The Initial Chest X-ray in Acute Myocardial Infarction
Prediction of Early and Late Mortality and Survival

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SUMMARY To evaluate the importance of the initial chest x-ray in predicting mortality and survival after acute myocardial infarction, the degree of pulmonary congestion, cardiothoracic ratio and left-heart dimension on the initial chest x-ray obtained from 273 patients within 24 hours of admission after acute myocardial infarction were related to early mortality (30 days) and late mortality (6 months, 1 year) mortality. The chest films were divided into four degrees of pulmonary venous congestion: grade 0 — no pulmonary congestion (n = 141); grade 1 — redistribution of pulmonary blood flow (n = 38); grade II — interstitial pulmonary edema (n = 61); grade III — localized alveolar edema (n = 20); grade IV — diffuse alveolar edema (n = 13). In the absence of pulmonary congestion, 94% of the patients survived the first month and 88% of them survived 1 year; when the heart size was also normal, more than 96% of patients survived 1 month and more than 91% survived 1 year. The 30-day mortality was significantly (p < 0.005) higher with grades II, III and IV pulmonary venous congestion than with grade 0, and late mortalities increased significantly (p < 0.005) with any degree of pulmonary venous congestion compared with grade 0. Mortalities with grades II and III congestion were similar, and less than 50% of the patients were alive after 1 year. With grade IV, only 18% of patients survived 30 days and none after 1 year. Without pulmonary venous congestion, 24% of patients with increased initial left-heart dimension (≥ 50 mm/m²) and increased cardiothoracic ratio (≥ 0.50) died during the subsequent year, compared with only 6% of patients with normal initial heart dimension and 9% with normal initial cardiothoracic ratio. Early and late mortality in patients without pulmonary venous congestion was significantly lower (p < 0.01) than in patients with any degree of pulmonary venous congestion, regardless of left-heart dimension or cardiothoracic ratio. Thus, the degree of congestion and left-heart size on the initial chest x-ray after acute myocardial infarction are highly useful for defining groups with increased risk of dying or surviving within the first month or the first year after the acute event.

THE CHEST ROENTGENOGRAM is often used to evaluate congestive heart failure in patients with acute myocardial infarction. Studies have shown a significant relationship between left ventricular hemodynamics and the chest film after acute myocardial infarction. However, only a few studies have dealt with the predictive value of findings on the chest x-ray for early and late mortality after myocardial infarction. In some reports, pulmonary congestion or cardiac enlargement on the chest x-ray were used as indicators of heart failure in conjunction with other clinical observations and then used in a multivariate statistical analysis to evaluate prognosis after acute myocardial infarction. In no study had the degree of pulmonary congestion or heart size alone on the initial chest x-ray been related to early and late mortality. Accordingly, we assessed the presence and severity of pulmonary venous congestion on admission chest x-rays along with radiographic measurements of heart dimensions and evaluated the findings as predictors of early and late mortality.

Materials and Methods
Among 445 consecutive patients with acute myocardial infarction admitted to the Research Unit of University Hospital, University of California, San Diego, 350 had initial chest x-rays taken during the first 24 hours after the acute event. These were interpreted independently by the attending physician at admission and later by one of the authors who had no knowledge of the patient's clinical or hemodynamic status. When disagreement occurred, a radiologist, also without knowledge of the patient's status, made the final decision. Seventy-seven of the films were excluded because of technical problems, i.e., nondiagnostic radiographic contrast or penetration, or inadequate inspiration, so that 273 films formed the basis for the study. In 12 of these patients, the left-heart dimension could not be measured because of triggering problems and in 88 patients the cardiothoracic ratio was not calculated because the edge of the thoracic wall at the level used for this measurement was not included in the field of the x-ray.

The diagnosis of acute myocardial infarction was established on the basis of at least two of the following criteria: 1) a history of prolonged typical chest pain; 2) electrocardiographic changes indicative of acute myocardial infarction; and 3) characteristic serial elevation of serum enzymes (CK, SGOT and LDH). Mortality for all patients admitted to the coronary care unit with acute myocardial infarction

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within the study period (445 patients) and for the subgroup with an interpretable initial chest x-ray (273 patients) was identical; the 1-month mortality was 20%, the 6-month mortality 27% and the 1-year mortality 33%.

Anterior posterior (AP) chest x-rays were exposed at end-diastole using an ECG-gated trigger with the patient supine or in a 45° reclining position. A standard inspiration of 1 liter from functional residual capacity was obtained using a hand spirometer. A radiographic system with a ceiling-mounted arm and a fixed tube-to-film distance of 36 inches was used. The midline was defined by placing two pieces of lead on the midline of the sternum before exposure.

Pulmonary congestion on the initial chest x-ray film was graded as follows (fig. 1):

Grade 0: No pulmonary venous congestion.

