
The Minnesota Heart Survey

Paul G. McGovern, PhD; Aaron R. Folsom, MD; J. Michael Sprafka, PhD; Gregory L. Burke, MD; Katherine M. Doliszny, PhD; Jasenka Demirovic, MD; Julie D. Naylor, MS; and Henry Blackburn, MD

Background. The Minnesota Heart Survey is a population-based study designed to monitor and explain trends in cardiovascular mortality, morbidity, and risk factors. As part of this effort, a 50% sample of patients hospitalized for myocardial infarction (MI) in the seven-county Twin Cities (Minneapolis and St. Paul) metropolitan area was reviewed in 1970, 1980, and 1985. Those with a validated definite MI were followed for 4-year mortality. The purpose was to determine whether the improved survival observed between 1970 and 1980 was extended to the 1980–1985 period.

Methods and Results. Crude 28-day mortality in men changed from 18% in 1970 to 12% in 1980 to 13% in 1985; in women it changed from 27% in 1970 to 22% in 1980 to 18% in 1985. After adjustment for severity factors (e.g., age, previous MI, and admission heart rate and systolic blood pressure), 28-day mortality was significantly lower in 1980 than in 1970 in men (RR, 0.66; 95% CI, 0.47, 0.92) and in women (RR, 0.69; 95% CI, 0.46, 1.04), but no change occurred from 1980 to 1985 (p > 0.25). After adjustment for severity indicators, 4-year survival was better in 1980 than in 1970 for men (RR, 0.67; 95% CI, 0.54, 0.83) and for women (RR, 0.72; 95% CI, 0.54, 0.98), but there was no significant change from 1980 to 1985 (p > 0.25).

Conclusions. These results suggest that improvements in survival among hospitalized MI patients contributed to the overall decline in coronary heart disease mortality in the Twin Cities area between 1970 and 1980 but not between 1980 and 1985. (Circulation 1992;85:172–179)

Coronary heart disease (CHD) mortality rates in the Twin Cities (Minneapolis and St. Paul, Minn.) have declined from 1970 to 1985 at an annual rate of 2.5% in both men and women while attack rates of hospitalized myocardial infarction (MI) have remained relatively constant. This suggests that out-of-hospital MI mortality rates and/or hospitalized MI survival rates have concomitantly improved. Burke et al1 presented evidence that out-of-hospital MI mortality rates in the Twin Cities fell between 1970 and 1985. Possible explanations for declining out-of-hospital MI mortality include substantial reductions in CHD risk factor levels in the general population during this period as well as improved emergency care.4 Gomez-Marín et al5 showed that 4-year survival for hospitalized MI patients improved about 30% between 1970 and 1980 in the Twin Cities, but data for the 1980s have not been reported.

In this study, we examine time trends in short- and long-term survival among hospitalized MI patients in three cohorts of definite MI patients (1970, 1980, and 1985) assembled as part of the Minnesota Heart Survey to determine whether survival improved from 1980 to 1985.

Methods

Hospitalized MI Data Collection

We examined the hospital records of a 50% sample of 30–74-year-old residents of the metropolitan area who were discharged with a diagnosis of acute myocardial infarction in 1970, 1980, and 1985. Listings of patients with a diagnosis code according to the International Classification of Diseases (ICD) of 410 (acute myocardial infarction) or 411 (other acute
coronary disease) were obtained from 35 of the 36 acute care hospitals in 1970 and 30 of the 31 hospitals in 1980 and 1985.

Data from patients’ hospital charts were abstracted by trained nurses under the supervision of physicians participating in the study. Information abstracted included presenting symptoms (i.e., chest pain) and signs (i.e., first systolic blood pressure and heart rate, presence of a third heart sound, and occurrence of rales), history of previous myocardial infarction, cardiac enzymes, 12-lead electrocardiogram (ECG), and first and maximal blood urea nitrogen levels. Chest film reports were obtained and classified as normal or abnormal (any abnormality present). Autopsy records for deaths in the hospital were also abstracted.

