Temporal Patterns in Long-Term Survival After Resuscitation From Out-of-Hospital Cardiac Arrest

Thomas D. Rea, MD, MPH; Matthew Crouthamel, BA; Mickey S. Eisenberg, MD, PhD; Linda J. Becker, MA; Ann R. Lima, BS

Background—During the past quarter century, advances in treatment of cardiovascular disease have occurred that might potentially benefit survivors of sudden cardiac arrest (SCA). Little is known, however, about the temporal patterns in long-term survival among persons resuscitated from SCA. We hypothesized that long-term survival would improve over time and that this temporal pattern would be most evident for cardiac causes of death.

Methods and Results—The investigation was a retrospective cohort study of survival among persons who were discharged alive from the hospital after resuscitation from out-of-hospital SCA due to heart disease in King County, Wash, between May 1, 1976, and December 31, 2001 (n = 2035). Calendar time was divided into four 5-year intervals: 1976 to 1980, 1981 to 1985, 1986 to 1990, and 1991 to 1995, and one 6-year interval, 1996 to 2001. Age-adjusted survival curves were constructed, and Cox proportional-hazards regression was used to compute hazard ratios (HRs) for the association between mortality and time period. During 11,201 person-years of follow-up, 1334 persons died. Compared with the initial time period, the HR for total mortality was 0.86 (95% confidence interval, 0.73 to 1.01) for 1981 to 1985, 0.82 (0.69 to 0.96) for 1986 to 1990, 0.66 (0.55 to 0.79) for 1991 to 1995, and 0.58 (0.47 to 0.71) for 1996 to 2001 (HR for trend = 0.87 [0.84 to 0.91] for each successive time period). In analyses that assessed cardiac mortality, an even stronger temporal association was evident (HR for trend = 0.79 [0.75 to 0.84]).

Conclusions—Long-term survival after resuscitation from SCA improved steadily over time in this cohort. To continue this trend, future studies should identify circumstances in which proven treatments are underutilized as well as investigate new therapies that might benefit survivors of SCA. (Circulation. 2003;108:1196-1201.)

Key Words: heart arrest ■ epidemiology ■ mortality ■ survival

Out-of-hospital sudden cardiac arrest (SCA) is a major cause of mortality, claiming hundreds of thousands of lives each year in the United States alone.1,2 Successful resuscitation from SCA is infrequent; only an estimated 5% of persons are discharged alive from the hospital after SCA.3 Nonetheless, given the considerable public health magnitude of SCA, thousands of persons are successfully resuscitated each year.4 Moreover, some evidence suggests that ongoing efforts to strengthen the “chain of survival” through prompt activation of 9-1-1, early bystander cardiopulmonary resuscitation, rapid defibrillation, and timely advanced cardiac life support might improve the likelihood of successful resuscitation, resulting in additional survivors.5—10 During the past quarter century, advances such as lifestyle modifications, coronary revascularization, antiischemia and antiarrhythmic pharmacotherapies, and implantable cardioverter defibrillators have occurred that might potentially benefit survivors of SCA.11 Little is known, however, about the temporal patterns in long-term survival among persons resuscitated from SCA. Since 1976, the Emergency Medical Services (EMS) of King County has maintained a registry of all cases of EMS-treated SCA, which includes ascertainment of long-term survival among persons successfully resuscitated and discharged from the hospital after SCA, thus providing the opportunity to assess temporal trends in long-term survival. We hypothesized that survival after hospital discharge would improve over time, given advances in cardiac care and secondary prevention, and that this temporal pattern would be most evident for cardiac causes of death.

Methods

Study Design, Subjects, and Setting

The investigation was a retrospective cohort study of survival among persons who were discharged alive from the hospital after resuscitation from out-of-hospital SCA due to heart disease by EMS in King County, Wash (excluding Seattle) between May 1, 1976, and December 31, 2001. Persons who were not residents of the United States (n = 9) or who were <18 years of age (n = 6) were excluded. Of the 2073 eligible persons who were discharged alive from the hospital after resuscitation by EMS for out-of-hospital SCA during the study period, 38 persons were lost to follow-up, leaving 2035
persons (98.2%) for the investigation. King County covers an area of approximately 2000 square miles and comprises urban, suburban, and rural components. The population of King County (excluding Seattle) grew steadily during the past 25 years, increasing from ~686 500 persons in 1976 to 1 196 000 persons in 2000.12 As of 2000, 76% of the population was white, 11% Asian-American, 5% African-American, 6% Hispanic, and 1% American Indian. Eleven percent of the King County population was 65 years of age or older. Median household income was $51 300, with 8% of persons living below the poverty line. King County is served by a 2-tiered EMS response system. The first tier comprises firefighter–emergency medical technicians who administer basic life support as well as defibrillation with automated external defibrillators. The second tier consists of paramedics who administer advanced cardiac life support. In cases of suspected cardiac arrest, both tiers are dispatched simultaneously. For cardiac arrest calls, emergency dispatchers offer and provide cardiopulmonary resuscitation instructions over the telephone.13

