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Left Ventricular Dysfunction After Acute Myocardial Infarction: Results of a Prospective Multicenter Study

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In a multicenter prospective study of 866 patients who survived the coronary care unit phase of an acute myocardial infarction, variables reflecting left ventricular function were examined to assess their impact on 2 year survival. Single variables that reflected left ventricular dysfunction before infarction and in the acute and recovery phases were, respectively, history of prior myocardial infarction, rales in the coronary care unit dichotomized at greater than bibasilar and predischarge radionuclide ejection fraction dichotomized at less than 0.40. When combined in a stepwise fashion, patients lacking these three risk characteristics had a 2 year 4.2% mortality rate, whereas patients possessing all three characteristics had a 45% mortality rate.

Rales in the coronary care unit and predischarge ejection fraction act independently, and each contributes to mortality. Fifty-two patients with advanced rales but an ejection fraction of 0.40 or greater had a 21% mortality rate. Similarly, 208 patients with few rales but an ejection fraction of less than 0.40 had a 15% mortality rate. These data suggest that the mortality risk imposed by those factors that assess permanent left ventricular damage is independent of and additive to the mortality risk contributed by dynamic, acute phase dysfunction. These data fit the hypothesis that acute phase dysfunction is, in part, due to transient ischemia that, on reversal, can restore function toward normal.

The results suggest 1) that assessment of left ventricular function during the acute and recovery phases of myocardial infarction is necessary to define prognostic characteristics of an individual patient, and 2) that of particular importance is the identification of patients whose postinfarction course is consistent with reversible ischemia.

In patients with acute myocardial infarction, left ventricular dysfunction is a well established predictor of mortality. Estimates of left ventricular function formed the basis of both short- (1,2) and long-term prognostications (3), and more recent studies (4–7) have confirmed these observations. In our current prospective multicenter study (8), left ventricular dysfunction again emerges as an important factor in the generation of a postinfarction risk stratification.

Estimates can be made of left ventricular function before the infarction and during the acute and recovery phases. Prior work (1–7) has established that the severity of left ventricular dysfunction at each of these time periods can be helpful in creating a prognostic assessment and in designing a risk stratification formula. Warnowicz et al. (9) observed a marked disparity between left ventricular function in the acute and recovery phases of an acute myocardial infarction. In their series of patients with myocardial infarction who presented with pulmonary edema, nearly half had a radionuclide ejection fraction greater than 45% 10 days later. Our study, which assessed changes in left ventricular function after acute myocardial infarction in a large, prospective multicenter study group, confirms and extends this observation.

Our prospective study assessed left ventricular dysfunction before the index infarction on the basis of historic information, during the acute phase by clinical observations and in the early recovery phase by determination of a radionuclide ejection fraction. Our objectives were: 1) to assess the relation between left ventricular dysfunction variables collected before and during the acute phase and during the

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recovery phase of an acute myocardial infarction; 2) to measure the impact of these variables on subsequent mortality; and 3) to assess the role of combining determinants of stable left ventricular dysfunction with determinants of dynamic acute phase dysfunction.

Methods

Patients. A detailed description of the multicenter postinfarction risk stratification study has been presented (8). Briefly, nine hospitals in four cities enrolled 866 of 1,417 eligible patients younger than 70 years of age who had had an acute myocardial infarction. Seventy-eight percent of the patients were men and 57% were younger than 60 years. The diagnosis was based on meeting two of the following three criteria: 1) typical chest pain; 2) appropriate electrocardiographic changes; and 3) elevation of cardiac serum enzyme levels. Patients with life-threatening coexisting disease and those believed to be incapable of appropriate follow-up were excluded. Patients had either clinic or phone follow-up visits at 3, 6 and 12 months and thereafter at yearly intervals until a common termination date of December 31, 1981, at which time 36 patients were lost to follow-up. One hundred-one patients died during the 2 year follow-up period.

