Myocardial Infarct Extension: Incidence and Relationship to Survival

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SUMMARY Myocardial infarct extension, defined as reerelevation or reappearance of creatine phosphokinase-MB (CK-MB) 48 hours after the onset of symptoms, was evaluated prospectively in 56 consecutive patients with acute myocardial infarction. Myocardial infarct extension occurred in eight patients (14%). The sensitivity, specificity and predictivity in the diagnosis of myocardial infarct extension were 63%, 85% and 42%, respectively, for recurrent chest pain requiring morphine; 50%, 65% and 19% for recurrent ST-segment elevation on routine 12-lead ECGs; and 88%, 63% and 28% for reerelevation of total CK. Three of the eight episodes of extension were clinically silent. Four of eight patients (50%) with extension died, compared with one of 46 patients (2%) without extension (p = 0.0009). CK-MB persisted for 72 hours or longer in 16 patients and identified seven of eight patients who subsequently had infarct extension.

We conclude that myocardial infarct extension is an infrequent complication of acute myocardial infarction and is associated with a very high mortality rate. Persistence of CK-MB for 72 hours or more identifies a subgroup of patients at high risk for subsequent infarct extension and death.

THE FREQUENCY of myocardial infarct extension, its clinical manifestations, and its relationship to morbidity and mortality are poorly defined. The reported frequency of myocardial infarct extension ranges from 9–86%.1, 2 In general, studies that define myocardial infarct extension on the basis of myocardial-specific enzyme changes report a lower incidence of extension1, 3 than studies that define it by electrocardiographic changes2, 4 The classic clinical hallmarks of myocardial infarct extension are recurrent chest pain or a sudden deterioration in functional class. However, myocardial infarct extension may be a silent complication of acute myocardial infarction.2, 3 The relationship between myocardial infarct extension and the acute prognosis of patients with myocardial infarction has not been clearly defined. Studies that reveal a high frequency of myocardial infarct extension show an associated low hospital mortality,2, 4 and studies that reveal a low frequency of myocardial infarct extension show an associated high hospital mortality.1, 3 The value of many reports on myocardial infarct extension is limited by the small number of patients studied or by failure to examine myocardial infarct extension prospectively.2, 4, 7

The purpose of the present study was to determine prospectively the frequency, clinical manifestations and relationship to hospital mortality of myocardial infarct extension more than 48 hours after the onset of symptoms in a consecutive group of patients with acute myocardial infarction.
Materials and Methods

Patient Selection

Consecutive patients who met the following criteria were entered into the study: (1) admission to the Durham Veterans Administration Medical Center coronary care unit with a diagnosis of acute myocardial infarction confirmed by the presence of creatine phosphokinase myocardial-specific isoenzyme (CK-MB) in their plasma during the 24 hours after the onset of symptoms that prompted admission; (2) survival beyond the first 48 hours; and (3) willingness to give informed consent for participation in this study. During the study period, 72 patients met criteria 1 and 2. Nine patients could not give informed consent because of the severity of their infarction, dementia, or delirium tremens. One patient refused to participate and four patients were missed. Fifty-eight patients entered the study over a 10-month period. CK-MB data were lost on two patients because of a technical error. The remaining 56 patients constitute the basis of this report.

Clinical Data

Day 1 was defined as the day the patient had symptoms that prompted admission. The time of onset of symptoms consistent with acute myocardial infarction was noted for each patient. All patients were interviewed and cardiovascular examination was performed by one of the physicians participating in the study at least once daily for 10 consecutive days after admission. The following data were recorded on flow charts each day: the character, duration and treatment of recurrent chest pain, dyspnea, heart rate, blood pressure, and the presence of gалlops, pericardial rubs or new murmurs.

Electrocardiographic Data

Standard 12-lead ECGs were obtained at 12-hour intervals during the 10-day period. The precordial lead positions were marked with gelltin violet on admission to ensure reproducibility of lead placement. Serial tracings for each patient were read independently by two cardiologists. Additional ST-segment elevation in a previously involved lead or new ST-segment elevation in a previously uninvolved lead that was equal to or greater than 0.1 mV was recorded. Differences in interpretation of the ECGs were resolved by mutual agreement between the two cardiologists. All interpretations were performed without knowledge of the enzyme data.