Data Collection and Definitions
Since May 1, 1976, the EMS of King County has maintained a registry of all EMS-treated SCA cases. The registry contains information regarding survival to hospital discharge and has been maintained in the Utstein format.14,15 Survival to hospital discharge and underlying etiology of arrest (ie, heart disease) were determined by review of EMS reports, death certificates, and hospital discharge records. For persons who survived to hospital discharge, a match was conducted between the EMS registry and the death records provided by the Washington State Department of Health and the National Death Index to determine whether and when a subject had died as of December 31, 2001. For each case of death, the underlying cause was recorded. Deaths were classified as cardiac or noncardiac. A death was classified as cardiac when the International Classification of Diseases 8 or 9 code was 390 to 398, 402, or 404 to 429 or when the International Classification of Diseases 10 code was 100–102, I05–I09, I11–I128, or I13–I151.1 To assess temporal trends, calendar time period was divided into four 5-year intervals: 1976 to 1980, 1981 to 1985, 1986 to 1990, and 1991 to 1995, and one 6-year time interval, 1996 to 2001. The investigators’ review board approved the study.

Statistical Analysis
Follow-up time started at the date of hospital discharge after the SCA and extended to the date of death or the end of the follow-up period (December 31, 2001). Age-adjusted survival curves were constructed for each time period. Cox proportional-hazards regression was used to compute hazard ratios (HRs) for the association between total mortality and time period, with the earliest time period serving as the referent time period. The proportional-hazards assumption was tested and confirmed. Analyses were done with commercially available software (STATA 7.0, STATA Corp).

Results
Of the 2073 persons who were discharged alive from the hospital after resuscitation by EMS for out-of-hospital SCA during the study period, 38 persons (1.8%) were lost to follow-up. The 38 persons lost to follow-up were distributed throughout the 5 time periods: 2.7% (8 of 296) were from the 1976 to 1980 time period, 2.4% (10 of 422) from 1981 to 1985, 1.3% (6 of 452) from 1986 to 1990, 2.2% (9 of 405) from 1991 to 1995, and 1.0% (5 of 497) from 1996 to 2001. Among the remaining 2035 persons for whom vital status was available, the specific cause of mortality (cardiac versus noncardiac) was missing for 36 persons (1.8%), with 1.7% (5 of 288), 1.0% (4 of 412), 1.1% (5 of 446), 3.0% (12 of 397), and 2.0% (10 of 492) missing for each time period, respectively.

During the 11 201 person-years of follow-up, 1334 persons died. Survival improved steadily over time (Figure 1). Compared with the 1976 to 1980 time period, the overall HR of total mortality for the 1996 to 2001 time period was 0.58 (95% confidence interval [CI], 0.47 to 0.71), with mortality decreasing, on average, 13% for each successive time period. Results were similar for 1-, 5-, and 10-year follow-up periods. In sensitivity analyses, results were comparable when the time period was grouped as five 4-year and one 6-year time periods or as seven 3-year and one 5-year period or when modeled as a continuous (1-year) variable. Exclusion of age from the Cox model modestly attenuated the HRs associated with time period (HR for trend without age adjustment = 0.91 [95% CI, 0.87 to 0.95]).

The temporal pattern of improved survival over time was evident among men (HR = 0.87 [95% CI, 0.83 to 0.92] for each successive time period) and women (HR = 0.88 [95% CI, 0.81 to 0.96] for each successive time period), as well as for persons < 65 years of age (HR = 0.84 [95% CI, 0.79 to 0.91] for each successive time period) and persons ≥ 65 years of age (HR = 0.89 [95% CI, 0.84 to 0.94] for each successive time period).

In analyses that assessed the relation between time period and cardiac mortality, an even stronger temporal association was evident, with cardiac mortality decreasing, on average, 21% with each successive time period (Figure 2). When the 36 cases with a missing cause of death were coded as a cardiac cause, the results were similar (HR = 0.81 [95% CI, 0.77 to 0.86]). In contrast, there was no evidence of a temporal trend for noncardiac mortality (Figure 3).

Discussion
In this retrospective cohort investigation of persons resuscitated from SCA and discharged alive from the hospital, long-term survival increased substantially over time. The pattern of improving survival over time was directly attributable to a temporal trend of decreasing cardiac mortality. Given that thousands of persons each year in the United States are discharged alive from the hospital after resuscitation from SCA,4 the results of this investigation have public health implications that could translate to thousands of additional life-years if the findings are generalizable to other communities. Moreover, the improved long-term survival buoys the efforts to strengthen the chain of survival and achieve better resuscitation, suggesting that if victims of SCA...
can be successfully resuscitated, they will on average experience a better prognosis than their predecessors.