Data acquisition. Nurse investigators interviewed the patients and reviewed their records during the hospitalization for the index infarction. The historical and clinical variables collected for each patient included demographic data, prior cardiac history, coronary care unit course, electrocardiogram, radionuclide ejection fraction, 24 hour Holter electrocardiogram, a low level predischarge treadmill exercise test and follow-up data on rehospitalization and mortality through December 31, 1981. Missing values on routine clinical data were approximately 0.5% or less. Only 6% of the patients did not have a radionuclide ejection fraction, most often because of logistic problems. Completed data forms were entered into a specifically designed archival data management system on an IBM 3032 computer. Ten percent of the data in the file was checked against the original data forms and a negligible number of discrepancies was found.

Risk variables: three variables of left ventricular dysfunction. In our data base, many variables reflect left ventricular function. We selected one variable from the patient's history before the myocardial infarction, one from the acute phase and one from the recovery phase, and concentrated our analysis on interactions among these three variables. We selected a history of prior myocardial infarction as the historical variable because it relates directly to left ventricular function and because a response to the inquiry was recorded for all but four patients. Rales in the coronary care unit and predischarge radionuclide ejection fraction were selected as the acute and recovery phase variables. In our earlier analysis (8), these variables at appropriate dichotomizations were powerful independent predictors of mortality. For most analyses, a single dichotomization was utilized. For radionuclide ejection fraction, a dichotomization at 0.40 was selected in our a priori hypothesis (8) and in this study. In addition, prior studies (6) have used this value. Rales were dichotomized at a level greater than bibasilar because of the dramatic break in the curve at this point and to avoid potential confusion with coexisting chronic obstructive lung disease. A history of chronic lung disease did not identify an increased risk of mortality (10 of 64 patients) and all analyses reported here remain valid when patients with clinical and radiographic evidence of chronic obstructive lung disease were eliminated from the data.

Rales versus chest roentgenogram. Because rales may be transient and are not subject to review, we compared the coronary care unit chest roentgenogram with coronary care unit rales to see if the correlation supported the assumption that rales would reflect pulmonary congestion secondary to left ventricular dysfunction. Since assessment of rales in the coronary care unit and the coronary care unit chest roentgenogram were obtained nearly simultaneously in the course of the index acute myocardial infarction, the detailed analysis will be restricted to a consideration of the coronary care unit rales. The relation of the rales to the chest roentgenogram will be discusssed later.

Assessment of data. *Prior infarction.* Occurrence of a prior myocardial infarction was extracted from the patient's record by the nurse investigator and documented by an available record of a previous hospitalization or the patient's report that his or her physician had stated that the electrocardiogram confirmed an earlier infarction. Silent infarctions, particularly in patients without available prior electrocardiograms, were most likely undetected as were historical inaccuracies where old records were not available.

Chest rales. The most advanced degree of rales described by two physician observers in the coronary care unit was assessed and graded as none, bibasilar, diffuse (or > one-third of the way up the posterior lung field) and pulmonary edema. Atelectatic rales that cleared after a cough were excluded. In the analyses, advanced rales will denote diffuse rales or pulmonary edema (Table 1, gradations III and IV) and absence of advanced rales will refer to either clear lungs or rales limited to bibasilar portions of the posterior lung field (Table 1, gradations I and II).

Ejection fraction. The radionuclide ejection fraction was obtained 6 to 25 days after the index infarction. The technique varied among the participating medical centers, with both first pass and gated blood pool techniques being used. Quality control studies established that in each medical center the radionuclide ejection fractions correlated clearly with angiographic ejection fractions performed in that institution, and that variation among the institutions in interpretation of standard angiographic ejection fractions was very small.