Plasma Enzyme Determinations

Blood samples for determination of total creatine phosphokinase (CK) and CK-MB activity were collected at approximately 12-hour intervals each morning and evening for 10 consecutive days after admission. After the initial diagnosis, the serial enzyme data beyond 48 hours were not made available to the physician who collected the clinical data. Blood obtained by standard venipuncture for plasma enzyme samples was frozen at −25°C and stored for subsequent analysis. Plasma CK-MB activity was assayed by a previously described electrophoretic method and CK levels were determined by a modified Rosalki procedure.

Myocardial Infarct Extension

Myocardial infarct extension was defined as a reappearence or reelevation of plasma CK-MB activity more than 48 hours after onset of infarction. This study does not deal with extension during the first 48 hours.

Statistical Methods

Clinical variables, including heart rate, age and systolic arterial blood pressure, were compared by oneway analysis of variance. Killip classification and location of infarction in patients with and without extensions were examined by chi-square analysis. All other data were analyzed by Fisher's exact test.

Results

The results are summarized in Table 1. Myocardial infarct extension occurred in eight of 56 patients (14%). Time-activity curves for the plasma CK-MB data for the eight patients with myocardial infarct extension are shown in Figure 1. The pattern of CK-MB detection was reelevation of CK-MB activity in six patients (75%) and reappearance of CK-MB activity in two patients (25%). One on day 5 and one on day 10. The mean time from the onset of symptoms of acute myocardial infarction to the plasma CK-MB documentation of myocardial infarct extension was 4.6 days.

Plasma CK-MB activity persisted for 72 hours or more after initial symptoms in 16 patients (29%); seven of these 16 patients had infarct extension. Only one of 40 patients (3%) in whom plasma CK-MB activity disappeared before 72 hours had myocardial infarct extension (p = 0.0003). CK-MB persistence identified seven of eight patients (88%) who subsequently had infarct extension. However, the predictive value of CK-MB persistence for subsequent infarct extension was 44%.

Reelevation of total plasma CK activity after 48 hours after acute myocardial infarction occurred in 25 of 56 patients (45%). This occurred in seven of eight patients (88%) with myocardial infarct extension in 18 of 48 patients (38%) without myocardial infarct extension. Although the sensitivity of total CK in detecting

Table 1. Comparative Results in Patients with and Without Myocardial Infarct Extensions

<table>
<thead>
<tr>
<th>Extention</th>
<th>No extention</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of pts</td>
<td>8</td>
<td>48</td>
</tr>
<tr>
<td>Chest pain — morphine</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>ST-segment reelevation</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>CK-MB persistence ≥ 72 hours</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>CK reelevation</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td>Mortality</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>
myocardial infarct extension in this study was 88%, the specificity was 63% and the predictive value was only 28%.

There was no statistically significant difference at the 5% level between patients with and without myocardial infarct extension with respect to age, heart rate, infarct location, Killip class or systolic blood pressure at entry into the study (table 2).

Twelve of 56 patients (21%) had recurrent chest pain that required i.v. morphine sulfate more than 48 hours after the initial symptoms. Six of these 12 patients (50%) subsequently had myocardial infarct extension, and four died in the hospital. Six of the eight patients (75%) with extension were treated with morphine sulfate for late pain (fig. 1), compared with six of 48 patients (13%) without extension (p = 0.0003). The chest pain was present within 36 hours before CK-MB enzyme documentation of extension in the six patients with myocardial infarction extension. The pain in each instance was consistent with myocardial ischemia, and none of these patients had a pericardial rub to suggest pericarditis. The requirement of morphine sulfate to relieve recurrent pain had a predictive accuracy for subsequent infarct extension of 42%.

Recurrent or new ST-segment elevation of at least 0.1 mV in one lead occurred in four of eight patients (50%) with infarct extension, compared with 17 of 48 patients (35%) without extension (p = 0.34). This ST-segment elevation was present within 24 hours before CK-MB elevation in four patients in the former group. The predictive value of ST-segment reelevation in detecting myocardial infarct extension was 19%. No patient had further evolution of Q waves after 3 days. No patient with enzymatic extension had additional QRS changes.

The overall mortality was 9% (five of 56 patients), and all deaths during the study period were related to cardiac disease. Four of eight patients (50%) with extension died, compared with one of 48 patients (2%) without extension (p = 0.0009). The clinical characteristics of all patients with infarct extension are presented in table 3.