Validation of MI

The hospital discharge diagnosis of myocardial infarction was validated in an identical manner for all years. The criteria were based on autopsy findings, chest pain, ECG (coded according to the Minnesota code), and cardiac enzyme levels (see Figure 1). To assist in comparability over the 15-year period, the enzyme criteria included only lactate dehydrogenase and aspartate aminotransferase because measurements of creatine kinase and creatine kinase MB were not widely available in 1970. Cases were classified as definite MI, possible MI, or no MI. Only definite MIs were used in this analysis.

Follow-up and End Points

Patients’ vital status at the time of hospital discharge was ascertained from medical records, and vital status after hospital discharge was obtained by computer linkage with Minnesota death certificates by use of the Minnesota Death Index, a system that has 98% agreement with the National Death Index. Information on death was available through 1988, allowing for the evaluation of at least 3 and up to 4 years of survival in the three periods of observation.

Patients admitted to the hospital for elective cardiac surgery who were discharged with validated MI were not included in the data analysis. There were 42 such patients, of whom 34 were men. Six such elective admissions occurred in 1970, 14 in 1980, and 22 in 1985. In the case of 37 duplicate admissions for definite MI in the same calendar year, one admission per patient chosen at random was included in the data analysis.

A total of 73 patients (56 men and 17 women) had missing heart rate and/or systolic blood pressure at admission; 57 of these patients were from the cohort of 1970 admissions. These patients were not included in severity-adjusted analyses.

Of the 856 total deaths that occurred among the patients with a definite myocardial infarction in the 4-year follow-up period, 742 (86.7%) were coded on the death certificate as having an underlying cause of cardiovascular disease (ICD 390–459). The proportion of these deaths attributed to cardiovascular disease was 90.3%, 88.3%, and 81.0% in 1970, 1980, and 1985, respectively. There were no sex differences in proportional cardiovascular mortality within any year. Death certificate diagnoses were not validated because clinical information about the 459 patients who died after hospital discharge was not available. Therefore, all-cause death was considered as the study end point.

Statistical Methods

Comparisons between the years 1970, 1980, and 1985 were made by sex for demographic variables,

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1970 (n=487)</td>
<td>1980 (n=581)</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>58.5</td>
<td>58.2</td>
</tr>
<tr>
<td>Mean heart rate (bpm)</td>
<td>85.5</td>
<td>81.7</td>
</tr>
<tr>
<td>Missing heart rate (%)</td>
<td>8.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Median BUN</td>
<td>19.0</td>
<td>18.0</td>
</tr>
<tr>
<td>Missing BUN (%)</td>
<td>20.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Digitalis on admission (%)</td>
<td>8.6</td>
<td>13.9</td>
</tr>
<tr>
<td>3rd heart sound (%)</td>
<td>12.7</td>
<td>18.2</td>
</tr>
<tr>
<td>Rales (%)</td>
<td>26.1</td>
<td>35.5</td>
</tr>
<tr>
<td>SBP&lt;70 mm Hg (%)</td>
<td>1.4</td>
<td>0.9</td>
</tr>
<tr>
<td>SBP&gt;140 mm Hg (%)</td>
<td>42.2</td>
<td>42.2</td>
</tr>
<tr>
<td>Missing SBP (%)</td>
<td>7.7</td>
<td>0.7</td>
</tr>
<tr>
<td>History of MI (%)</td>
<td>32.7</td>
<td>28.9</td>
</tr>
<tr>
<td>Unknown prior MI (%)</td>
<td>32.9</td>
<td>20.8</td>
</tr>
<tr>
<td>Abnormal x-ray (%)</td>
<td>57.1</td>
<td>49.2</td>
</tr>
<tr>
<td>Missing x-ray (%)</td>
<td>9.5</td>
<td>6.5</td>
</tr>
</tbody>
</table>

*pTest that characteristic has remained unchanged across the 3 years.
BUN, blood urea nitrogen; bpm, beats per minutes; SBP, systolic blood pressure; MI, myocardial infarction.