Table 1. Variables Reflecting Left Ventricular Dysfunction

Gradation	Ejection Fraction	Rales	Prior Myocardial Infarction	Coronary Care Unit Chest Roentgenogram
I	(≥ 0.50)	(none)	(absent)	(no congestion)
	336	451	658	604
	7.1%	6.4%	9.9%	6.6%
II	(0.40 to 0.49)	(bibasilar)	(present)	(venous congestion)
	204	292*	204*	161*
	5.9%	11.3%	16.7%	18.6%
III	(0.30 to 0.39)	(1/3 to 2/3 posterior lung field)	–	(interstitial edema)
	147	60*	–	38
	10.9%	26.7%	–	21.1%
IV	(<0.30)	(> 2/3 posterior lung field)	–	(pulmonary edema)
	124*	63	–	40*
	31.5%	36.5%	–	52.5%
Total no.	811	866	862	843
Data missing (patient dead)	55 (10)	0	4 (2)	23 (2)

*Mortality is significantly different at the $p < 0.05$ level from the value at the next lowest gradation. Gradations (top line of each cell) were selected on the basis of prior use (see text). In each cell, the second figure is the number of patients and the bottom figure is the mortality rate.

Chest roentgenograms in the coronary care unit were often obtained with portable units and the techniques were standard to each institution. The findings were graded as normal or as showing venous congestion, interstitial edema or pulmonary edema.

Therapy, follow-up and mortality data. Therapy was not controlled and management was left to the discretion of the patient's personal physician. At the time of hospital discharge, 33% of the patients were taking beta-adrenergic blocking agents, 21% were taking antiarrhythmic agents and 31% were taking cardiac glycosides. Two hundred seventy-eight patients were readmitted to the intensive care unit or rehospitalized during the first year. Ischemic events, including definite myocardial infarction, suspect infarction or unstable angina pectoris, were the most frequently cited causes and accounted for 54% of rehospitalizations. Sixty patients underwent coronary artery bypass graft surgery. Of the 101 deaths, 83 were considered cardiac deaths, and of these, 31 were considered sudden, defined as death less than 1 hour from the onset of acute cardiac symptoms or occurring unexpectedly during sleep.

Results

Relation to total mortality of the three selected variables and coronary care unit chest roentgenogram (Table 1). The continuous variables are presented in four gradations. The gradations were generally selected on the basis of traditional clinical use. Each of the three continuous variables had a significant mortality gradient from most benign to most severe. A history of prior myocardial infarction was also a significant predictor of increased mortality. The statistical significance and clinical effectiveness of stratification at each point selected for a gradation differs from one variable to another.

Relations Among the Three Variables That Reflect Left Ventricular Function

Relation between coronary care unit rales and subsequently measured ejection fraction (Table 2). Of the 115 patients with advanced rales, only 43 (37%) had a subsequent radionuclide ejection fraction of less than 0.30, whereas 34 patients (30%) had a normal ejection fraction (> 0.50). Marked pulmonary congestion in the coronary care unit phase of an acute myocardial infarction did not predict a low radionuclide ejection fraction during the recovery phase. These observations are similar to those reported by Warnowicz et al. (9). Among patients with recovery phase radionuclide ejection fraction values greater than 0.30, a total of 90% (615 of 687) had few, if any, rales. Only in those patients whose subsequent radionuclide ejection fraction was less than 0.30 did even one-third (43 of 124) present with advanced rales. Although the clinical relation between advanced coronary care unit rales and subsequent depressed ejection fraction is not strong, the mortality data show the additive effect of both depressed ejection fraction and advanced rales (Table 3, panel 1). Patients with an ejection fraction of 0.40 or greater and minimal or absent

Table 2. Relation Between Predischarge Radionuclide Ejection Fraction and Coronary Care Unit Rales

Ejection Fraction	Bibasilar or Absent Rales	Advanced Rales	Total
≥ 50	302 (90%)	34 (10%)	336
40 to 49	186 (91%)	18 (9%)	204
30 to 39	127 (86%)	20 (14%)	147
< 30	81 (65%)	43 (35%)	124
Total	696 (86%)	115 (14%)	811

