in lead V_1 was present in only 11 (12%) of 92 patients with posterior asynergy. Howard et al. (22) found the ECG to be diagnostic of posterior infarction in only 6 (16%) of 38 patients with asynergy of the posterior wall. Finally, the pathologic study of Savage et al. (23) found that only 4 (33%) of 12 patients with posterior infarction had an abnormal R wave in lead V_1 . Other studies (22,24) have found the vectorcardiogram to be more sensitive than the standard ECG in detecting circumflex artery-related or posterior infarction.

Subset analysis. We previously reported (15) that dichotomization of patients with acute myocardial infarction according to the presence or absence of pathologic Q waves identified two groups with important clinical, functional and prognostic differences. This held true for both right coronary and left anterior descending artery-related infarction, but not for circumflex artery-related infarction. In the present study, when patients with circumflex artery-related infarction were stratified according to the presence or absence of an abnormal R wave in lead V_1 or V_2 , a number of important differences emerged. Patients who developed abnormal R waves had more striking admission ECG changes, a larger infarct and more widespread coronary artery disease (especially in patients with an abnormal R wave in lead V_1) compared with the group without abnormal R waves. Thus, in our group of patients with circumflex artery-related infarction, an abnormal R wave in lead V_1 or V_2 , or both, appears to be a marker for a large infarct and more extensive underlying coronary artery disease. These findings are supported by the study of Movahed and Becker (3), who found that 51% of their patients with scintigraphically localized lateral infarction who had a non-Q wave infarct in fact appeared to have a large, transmural infarct. In support of our angiographic findings, Bough and Korr (4) concluded from their study of circumflex artery disease in ECG posterior infarction that "the RV_{1-2} pattern in patients with inferior infarction is highly predictive of at least two vessel coronary artery disease."

Predicting circumflex artery-related infarction. An abnormal R wave in lead V_1 or V_2 evolved on serial ECGs in 50% of our patients with circumflex artery-related infarction, a finding that agrees closely with the 51% reported by Dunn et al. (17). Our data show that an abnormal R wave lead in V_1 had high specificity (96%) but low sensitivity (21%) for predicting circumflex artery-related infarction, as originally noted by Perloff (25) for posterior infarction. Although including an abnormal R wave in lead V_2 increased the sensitivity to 50%, 35 of the 105 patients with right coronary artery-related infarction also had an abnormal R waves in lead V_2 and, therefore, the specificity for predicting circumflex artery-related infarction decreased significantly to 67%.

Discriminant function analysis identified inferior and lateral ST elevation as the only two clinical and ECG variables available at hospital admission that were independent pre-

Table 4. Predicted Versus Observed Infarct-Related Vessel Based on the Location of Admission ST Elevation in ECG

Location of ST Elevation	Predicted Infarct Vessel	Observed RCA (n = 107)	LCx (n = 40)
Inf only	RCA	59 (55%)	6 (15%)
Both Inf and Lat	LCx	7 (7%)	7 (18%)
Neither Inf or Lat	LCx	39 (36%)	23 (58%)
Lat only	LCx	2 (2%)	4 (10%)

ECG = electrocardiogram; Inf = inferior; Lat = lateral; other abbreviations as in Table 1.

dictors of circumflex versus right coronary artery-related infarction. Three patterns of ST elevation predicted the former (Table 4). Lateral ST elevation, either alone or in combination with inferior ST elevation, was predictive of circumflex artery-related infarction because lateral ST elevation was more common in the circumflex versus the right coronary infarct group. Also, the absence of ST elevation suggested circumflex artery-related infarction because only 48% of our patients had ST elevation compared with 71% in the right coronary group (Table 2). The pattern of ST elevation correctly predicted 85% of the circumflex group versus only a 55% correct prediction rate for the right coronary group (inferior ST elevation only pattern). Incorrect classification of right coronary artery-related infarction resulted from the fact that 36% of the patients in this group had neither inferior nor lateral ST elevation.

Conclusions. Our data indicate that: 1) the clinical characteristics and prognosis following circumflex artery-related infarction are no different from those of patients with right coronary or left anterior descending artery-related infarction; 2) circumflex artery-related infarction is less likely to result in acute ST segment changes because of its posterior location; 3) in patients with acute ST elevation, only lateral ST elevation is helpful in distinguishing circumflex from right coronary artery-related infarction; and 4) an abnormal R wave in lead V₁ on serial ECG is a specific but insensitive marker for circumflex artery-related infarction. In addition, this finding indicates a large infarct and correlates with more extensive coronary artery disease.

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