Clinical conditions on admission to the hospital, and for several indicators of disease severity determined from the medical record using analysis of variance for continuous variables and χ² analysis for categorical variables. History of prior MI and abnormal chest x-ray variables were trichotomized as present, absent, or missing to allow analysis for the effects of data not included in the chart. All other conditions routinely measured by medical examination upon admission (e.g., rales and third heart sound) were assumed absent if there was no note in the medical record. Sensitivity analysis (where alternative assumptions about data not recorded were made) indicated that this assumption had little effect on the temporal trends reported below.

Univariate survival analyses were performed using the Kaplan-Meier method, and the unadjusted survival curves were compared by means of the log-rank test. Age-adjusted analyses of the percentage surviving 3 years after admission were performed using logistic regression. (Although up to 4 years of survival information was collected, 3-year data were available for everyone.) The Cox proportional hazards method was used to model survival up to 4 years with adjustment for temporal differences in a number of measures of MI severity: recurrent MI (versus incident MI, versus unknown), abnormal chest x-ray (versus normal chest x-ray, versus unknown), rales, third heart sound, digitalis on admission, and heart rate and systolic blood pressure on admission. A quadratic term for systolic blood pressure was also included in all fitted proportional hazards models. The proportional hazards assumption was tested in each case and supported unless noted.

Results

The proportion of patients discharged from the hospital with a 410 code (acute MI) that was validated as definite MI by Minnesota Heart Survey criteria decreased from 54% (of 1,292 abstracted) in 1970 to 53% (of 1,450) in 1980 to 47% (of 1,632) in 1985. A similar trend was observed for patients discharged with a 411 code (other acute ischemic heart disease) in the absence of a 410 code, declining from 9% (of 609) in 1970 to 7% (of 430) in 1980 to 6% of 1,153 in 1985. The age-adjusted attack rate of hospitalized definite MI (using the 1980 Twin Cities population as the standard) showed no change from 1970 to 1985, going from 566 (per 100,000) in 1970 to 572 in 1980 to 576 in 1985 in men, and from 223 in 1970 to 205 in 1980 to 211 in 1985 in women. This lack of change in the definite MI attack rate while the proportion of discharged patients with 410 or 411 codes who were categorized as definite MI declined is explained by increases in the rate of discharge of all listed diagnoses of 410 and 411 codes during this period.1,8

Characteristics of Hospitalized Patients With Definite MI

A comparison of sex-specific characteristics at admission of the 1970, 1980, and 1985 cohorts (Table 1) shows clear differences in the proportion of missing data that dropped considerably from 1970 to 1985, especially the percentage of patients with unknown history of previous MI status. These characteristics were significant predictors of short- and long-term survival. Although there were significant differences over time on a number of severity measures, there was little evidence that the overall severity of MI changed from 1970 to 1985.

Short-term Mortality

There were sharp and consistent declines in age-adjusted hospital fatality rates of definite MI in
both sexes during the 1970–1985 period (Table 2). These persisted when a multiple-factor severity adjustment was applied. However, these declining case fatality rates are confounded by parallel declines in length of hospital stay during this period (Table 2).

Crude 28-day mortality in men changed from 18% in 1970 to 12% in 1980 to 13% in 1985; in women it changed from 27% in 1970 to 22% in 1980 to 18% in 1985. After adjustment for age, 28-day survival (Table 3) improved significantly in both men and women from 1970 to 1985. In men, this improvement occurred exclusively in the 1970–1980 period. There was a suggestion, however, that very early survival after a hospitalized definite MI improved in the early 1980s. For example, in men, 1-week mortality was 9.8%, 7.9%, and 5.0% in 1970, 1980, and 1985, respectively; in women, it fell from 18.3% in 1970 to 14.5% in 1980 to 12.9% in 1985. Although the changes from 1980 to 1985 were not statistically significant, they were proportionately consistent with the improvement in 1-week mortality registered in the longer 1970–1980 period.