Table 3. Relation Between Major Left Ventricular Dysfunction Variables

	RNEF ≥ 40	RNEF < 40		No Prior MI	Prior MI			RNEF ≥ 40	RNEF < 40	
Rales	488	207	696	570	171	741	No Prior MI	444	174	618
None or bibasilar	5.1%	15.0%	8.1%	7.2%	12.3%	8.4%		5.6%	19.6%	9.6%
Advanced	52	63	115	88	33	121	Prior MI	95	94	189
	21.2%	38.1%	30.4%	27.3%	39.4%	30.6%		11.6%	20.4%	16.0%
	540	271	811	658	204	862		539	268	807
	6.7%	20.4%		9.9%	16.7%			6.7%	19.9%	

Each 2 × 2 panel displays clinical and mortality relations between two variables. In each cell, the top figure is the number of patients and the bottom figure is the mortality rate. The significance value for the Mantel-Haenszel odds ratio, which reflects the contribution to mortality of each clinical variable in each cell, is as follows. In panel 1, the contribution of both advanced rales and reduced radionuclide ejection fraction (RNEF) is significant at $p < 0.001$; in panel 2, prior myocardial infarction (MI) is significant at $p < 0.025$ and advanced rales at $p < 0.001$; in panel 3 radionuclide ejection fraction is significant at $p < 0.001$ and prior myocardial infarction is not significant. See text for discussion.

rales had a 5% (25 of 488) mortality rate, whereas 38% (24 of 63) of the patients with advanced rales and depressed ejection fraction died. This sevenfold gradient demonstrates that patients with advanced rales in the coronary care unit and reduced radionuclide ejection fraction before hospital discharge constitute a subset comprising 8% of the postinfarction group that is at extremely high risk of early death. This subset contributes 24% of all deaths observed in the total study group. Statistical analysis using the Mantel-Haenszel odds ratio (10) shows that rales and radionuclide ejection fraction are each independent contributors to mortality, each significant at the probability less than 0.001 level.

History of myocardial infarction and coronary care unit rales. Although a history of prior myocardial infarction lacks quantification, it may reflect a prior, fixed tissue loss and does contribute to the profile of a patient in a coronary care unit with another acute myocardial infarction. Approximately one-quarter of our patients (204 of 862 or 24%) had such a history which nearly doubles the mortality rate in the postinfarction period ($p < 0.05$) (Table 1). The relation of prior myocardial infarction, rales and mortality is shown in Table 3, panel 2. A history of prior myocardial infarction does not predict advanced rales in the coronary care unit. Only 16% (33 of 204) of patients with a prior myocardial infarction had advanced rales in the coronary care unit compared with 13% (88 of 658) of patients without a prior infarction. These differences are not significant. Similarly, approximately one-quarter of patients with and without advanced rales gave a history of prior infarction. However, when mortality data are added to the clinical relation, patients without either prior myocardial infarction or advanced rales had a 7% (41 of 570) mortality rate, whereas patients with both a prior infarction and advanced rales had a 39% (13 of 33) mortality rate. Although a very high risk group is identified, the number of individuals in this subset is smaller than the similarly high risk group identified by advanced rales and reduced radionuclide ejection fraction. Although the bulk of the increased mortality is contributed by advanced rales, the Mantel-Haenszel odds ratio shows that the contribution to mortality of a history of prior infarction is also significant ($p < 0.025$).

Ejection fraction and prior myocardial infarction related to mortality (Table 3, panel 3). Absence of prior myocardial infarction correlates well with an ejection fraction of 0.40 or greater with 72% (444 of 618) of patients in this category. A prior myocardial infarction, however, does not predict a radionuclide ejection fraction of less than 0.40. Only 50% (95 of 189) of patients are in that category. This pattern is similar to that seen with rales and ejection fraction where the markers of normal left ventricular function correlated well with each other, while the markers of left ventricular dysfunction did not. The data show that most of the contribution to mortality is given by ejection fraction.