The only patient without extension who died was a patient whose initial hospital course was complicated only by atrial tachyarrhythmias. On the fifth day the patient developed recurrent chest pain, new ST-segment elevation and hypotension, and died despite resuscitative efforts; postmortem examination revealed a ruptured papillary muscle.
The hospital mortality among the 16 patients with CK-MB persistence was 25% (four patients, all of whom who had myocardial infarct extension), compared with 2.5% (one of 40 patients) in the group without CK-MB persistence beyond 72 hours. This 10-fold increase in mortality associated with CK-MB persistence was significant (p = 0.02).

Discussion

The incidence of infarct extension occurring more than 48 hours after myocardial infarction was 14% in our 56 patients. The hospital mortality for all patients in the study was 9%, while the mortality for patients with extension was 50%. Rothkopf et al.3 reported similar results in a prospective study of infarct extension in 43 patients with acute myocardial infarction. Using a radioimmunoassay technique to measure CK-MB every 12 hours for 14 days after acute myocardial infarction, they found secondary rises in CK-MB in 10 patients (23%) 3–14 days after infarction. Four of these 10 patients (40%) died in hospital; none of the 33 patients without extension died. In six patients, extension was not detected clinically. In our study, two of eight episodes of extension (25%) were clinically silent.

The slightly higher incidence of infarct extension in the study by Rothkopf et al.3 may be explained by differences in techniques used to assay CK-MB activity. The radioimmunoassay technique detects CK-MB in normal plasma; the electrophoretic method does not.28 In addition, the radioimmunoassay detects BB isoenzymes as well as the MB isoenzymes of CK,24 whereas the electrophoretic method measures only CK-MB, the myocardial-specific isoenzyme.

Fraker et al.1 reported a retrospective study of 458 patients with acute myocardial infarction who had no symptoms of heart failure on admission. A definite infarct extension was defined as a clinical event that suggested extension, occurred more than 24 hours after the onset of initial symptoms and was accompanied by two of the following: new QRS changes, reappearance of CK-MB, or reelevation of total CK. Blood samples were obtained for isoenzyme analyses based on the clinical event and were not obtained in a serial prospective fashion. Suspected extension was defined as a clinical event accompanied by only one other variable. Definite extension occurred in 9.4% and was associated with a 33% mortality. The combined incidence of both definite and suspected extension was 12.7%; the associated mortality was 36%. The lower incidence of extension compared with our study and the study of Rothkopf et al.3 may be the result of selecting uncomplicated patients on admission or the failure of the retrospective analysis to identify asymptomatic extension.

The development of techniques18 to measure isoenzyme activity of creatine phosphokinase and the recognition that the isoenzyme CK-MB is present in appreciable amounts only in the myocardium17,18 have provided a highly specific and sensitive means for detecting acute myocardial infarction.19–21 Since CK-MB peaks at approximately 19 hours and then progressively declines to undetectable levels by 48 hours after the onset of acute infarction,22 reelevation of CK-MB after 48 hours or reappearance of CK-MB plasma activity after its disappearance should provide a sensitive means for detecting extension. Several points should be stressed about our definition of infarct extension. The standard deviation for measurements on paired samples in our laboratory using epiagar gel

**Table 2. Comparison of Clinical Characteristics in Patients with Infarct Extensions and Those Without Extension**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Extension</th>
<th>No extension</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of pts</td>
<td>8</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>64 ± 6</td>
<td>57 ± 10</td>
<td>0.07</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>92.5 ± 15</td>
<td>83 ± 15</td>
<td>0.08</td>
</tr>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>130 ± 30</td>
<td>118 ± 12</td>
<td>0.06</td>
</tr>
<tr>
<td>Infarct location</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inferior</td>
<td>4</td>
<td>23</td>
<td>0.25</td>
</tr>
<tr>
<td>Anterior</td>
<td>2</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Subendocardial</td>
<td>0</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Indeterminate</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Killip class*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>4</td>
<td>40</td>
<td>0.10</td>
</tr>
<tr>
<td>II</td>
<td>3</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

*Values are mean ± sd. Chi-square analysis was applied only to Killip classes I and II.

*Values at 48 hours after onset of symptoms.