When an adjustment for multiple severity factors was applied, 28-day mortality in men changed from 17% in 1970 to 12% in 1980 to 14% in 1985; in women it changed from 27% in 1970 to 20% in 1980 to 20% in 1985. The decrease in adjusted 28-day mortality between 1970 and 1980 was significant in men ($p=0.01$) and marginally significant in women ($p=0.08$). The differences between 1980 and 1985 were both nonsignificant ($p>0.25$).

### Long-term Survival

Unadjusted survival for men (Figure 2) and women (Figure 3) after hospitalized definite MI improved in both sexes since 1970 ($p<0.001$ in men; $p=0.06$ in women). Most of the improvement occurred in the 1970–1980 period, with little gain in survival from 1980 to 1985.

Age-adjusted logistic regression performed on 3-year survival (Table 3) showed that survival improved substantially from 1970 to 1980 but changed little from 1980 to 1985. Three-year survival from 1970 to 1980 improved 9.6 percentage points in men ($p<0.001$) and 5.7 percentage points in women ($p=0.22$). This improved survival because 1970 was not restricted to the acute phase after hospitalization. Three-year survival among 28-day survivors improved significantly in men from 1970 to 1985, although there was no change in women (Table 3). Again, almost all of the improvement occurred before 1980.

A Cox proportional hazards model including adjustment for multiple severity factors was fitted to the up-to-4-year survival data. As shown in Figure 4, the sex-specific relative risks (and their 95% confidence intervals) for the risk of death after an acute MI relative to 1970 risk (i.e., 1.00) revealed significant improvements for both sexes in 1980 (RR, 0.67 [CI, 0.54, 0.83] in men; RR, 0.72 [CI, 0.54, 0.98] in women) but no subsequent change from 1980 to 1985. The wider confidence intervals for relative risks in women are due to the much smaller number of definite MIs observed in women.

The time trends in adjusted survival were consistent in the acute phase (up to 28 days) and the long-term phase (up to 4 years among 28-day survivors). Twenty-eight day risk of death declined significantly from 1970 to 1980 in men (RR, 0.66; CI, 0.47, 0.92) and marginally significantly in women (RR, 0.69; CI, 0.46, 1.04). There was no significant change ($p>0.25$) in either sex from 1980 to 1985. Adjusted 4-year risk of death among those who survived the first 28 days after a hospitalized definite MI improved significantly between 1970 and 1980 in men (RR, 0.67; CI, 0.51, 0.89) but not in women (RR, 0.77; CI, 0.49, 1.21). Again, there was no significant change ($p>0.25$) between 1980 and 1985.

### Trends in Hospital Care

Hospital care information was collected on a randomly chosen 5% sample of patients from 1970, 1979, and 1985. Results for definite MI patients who were not admitted for elective cardiac surgery (Table 4) indicated that there were substantial changes in hospital care (including cardiac procedures) from 1970 to 1979 and from 1979 to 1985. For instance, the use of β-blockers increased steadily over this 15-year period from 4.3% in 1970 to 52.8% in 1985. Cardiac procedures such as coronary artery bypass and angiography, which were being introduced in 1970, were performed on 11.1% and 31.9% of patients in 1985, respectively.

### Table 2. Age-Adjusted, In-Hospital Case Fatality Rate and Average Length of Hospital Stay Among Hospitalized Definite Myocardial Infarction Patients by Sex and Year: The Minnesota Heart Survey, 1970–1985

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case fatality rate*</td>
<td>20.9</td>
<td>13.6</td>
</tr>
<tr>
<td>Length of stay (days)</td>
<td>21.0</td>
<td>14.8</td>
</tr>
</tbody>
</table>

*Age-adjusted by direct method to 1980 Twin Cities (Minneapolis and St. Paul, Minn.) myocardial infarction population.