Table 4. Mortality Rates for Patients Cross-Classified by Three Left Ventricular Dysfunction Variables

Rales	Ejection Fraction	Prior MI	No.	Mortality
Not Advanced/ Advanced	≥ 0.40/ < 0.40	No/Yes	Dead	Rate (%)
743	488	402	17	4.2
		85	8	9.4
	207	133	21	15.8
		73	10	13.7
123	52	42	8	19.0
		10	3	30.0
	63	41	13	31.7
		20	9	45.0

Radionuclide ejection fraction dichotomized at 0.40 and history of prior myocardial infarction are added stepwise to rales that are dichotomized at greater than bibasilar. The eight subgroups display a nearly linear increase in mortality rate from 4.2% when all variables are favorable to 45% when all are unfavorable. See text for discussion. The number of patients in each clinical subgroup differs because of missing data, which are given in Table 1. MI = myocardial infarction.

The Mantel-Haenszel odds ratio for the contribution of prior myocardial infarction is not significant. The marginal influence of prior infarction is not surprising since a history of prior myocardial infarction did not improve the prediction of mortality in the original survivorship model (8), whereas rales and ejection fraction did.

Three left ventricular function variables combined in a stepwise fashion (Table 4). The 2 year mortality rate of patients without advanced rales, an ejection fraction of 0.40 or more and no prior myocardial infarction is 4.2%. For patients with advanced rales, an ejection fraction of less than 0.40 and a prior myocardial infarction, the mortality rate is 45%. The 4.2% mortality rate for the large group of patients with none of the three markers of left ventricular dysfunction is lower than the mortality rate for any model utilizing only two of the markers. Although the 45% mortality rate in the group possessing all three variables is higher than that for any model utilizing only two, the number of patients in this group is very small. A stepwise logistic regression shows that the addition of history of prior myocardial infarction to the model already containing rales and radionuclide ejection fraction contributes this added refinement.

Relation between rales and chest roentgenogram in the coronary care unit (Table 5). We have assumed a parallel progression through three grades of abnormality for each variable. There are few available data on which to make this assumption, but, likewise, few to dissuade us from it. However, equating venous congestion with bibasilar rales, interstitial congestion with rales more than one-third of the way up the posterior lung fields and pulmonary edema on chest roentgenogram with rales more than two-thirds up the posterior lung fields has produced a striking relation. A substantial majority of patients (527 of 843 or 63%) had parallel degrees of pulmonary congestion, or lack of it, and only 5% (42 of 843) differed by more than one gradation.

Discussion

No risk stratification scheme for patients with a myocardial infarction can exclude variables reflecting left ventricular function. Earlier studies have shown left ventricular

Table 5. Relation Between Coronary Care Unit Rales and Chest Roentgenogram

	Coronary Care Unit Rales				
Chest Roentgenogram	None	Bibasilar	Diffuse	Pulmonary Edema	Total
Normal	399	181	17	7	604
Venous congestion	38	86	25	12	161
Interstitial edema	1	12	12	13	38
Pulmonary edema	0	5	5	30	40
Total	438	284	59	62	843

dysfunction variables to be predictive of subsequent mortality when the variable reflects either preinfarction (3,4), peri-infarction (1,3–5) or postinfarction (6,9) status. Our study confirms that evaluation during each of these time periods is predictive in a multicenter population evaluated prospectively. Earlier prospective long-term studies (1–5) of patients after infarction are not directly comparable with our study because they did not include a recovery phase assessment of left ventricular function. This refinement permits us to define subgroups with different risks and potentially different management needs.

Left ventricular dysfunction at the onset of a myocardial infarction can be assessed clinically, as in our study, by the measurement of rales (2) or congestion on the chest roentgenogram. Hemodynamic monitoring can assess left ventricular dysfunction acutely (11–14); radionuclide ejection fraction (15–18) and abnormalities of wall motion (15,16,18) can also be used.