**Table 3. Comparison of Clinical Characteristics in Fatal and Nonfatal Myocardial Infarct Extension**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Died</th>
<th>Survived</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of pts</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Infarct location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Inferior</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Indeterminate</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Age (years)</td>
<td>61.25 ± 3.86</td>
<td>65.75 ± 6.5</td>
</tr>
<tr>
<td>Heart rate (beats/min)*</td>
<td>97 ± 18.22</td>
<td>88 ± 12.75</td>
</tr>
<tr>
<td>Systolic arterial pressure (mm Hg)*</td>
<td>122.25 ± 31</td>
<td>137 ± 31</td>
</tr>
<tr>
<td>MS after 48 hours</td>
<td>75% (3/4)</td>
<td>50% (2/4)</td>
</tr>
<tr>
<td>AVO2 ≥ 6</td>
<td>4/4</td>
<td>Unknown</td>
</tr>
<tr>
<td>PCWP</td>
<td>4/4</td>
<td>Unknown</td>
</tr>
<tr>
<td>Clinical CHF (S3 or CXR)</td>
<td>4/4</td>
<td>1/4</td>
</tr>
<tr>
<td>Prior infarction†</td>
<td>4/4</td>
<td>2/4</td>
</tr>
</tbody>
</table>

*Values 48 hours after entry into the study.

†Prior infarction was defined by significant Q waves on the ECG or a history of myocardial infarction.

Abbreviations: MS = morphine sulfate; AVO2 = arteriovenous oxygen difference; PCWP = pulmonary capillary wedge pressure; CHF = heart failure manifested by a ventricular gallop (S3) or congestion on chest x-ray (CXR).
electrophoresis was ± 3%, which should allow clear separation of levels measured at 12-hour intervals, given the rapid disappearance constant of CK-MB. The sampling interval of 12 hours was based on previous studies in which we found that CK-MB was present in at least one of two samples obtained at 12-hour intervals after the onset of symptoms of acute infarction in 100% of the patients. Additional tissue necrosis might have occurred that did not release enough enzyme to elevate the disappearance curve of CK-MB or to persist in the blood for 12 hours. Another mechanism that might cause enzyme release is late perfusion of the infarcted region as a result of intracoronary thrombolysis. Although one may question the pathophysiologic basis for the reelevation or reappearance of CK-MB, the changes were clinically important because they were associated with a high mortality.

CK-MB plasma activity persisted beyond 72 hours after the onset of symptoms of acute myocardial infarction in 16 patients (29%). Subsequent infarct extension occurred in 44%, compared with 3% in the group without CK-MB persistence. The mortality rate in the patients with CK-MB persistence greater than 72 hours was 25%. Three patients had CK-MB persistence beyond 96 hours after acute myocardial infarction; each patient had myocardial infarct extension and subsequently died. Thus, persistence of CK-MB activity beyond 72 hours appeared to identify a group of patients at risk for myocardial infarct extension and death in hospital.

Persistence of CK-MB activity, as with reappearance of reelevation, may represent additional enzyme release and additional tissue necrosis. Infarct extension was defined by CK-MB persistence in one patient in the report of Rothkopf et al. It is possible that these deviations from expected enzyme time-activity curves represent delayed enzyme release without further necrosis, as a result of reperfusion of an occluded vessel or perfusion by collateral vessels. Regardless of the mechanism, the patients with these findings have a high risk of death in the hospital.

In several studies, reelevation of total CK has been used to detect infarct extension, in association with either precordial ST-segment mapping or clinical events. In the present study, reelevation of total CK activity detected extension in 88% of the patients. However, secondary increases in total CK also occurred in 38% of patients without reelevation of CK-MB. Elevation of total CK in the present study was sensitive but not specific for extension. The predictive value for reelevation of total CK to detect infarct extension in our population was only 28%.

The four patients with infarct extension who died had evidence of congestive heart failure at the time of extension. One patient became abruptly hypotensive and three had marked worsening of heart failure. All four patients had an arteriovenous oxygen difference ≥ 6 vol%. Pulmonary capillary wedge pressure and arteriovenous oxygen difference were not available in the four patients with myocardial infarct extension who survived. The higher mortality rate associated with myocardial infarct extension in this study was due to the heart failure rather than arrhythmias. This is consistent with observations that the extent of infarction is an important determinant of survival. The single death in the group without myocardial infarct extension occurred in a patient who was in Killip class I and was related to acute rupture of a papillary muscle.