### Table 3. Age-Adjusted Percentage Surviving After a Hospitalized Definite Myocardial Infarction by Sex and Year*. The Minnesota Heart Survey, 1970–1985

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-year survival</td>
<td>63.5</td>
<td>73.1</td>
</tr>
<tr>
<td>28-Day survival</td>
<td>83.4</td>
<td>89.5</td>
</tr>
<tr>
<td>Three-year survival among 28-day survivors</td>
<td>76.3</td>
<td>81.5</td>
</tr>
</tbody>
</table>

*Age-adjusted to 1980 Twin Cities (Minneapolis and St. Paul, Minn.) myocardial infarction population.
†Significant improvement ($p<0.05$) in survival from 1970 to 1985.
Discussion

There is a considerable body of literature indicating improvements in hospital or short-term mortality of MI during the 1970s. However, there is little information about trends in the 1980s. The Worcester Heart Attack Study reported declines in hosp-
Figure 4. Severity-adjusted log relative risk (and 95% confidence limits) of long-term death after hospitalized definite myocardial infarction: The Minnesota Heart Survey.

The literature regarding temporal change in long-term survival after MI is inconsistent. Weinblatt et al.\textsuperscript{16} reported no difference in 4.5-year survival between men who experienced a first MI in the 1960s versus the 1970s. Elveback et al.\textsuperscript{17} observed a similar lack of improvement from the 1960s to the 1970s in 5-year survival among 30-day survivors of MI in Rochester, Minn. Goldberg et al.\textsuperscript{13} found no improvements between 1975 and 1984 in long-term survival among patients discharged from the hospital after acute MI. In contrast, Aberg et al.\textsuperscript{18} observed improvements in long-term survival after MI in Sweden between 1968 and 1977, although much of the reported improvement occurred from 1968–1969 to 1970–1971. Stewart et al.\textsuperscript{19} found no improvement in long-term survival in New Zealand between 1974 and 1981, but later\textsuperscript{20} reported improved 3-year, severity-adjusted survival rates from 1966–1967 to 1981–1982 of definite MI patients discharged alive from the hospital.

We previously reported considerable improvement in long-term survival of hospitalized definite MI patients in the Twin Cities between 1970 and 1980.\textsuperscript{5} This report extends the observation period and found no consistent survival improvement from 1980 to 1985.

The absence of a clear trend in survival after hospitalized definite MI between 1980 and 1985 requires explanation. Although changes in survival might be expected to be smaller in this shorter 5-year period than in the previous 10-year period, with consequent reduced power to detect such change, there was no evidence of improvement during the early 1980s in either 28-day survival or in long-term survival among those alive at 28 days. There was some evidence, albeit statistically nonsignificant, that 1-week mortality improved during the latter 5-year period. These results suggest that the continued and

### Table 4. Time Trends in Medical Care Given in Twin Cities Definite Myocardial Infarction Cases: The Minnesota Heart Survey, 1970–1985

<table>
<thead>
<tr>
<th>Procedure / Medication</th>
<th>1970 (n=93)</th>
<th>1979 (n=88)</th>
<th>1985 (n=72)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronary artery bypass</td>
<td>0.0%</td>
<td>5.7%</td>
<td>11.1%</td>
</tr>
<tr>
<td>Angiography</td>
<td>1.1%</td>
<td>7.0%</td>
<td>31.9%</td>
</tr>
<tr>
<td>Angioplasty</td>
<td>0.0%</td>
<td>0.0%</td>
<td>5.6%</td>
</tr>
<tr>
<td>Thrombolytic therapy</td>
<td>0.0%</td>
<td>0.0%</td>
<td>18.1%</td>
</tr>
<tr>
<td>Antiarrhythmic therapy</td>
<td>49.5%</td>
<td>77.3%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Lidocaine</td>
<td>43.0%</td>
<td>67.0%</td>
<td>79.2%</td>
</tr>
<tr>
<td>β-Blocker</td>
<td>4.3%</td>
<td>31.0%</td>
<td>52.8%</td>
</tr>
<tr>
<td>Calcium channel blocker</td>
<td>0.0%</td>
<td>0.0%</td>
<td>63.9%</td>
</tr>
<tr>
<td>Nitroglycerin (prn)</td>
<td>22.6%</td>
<td>53.4%</td>
<td>62.5%</td>
</tr>
<tr>
<td>Long-acting nitrates</td>
<td>17.2%</td>
<td>40.9%</td>
<td>76.4%</td>
</tr>
<tr>
<td>Transported by ambulance</td>
<td>27.1%</td>
<td>33.0%</td>
<td>55.4%</td>
</tr>
<tr>
<td>Treated in cardiac care unit</td>
<td>75.3%</td>
<td>94.3%</td>
<td>98.6%</td>
</tr>
</tbody>
</table>