Studies with serial assessments of left ventricular function. There are several studies in which serial hemodynamic or radionuclide angiographic studies have been performed during the acute and recovery phases and in a few, mortality data are available. Although acute phase hemodynamic data, primarily left ventricular end-diastolic pressure, are related to subsequent mortality (11–14), several of these studies (11–13) have shown that the clinical status and survival are better predicted by improvement or deterioration in hemodynamic status than by values at a single point in time. Likewise, ejection fraction during the acute phase of infarction can predict survival (15,16,18,19). In these studies, pulmonary congestion at the onset of infarction paralleled degree of dysfunction measured by hemodynamic or radionuclide studies. Overall, these studies support the stratification scheme introduced by Killip and Kimball (2), which related mortality to clinically assessed pulmonary vascular congestion.

Recent observations (9) of recovery phase radionuclide ejection fraction in patients with infarction presenting with pulmonary edema revealed a marked disparity between acute phase observations and recovery phase performance. Similarly, our study shows a striking discrepancy between the recovery phase ejection fraction and coronary care unit rales. Although the absence of advanced rales is a very good predictor of the higher ejection fraction at any stratification (Table 2), the presence of advanced rales in the coronary care unit is nearly equally often associated with low ($<$ 0.40) and high ($\geq$ 0.40) recovery phase radionuclide ejection fraction. These data differ from some work (16,17) suggesting that mortality and complications were predicted by early postinfarction ejection fraction, which, in turn, paralleled clinical presentation. In addition, these earlier studies do not account for those patients who exhibit few, if any, rales but who have a depressed ejection fraction during recovery. Of 696 patients without advanced rales, 208 (30%) had a radionuclide ejection fraction of less than 0.40 during recovery; in this subset the mortality rate was 15%, a value three times higher than that of patients without advanced rales but with a radionuclide ejection fraction of 0.40 or greater. The failure to demonstrate clinically significant pulmonary congestion at the onset of infarction does not, by itself, fully identify a low risk group, and recovery phase evaluation of left ventricular function is required for optimal clarification and prognostication.

Potential role of reversible ischemia. Left ventricular dysfunction can result from either transient or permanent myocardial damage. Even very brief periods of reversible ischemia induced by pacing (20,21) in patients with angina can lead to transient derangement of left ventricular mechanical function. The persistence of left ventricular dysfunction after transient ischemic appears to be directly proportional to the duration of ischemia (22–25). Such observations suggest that evaluation of postinfarction angina and left ventricular dysfunction includes consideration of the degree and duration of ischemia as well as the recovery period required for restitution of function (25).

Left ventricular dysfunction at the onset of myocardial infarction is the sum of contributions from prior myocardial infarction, current irreversible damage and current reversible dysfunction. Each of these three factors participates in creating the clinical presentation. Over time, the reversible component can be relieved and left ventricular dysfunction may be less severe (20–25). Such a course would then create a group of patients with evidence of advanced left ventricular dysfunction at the onset of infarction, but improved function on predischarge assessment. We, and others (9), have found a sizable subgroup with this clinical pattern. The risk of death after myocardial infarction for those patients with significant left ventricular dysfunction at the onset of infarction and improved function before discharge is four times higher than that for the group with preserved function both on admission and at discharge (Table 3, panel 1). We attribute the improvement in left ventricular function after myocardial infarction in this subgroup to the relief of ischemia followed by a time-dependent return to baseline function for that ischemic myocardium. Alternatively, the changes in left ventricular function after myocardial infarction may be due to other mechanisms. Changes in ventricular size, muscle stiffness or myocardial edema, for example, may all play a role (20,24). This sequence is clearly complex, and our study does not permit us to identify the mechanisms involved in either the establishment or alleviation of this transient ischemia.