Grade I: Redistribution of pulmonary blood flow, defined as a greater diameter of the upper compared to the lower lobe pulmonary vessels. Some of the chest x-rays taken with the patient in the supine position had redistribution of vascularity as the only sign of pulmonary venous congestion; in these instances, the chest x-ray was interpreted as normal. However, when the loss of the hilar angle was also evident, or when the heart size had increased relative to a previous control chest x-ray or to a discharge x-ray, the interpretation of pulmonary venous hypertension was made.

Grade II: Interstitial pulmonary edema, defined by loss of definition of the pulmonary vascular markings in association with Kerley’s B lines.

Grade III: Localized alveolar edema defined as confluent alveolar infiltrates in perihilar areas and lower lung fields.

Grade IV: Diffuse alveolar edema defined as diffuse confluent alveolar infiltrates throughout most areas of both lung fields.

Cardiomegaly was evaluated on the basis of either an increased cardiothoracic ratio or an increased left-heart dimension. The cardiothoracic ratio (fig. 2) was defined as the relation between the transverse diameter of the heart and the internal diameter of the chest, the latter being measured at the level of the highest point on the left hemidiaphragm. The transverse diameter of the heart was measured as the sum of the widest portions of the heart to the right and left of the midline. Although the normal upper limit of cardiothoracic ratio on AP chest x-ray has not been defined, we separated and compared patients with a cardiothoracic ratio < 0.50 with those with a cardiothoracic ratio ≥ 0.50. The left-heart dimension (fig. 2) was defined as the distance from the midline to the apex of the left ventricle corrected for magnification and normalized for body surface area.

Statistical Analysis

Comparisons of mortality rates among the patients with the various grades of pulmonary congestion and various radiographic heart dimensions were made using the life-table method of Cutler. To protect against spurious significance due to multiple tests, a p value of 0.005 was selected because 10 comparisons were made (0.05/10). For radiographic heart dimensions, five comparisons were made and a p value of 0.01 was selected.

Results

The prognosis of patients after acute myocardial infarction according to the severity of congestion in the initial chest x-ray is presented in figure 3. The 30-day mortality was significantly (p < 0.005) higher in patients with grades II (19 of 61, 31%), III (eight of 20, 40%) and IV (11 of 13, 82%) pulmonary venous congestion than in patients with grade 0 (eight of 141, 6%); the late mortalities (6 months, 1 year) increased significantly (p < 0.005) with any degree of pulmonary venous congestion compared with grade 0. Thus, during the first year after acute myocardial infarction only 17 of 141 patients (12%) died without pulmonary congestion (grade 0), compared with 13 of 18 deaths (35%) with grade I, 36 of 61 (59%) with grade II, 10 of 20 (50%) with grade III and 13 of 13 (100%) with grade IV. There were also significant (p < 0.005) increases in early and late mortalities in grade IV compared with lesser grades of pulmonary venous congestion. There was no significant difference in the survival rate between patients with either interstitial pulmonary edema (grade II) or localized alveolar edema (grade III) in the initial chest x-ray after acute myocardial infarction, and in both groups the survival rate after 1 year was less than 50%. With diffuse pulmonary edema (grade IV), only two of 13 patients (18%) survived 30 days and none survived after 1 year (fig. 3).

To test interobserver variation in grading, 246 chest x-rays (not necessarily initial studies) were given to two independent observers. There was agreement in all but 64 cases, 29 of which concerned the technical quality of the x-rays. In 22 of these instances one observer (not necessarily the same one in each case) felt no congestion was present and the other thought the quality of the x-ray was too poor to interpret. In the other seven cases one observer thought some degree of congestion was present while the other thought that the x-ray was not interpretable. In 22 cases there was disagreement whether no congestion (grade 0) or some degree of congestion (mainly grade I) was present. In the remaining 13 cases, both observers agreed that congestion was present but disagreed as to its extent. Six discrepancies were between grades I and II and seven were between grades II and III. In a clinical situation, it is likely that an x-ray of substandard quality would be reinterpreted. Therefore, if the 29 radiographs of poor technical quality are excluded, the level of agreement in this series is quite good (211 of 246 or 86%).

To evaluate the importance of initial radiographic heart dimensions for prognosis of patients with acute myocardial infarction, normal and increased cardiothoracic ratio (in 185 patients) and left-heart dimension (in 261 patients) measurements with and
FIGURE 1. Chest x-rays graded according to the degree of pulmonary venous congestion. A) Grade 0 — normal chest x-ray: no pulmonary congestion, normal heart size. B) Grade I — redistribution of pulmonary blood flow: redistribution to upper lobe vessels, loss of acute right hilar angle, peribronchial cuffing in right upper lobe. C) Grade II — interstitial pulmonary edema: Kerley B lines. D) Grade III — localized pulmonary edema: confluent alveolar infiltrates in perihilar areas and lower lung fields. E) Grade IV — diffuse pulmonary edema: diffuse confluent alveolar infiltrates throughout most areas of both lung fields.
CHEST X-RAY IN ACUTE MI/Battler et al.

**Figure 2.** Method by which radiologic heart dimensions were measured on the initial chest film. The midline was designated by connecting the images of two lead markers (one on the suprasternal notch, the other on the xiphoid). LHD = left-heart dimension; \(1/2\) TTD = half transthoracic diameter; \(LHD + X/TTD\) = cardiothoracic ratio.