Twin Cities, Minneapolis and St. Paul, Minn.
substantial changes in medical care of MI in the 1980s had little apparent added effect on community-wide long-term survival. Some of the reported changes in medical care may be an artifact of better medical reporting, yet most of them, such as the introduction of new procedures (e.g., angioplasty), are undoubtedly real. Moreover, reperfusion techniques were not yet widely used in the Twin Cities in 1985. Thus, medical care improvements in the early 1980s may have improved survival prospects for hospitalized MI victims in the very-short term, but these improvements appear not to have affected long-term survival.

Results for men and women were consistent in direction, although the degree of change tended to be smaller in women. However, observed differences in significance level between sex-specific trends appear to be attributable more to differences in statistical power, because there were no sex-by-time cohort interactions for any of the survival end points.

The mortality rate of CHD as a whole in the Twin Cities declined 35.5% between 1970 and 1980, and 18.2% from 1980 to 1985 in men; in women, the declines were 39.3% and 10.4%, respectively. These downward trends are quite similar to total U.S. trends for the same periods. The previous report from the Minnesota Heart Survey on survival concluded that some of the drop in CHD mortality rates between 1970 and 1980 in the Twin Cities was attributable to improved survival of hospitalized MI cases. A similar conclusion cannot be reached with respect to the 1980–1985 mortality decline.

Reduced CHD risk factors and out-of-hospital mortality seem to have contributed more prominently to the overall CHD decline in the Twin Cities. Nevertheless, the overall hospitalized definite MI attack rate has remained largely unchanged from 1970 to 1985. This may be due in part to improved detection of MI, increased survival to hospital admission, increased elective admissions subsequently discharged with an acute MI discharge code, and changed MI coding practices of hospitals. Another report from the Minnesota Heart Survey concluded that the advent of emergency medical services in the mid-1970s improved the survival of out-of-hospital cardiac arrest patients. If more MI are surviving to admission or more are being detected, the severity of hospital MI would be expected to change. However, we found no consistent evidence for change in severity (Table 1) although more sophisticated measures such as ejection fraction and indexes of infarct size were not routinely available in hospital records, and we have no information on delay between symptoms and hospital arrival. Undetected change in severity could have affected these results, even though we adjusted for the severity indicators available. On the other hand, research elsewhere has found no change in severity of validated MI. Gore et al reported no MI severity change from 1975 to 1984. Stewart and coworkers found no change in severity in New Zealand between 1966–1967 and 1981–1982 in definite MI patients discharged from the hospital alive.

Summary

Our results suggest that improvement in the short- and long-term survival of hospitalized MI patients contributed to the decline in CHD mortality observed in the Twin Cities area during the 1970s but not in the early 1980s. From other Minnesota Heart Survey data, it appears that a reduction in average risk factor levels and in out-of-hospital CHD deaths were more instrumental in the continued fall in CHD mortality during the early 1980s.

Acknowledgments

We are indebted to the following for important contributions to the design, initiation, and operation of this study: Dr. Richard Gillum, Dr. Russell Luepker, and Dr. Ronald Prineas; our nurse abstractors; and the Minneapolis-St. Paul area hospitals that took part in this project.

References


**KEY WORDS** • coronary disease • myocardial infarction • survival
The Minnesota Heart Survey.
and H Blackburn

Circulation. 1992;85:172-179
doi: 10.1161/01.CIR.85.1.172

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1992 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on
the World Wide Web at:
http://circ.ahajournals.org/content/85/1/172

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally
published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the
Editorial Office. Once the online version of the published article for which permission is being requested is
located, click Request Permissions in the middle column of the Web page under Services. Further
information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/