Schuster and Bulkley (26) showed in patients with mean ejection fraction of 0.52 that postinfarction ischemia manifested by angina was associated with a very high mortality rate that appeared to be related to the mass of potentially ischemic myocardium and not the myocardium actually infarcted. Similarly, our study identifies a group of patients

with normal or near normal recovery phase ejection fraction who are at high risk, assuming that reversible myocardial ischemia may cause transient pulmonary venous congestion and advanced rales in the coronary care unit. We would have to postulate additionally that the increased subsequent mortality would be a result of recurrent ischemia, whether or not the patient had angina pectoris.

The data in Table 3 show that advanced rales contribute significantly to the mortality rate attributable to either prior myocardial infarction or recovery phase radionuclide ejection fraction. However, prior infarction does not contribute to the mortality attributable to recovery phase ejection fraction. These observations also fit the hypothesized dual origin for the generation of coronary care unit rales. Predischarge ejection fraction and prior infarction both reflect fixed, permanent tissue loss, and their impact on mortality is not additive. The postinfarction assessment incorporates the prior infarction and, as expected, is a more effective predictor. Since coronary care unit rales are due to the combined impact of transient, reversible myocardial injury and permanent myocardial damage, the impact on mortality of advanced rales is additive to either assessment of fixed tissue loss.

Agreement between rales and chest roentgenogram. Rales are transient, lacking the capacity for objective assessment or measurement. They can be produced or mimicked by conditions other than increased pulmonary venous pressure secondary to left ventricular dysfunction, thus offering the potential for a contaminated analysis. In a multicenter study, interobserver variability in the assessment of rales may exist; therefore, we were surprised by the frequent agreement between the observation of rales and chest roentgenographic findings. Although 63% of patients had comparable findings on the chest roentgenogram and physican examination, most of this agreement is contributed to by the 50% of patients with normal findings on both studies. Most of the variation is due to the fact that bibasilar rales were most often associated with a normal chest roentgenogram (Table 5). However, variation of more than one grade from the identity line occurred in less than 5% of patients. Nonetheless, our results suggest that the chest roentgenogram can act as a control for clinical evaluations in subsequent trials and that it reflects the state of the pulmonary vasculature at the onset of infarction. This comparability is valid only for assessment of peak congestion since the vascular pattern on chest roentgenogram has been shown to lag behind the decrease of the wedge pressure and the auscultatory findings in the immediate recovery phase of an acute myocardial infarction (27,28).

Clinical implications. This study suggests that the high risk subgroup of patients whose postinfarction course is consistent with reversible ischemia should be identified. Because the risk of death is four times as high in patients with such reversible ischemia, more aggressive evaluation and therapy may be indicated. Therapy, either medical or surgical, may reduce subsequent mortality.

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References

1. Peel AAF, Semple T, Wang I, Lancaster WM, Dall JLG. A coronary prognostic index for grading severity of infarction. Br Heart J 1962;24:745–60.
2. Killip T III, Kimball JT. Treatment of myocardial infarction in a coronary care unit. Am J Cardiol 1967;20:457–64.
3. Norris RM, Caughey DE, Mercer CJ, Scott PJ. Prognosis after myocardial infarction. Br Heart J 1974;36:786–90.
4. Davis HT, DeCamilla J, Bayer LW, Moss AJ. Survivorship patterns in the post-hospital phase of myocardial infarction. Circulation 1979;60:1252–8.
5. Bigger JT, Heller CA, Wenger TL, Weld FM. Risk stratification after acute myocardial infarction. Am J Cardiol 1978;42:202–10.
6. Schulze RA Jr, Strauss HW, Pitt B. Sudden death in the year following myocardial infarction. Am J Med 1977;62:192–9.
7. Silverman KJ, Becker LC, Bulkley BH, et al. Value of early thallium-201 scintigraphy for predicting mortality in patients with acute myocardial infarction. Circulation 1980;61:996–1002.
8. Multicenter Post-Infarction Research Group. Risk stratification and survival after myocardial infarction. N Engl J Med 1983;309:331–6.
9. Warnowicz MA, Parker H, Cheitlin MD. Prognosis of patients with acute pulmonary edema and normal ejection fraction after acute myocardial infarction. Circulation 1983;67:330–4.
10. Fleiss JL. Statistical Methods in Rates and Proportions. 2nd Ed., New York: John Wiley & Sons, 1981:160–87.
11. Shell W, Thomas P, Mickle D, Forrester JS, Swan HJC. Prognostic implications of reductions of left ventricular filling pressure in early transmural acute myocardial infarction. Am Heart J 1981;102:355–40.
12. Kupper W, Bleifeld W, Hanrath P, Mathey D, Effert S. Left ventricular hemodynamics and function in acute myocardial infarction: studies during the acute phase, convalescence, and late recovery. Am J Cardiol 1977;40:900–5.
13. Rahimtoola H, DiGilio MM, Ehsan A, Loeb HS, Rosen KM, Gunnar RM. Changes in left ventricular performance from early after acute myocardial infarction to the convalescent phase. Circulation 1972;46:770–9.
14. Mathey D, Bleifeld W, Hanrath P, Effert S. Attempt to quantitate