The finding of a low incidence of myocardial infarct extension associated with a high mortality contrasts sharply with the results of several earlier studies that suggest a high incidence of infarct extension with a low mortality based on precordial ST-segment mapping. Reid et al. reported an 86% incidence of extension in 14 patients 2-15 days after acute transmural anterior myocardial infarction and an associated mortality of 8.3%. Detection of extension in that study was based on reelevation of ΣST segments measured with a 48-lead precordial electrocardiographic map; reelevation of ΣST segments was associated with elevations of total CK in only 57% of the patients. Myocardial-specific isoenzymes of CK-MB were not analyzed. Similar results were reported by Gulati et al., who obtained daily 48-lead precordial ST-segment maps in 25 patients with acute transmural anterior myocardial infarction who survived the first 24 hours of hospitalization. Seventeen episodes of recurrent elevation of ΣST segments occurred in 14 patients (56%), and the associated mortality was 14%. Reelevation of ΣST segments was associated with elevation of SGOT in 11 patients. Total CK and CK-MB were not analyzed. Clinical evidence of pericarditis was reported as absent in all patients.

Precordial ST-segment mapping has been used to assess ST-segment changes early after coronary occlusion. Precordial ST-segment deflections usually reach a plateau 12 hours after acute infarction and then decline over several days. The magnitude and direction of ST-segment changes can be influenced by variables other than the natural course of infarction or recurrent ischemia, including fluctuating potassium levels, antiarrhythmic or other drug therapy, and pericarditis. Precordial ST-segment changes are, therefore, not a specific indicator of infarct extension. This view is supported by the observation of Kronenberg et al. that vectorcardiographic ST segments increased without relationship to significant clinical events in their patients with myocardial infarction. Reese et al., in a study of 20 patients with acute myocardial infarction using serial 35-lead ST-segment precordial maps, reported that eight patients with secondary rises in ΣST segments did not have clinical symptoms or enzymatic evidence of extension. In the present study, routine 12-lead ECGs were obtained every 12 hours. Although 50% of the episodes of extension were associated with recurrent ST-segment elevation, 33% of the patients without enzymatic evidence of extension also showed these ST-segment changes. Recurrent ST-segment elevation, therefore, was neither a sensitive nor a specific indicator of myocardial infarct extension.

We initially treat recurrent ischemic chest pain that
occurs after 48 hours following acute myocardial infarction with sublingual nitroglycerin; i.v. morphine sulfate is used if the pain does not respond to nitroglycerin. In this study, 21% of the patients required i.v. morphine sulfate for relief of recurrent ischemic chest pain unrelated by nitroglycerin. Morphine sulfate was required five times more frequently in patients with late myocardial infarct extensions than in patients without extensions. In 75% of the patients with late myocardial infarct extension, morphine sulfate was administered within 36 hours before reelevation of CK-MB. Morphine sulfate administration did not result in hypotension that might have contributed to the subsequent extension. The requirement of morphine sulfate to relieve recurrent chest pain was a better predictor of subsequent late myocardial infarct extension than reelevation of ST-segments on the ECG.

In conclusion, this prospective study in a consecutive group of patients with acute myocardial infarction found that myocardial infarct extension occurred in 14% of the patients and was thus an infrequent complication of acute myocardial infarction. Twenty-five percent of late infarct extensions were clinically undetected by recurrent prolonged chest pain. Myocardial infarct extension was associated with a very high incidence of morbidity and mortality from heart failure.

Recurrent chest pain requiring morphine sulfate administration for relief and persistence of CK-MB for more than 72 hours after the onset of infarction were more sensitive and better predictors of subsequent myocardial infarct extension than new or recurrent ST-segment elevations on serial 12-lead ECGs or recurrent elevations of total CK activity. Recurrent elevation of total CK was a sensitive but not a specific indicator of infarct extension. New or recurrent ST elevation on serial 12-lead ECGs was neither sensitive nor specific for extension.

Because myocardial infarct extension was not a common complication of acute myocardial infarction in the present study, these data do not support the routine serial analysis of CK-MB beyond 72 hours in all patients with acute myocardial infarction. Persistence of CK-MB to 72 hours, however, identified patients with acute myocardial infarction who were at high risk for infarct extension and death in hospital.

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