**Figure 3.** The early and late survival rates after acute myocardial infarction according to the severity of pulmonary venous congestion (PC) in the initial chest x-ray.

**Figure 4.** The relation of early and late mortality to normal cardiothoracic ratio (CTR) (<0.50) and increased CTR (≥0.50) without and with pulmonary congestion (PC) in the initial chest x-ray after acute myocardial infarction. There is a significant \((p < 0.01)\) increase in mortality when PC is present, with or without increased CTR. B) The relation of early and late mortality to normal left-heart dimension (LHD) (<50 mm/m²) and increased LHD (≥50 mm/m²) without and with PC obtained from the initial chest x-ray after acute myocardial infarction. There is a significant \((p < 0.01)\) increase in late mortality in patients without PC and increased LHD. However, with PC, there is significantly \((p < 0.01)\) higher early and late mortality with or without increased LHD.
without pulmonary venous congestion were related to early and late mortality (figs. 4A, 4B and 5). Without initial pulmonary congestion (grade 0) and with initial normal cardiothoracic ratio (< 0.50, 65 patients) and left-heart dimension (< 50 mm/m², 85 patients), more than 96% of the patients survived 30 days and more than 91% survived 1 year (figs. 4A and 4B). However, among patients with grade 0 congestion and increased cardiothoracic ratio (≥ 0.50), early mortality (five of 34, 14%) and late mortality (eight of 34, 24%) were 2.5 and 2.7 times greater, respectively, than mortalities among patients with normal initial cardiothoracic ratios (early mortality three of 65, 4%; late mortality six of 65, 9%) (figs. 4A and 5). Among patients with increased initial left-heart dimension (≥ 50 mm/m²) and grade 0 congestion, early mortality (six of 52, 11%) was 3.7 times greater and late mortality (12 of 52, 24%) was 4 times greater (p < 0.01) than in patients with normal initial left-heart dimensions during the same periods (early mortality three of 85, 5%; late mortality five of 85, 6%) (figs. 4B and 5). With any degree of pulmonary venous congestion, early and late mortalities with or without increased radiographic heart dimensions were significantly (p < 0.01) higher than without pulmonary venous congestion (figs. 4A and 4B), and the 1-year mortality did not differ significantly for either increased or normal radiographic heart dimensions (fig. 5).

Discussion

In previous studies, congestion or cardiomegaly on the chest x-ray of patients with acute myocardial infarction was related to prognosis as one of many variables in a multivariate analysis.7-10 We evaluated the usefulness of radiographic findings on the initial chest x-ray (within 24 hours from admission to the coronary care unit) in predicting the prognosis of 273 patients with acute myocardial infarction. The 1-month and 1-year mortalities in these patients are comparable with those in previous studies.10, 14

The prognosis of patients with acute myocardial infarction depends mainly on the extent of myocardial damage, and thus on the extent of left ventricular dysfunction. A feature of ischemic dysfunction is a decrease in left ventricular compliance and, in many instances, a substantial increase in filling pressure with a concomitant increase in left ventricular or overall heart size. Changes in left ventricular filling pressures or pulmonary artery wedge pressures also may cause changes in lung fields. Thus, as wedge pressure increases, changes in lung fields generally become more severe; with redistribution of pulmonary vascularity, wedge pressures are approximately 12-18 mm Hg and with pulmonary edema, approximately 22-25 mm Hg, although exceptions to this relation exist with rapid hemodynamic changes. In the present study any degree of pulmonary congestion was associated with a significant increase in early and late mortality compared with the risk when the initial chest x-ray was normal. If the initial chest x-ray showed either interstitial pulmonary edema or localized alveolar edema, early mortality rates were 31% and 40%, respectively, and after 1 year the mortality was greater than 50%. If the initial chest x-ray showed diffuse pulmonary edema, the 30-day survival was only 18%, and after 1 year there were no survivors. Thus, it is important to distinguish between localized and diffuse alveolar edema. Although pneumonia could be mistakenly interpreted as localized alveolar edema and thus explain the better survival with localized edema than with diffuse edema, none of the patients with localized alveolar edema had clinical evidence of pneumonia during the period when the chest x-rays were taken.

This study also shows that when pulmonary venous congestion is absent, cardiomegaly is an important prognostic factor. Thus, with increased cardiothoracic ratio, the 1-year mortality was 2.7 times greater and with increased left-heart dimension 4 times greater than in patients with normal initial heart size.
However, with any degree of pulmonary venous congestion, the mortality was significantly higher than when it was absent, whether or not cardiomegaly existed. In the absence of pulmonary venous congestion or cardiomegaly in the initial chest x-ray after acute myocardial infarction, both the early and late survival rates were more than 91%.

We conclude that the chest x-ray obtained during the first day of admission for acute myocardial infarction provides much information about early and late prognosis and can define a low-risk group and groups with increasing risk of dying during the first month or year after the acute infarction.

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