relation between cardiac function and infarct size in acute myocardial infarction. Br Heart J 1974;36:271–9.

15. Schelbert HR, Henning H, Ashburn WL, Verba JW, Karliner JS, O'Rourke RA. Serial measurements of left ventricular ejection fraction by radionuclide angiography early and late after myocardial infarction. Am J Cardiol 1976;38:407–15.
16. Kostuk WJ, Ehsani AA, Karliner JS, et al. Left ventricular performance after myocardial infarction assessed by radioisotope angiocardiography. Circulation 1973;47:242–9.
17. Shah PK, Pichler M, Berman DS, Singh BN, Swan HJC. Left ventricular ejection fraction determined by radionuclide ventriculography in early stages of first transmural myocardial infarction. Am J Cardiol 1980;45:542–6.
18. Reduto LA, Gerber HJ, Cohen LS, Gottschalk A, Zaret BL. Sequential radionuclide assessment of left and right ventricular performance after acute transmural myocardial infarction. Ann Intern Med 1978;89:441–7.
19. Rigo P, Murray M, Strauss HW, et al. Left ventricular function in myocardial infarction evaluated by gated scintiphotography. Circulation 1974;50:678–84.
20. Dwyer EM Jr. Left ventricular pressure-volume alterations and regional disorders of contraction during myocardial ischemia induced by atrial pacing. Circulation 1970;42:1111–22.
21. Parker JO, Ledwich JR, West RO, Case RB. Reversible cardiac failure during angina pectoris. Circulation 1969;39:745–57.
22. Pagani M, Vatner SF, Baig H, Braunwald E. Initial myocardial adjustments to brief periods of ischemia and reperfusion in the conscious dog. Circ Res 1978;43:83–92.
23. Heyndrickx GR, Millard RW, McRichie RJ, Maroko PR, Vatner SF. Regional myocardial function and electrophysiological alterations after brief coronary artery occlusion in conscious dogs. J Clin Invest 1975;56:978–85.
24. Theroux P, Ross J Jr, Franklin D, Kender WS, Sasayama S. Coronary arterial reperfusion. III. Early and late effects on regional myocardial function and dimensions in conscious dogs. Am J Cardiol 1976;38:599–606.
25. Braunwald E, Kloner RA. The stunned myocardium: prolonged, postischemic ventricular dysfunction. Circulation 1982;66:1146–9.
26. Schuster EH, Bulkley BH. Early post-infarction angina:ischemia at a distance and ischemia in the infarct zone. N Engl J Med 1981;305:1101–5.
27. Kostuk W, Barr JW, Simon AL, Ross J Jr. Correlations between the chest film and hemodynamics in acute myocardial infarction. Circulation 1973;48:624–32.
28. Battler A, Karliner JS, Higgins CB, et al. The initial chest x-ray in acute myocardial infarction. Circulation 1980;61:1004–9.