Mortality for the entire cohort regardless of time period was greatest during the first year after hospital discharge and in part likely reflects the greater early mortality of those with neurological impairment and the elevated risk of recurrent cardiac ischemic or arrhythmic events that occur early after a cardiac event.12,17,18 After the first year, the mortality rate declined for all time periods. Indeed, among the more recent time periods, the mortality rate approached that of the clinical trial populations that evaluated implantable cardioverter defibrillators versus pharmacotherapy among survivors of near-fatal arrhythmias, suggesting that SCA survivors in the community are receiving care that might be comparable to that of clinical trial populations.19–21

In this investigation, survival improved steadily over time. The reason for this improvement was likely multifactorial. SCA often represents the critical confluence of ischemic and arrhythmic risk factors.22 Numerous therapies have been developed during the past 25 years to prevent or treat 1 or both of these components.11,22 Although temporal trends regarding health behaviors and treatments are generally unavailable for the specific clinical population of SCA survivors, most evidence suggests that beneficial therapies for persons with various forms of heart disease have increased over time. For example, the use of coronary revascularization as either bypass surgery or percutaneous intervention, both associated with improved survival among persons resuscitated from SCA,23,24 has increased several-fold during the 1980s and 1990s, with ongoing improvements in approach and technique.11,25,26 Similarly, the use of pharmacotherapies that have been demonstrated to reduce mortality in various heart disease populations, such as aspirin, lipid-lowering medications, β-blockers, angiotensin-converting enzyme in-

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**Figure 1.** Age-adjusted all-cause mortality according to time period.∗

<table>
<thead>
<tr>
<th>Time Period</th>
<th>1-year mortality</th>
<th>5-year mortality</th>
<th>10-year mortality</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D</td>
<td>P·Y</td>
<td>Rate</td>
<td>HR (95% CI)</td>
</tr>
<tr>
<td>1976-1980</td>
<td>65</td>
<td>242</td>
<td>26.9</td>
<td>1</td>
</tr>
<tr>
<td>1981-1985</td>
<td>104</td>
<td>343</td>
<td>30.3</td>
<td>1.04 (0.76, 1.42)</td>
</tr>
<tr>
<td>1986-1990</td>
<td>126</td>
<td>353</td>
<td>35.7</td>
<td>1.20 (0.89, 1.62)</td>
</tr>
<tr>
<td>1991-1995</td>
<td>73</td>
<td>346</td>
<td>21.1</td>
<td>0.71 (0.51, 0.99)</td>
</tr>
<tr>
<td>1996-2001</td>
<td>91</td>
<td>407</td>
<td>22.4</td>
<td>0.70 (0.51, 0.97)</td>
</tr>
<tr>
<td>HR for trend</td>
<td>0.89 (0.83, 0.95)</td>
<td>0.87 (0.82, 0.91)</td>
<td>0.86 (0.83, 0.90)</td>
<td>0.87 (0.84, 0.91)</td>
</tr>
</tbody>
</table>

* Deaths is abbreviated D. Person years abbreviated P·Y. Hazard ratio is abbreviated HR. Confidence interval is abbreviated CI.
Rate is per 100 person-years.
Hazard ratio is adjusted for age and gender.
hibitors, thrombolytics, and amiodarone, has also increased over time. Temporal trends in some health behaviors such as smoking have improved over time, while trends in others such as exercise or diet are less certain. Finally, among persons aged 65 years or greater who are admitted to the hospital with a diagnosis of ventricular arrhythmia in the United States, the use of implantable cardioverter defibrillators has increased substantially from the mid 1980s through the mid 1990s. The temporal trend of improved long-term survival was evident among men and women as well as older and younger

<table>
<thead>
<tr>
<th>Time Period</th>
<th>1-year mortality</th>
<th>5-year mortality</th>
<th>10-year mortality</th>
<th>Overall HR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D</td>
<td>P-Y</td>
<td>Rate</td>
<td>HR (95% CI)</td>
</tr>
<tr>
<td>1976-1980</td>
<td>58</td>
<td>239</td>
<td>24.3</td>
<td>1</td>
</tr>
<tr>
<td>1981-1985</td>
<td>84</td>
<td>339</td>
<td>24.8</td>
<td>0.93 (0.67, 1.22)</td>
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<tr>
<td>1986-1990</td>
<td>96</td>
<td>349</td>
<td>27.5</td>
<td>1.02 (0.73, 1.41)</td>
</tr>
<tr>
<td>1991-1995</td>
<td>58</td>
<td>334</td>
<td>17.4</td>
<td>0.64 (0.44, 0.92)</td>
</tr>
<tr>
<td>1996-2001</td>
<td>58</td>
<td>398</td>
<td>14.6</td>
<td>0.50 (0.35, 0.72)</td>
</tr>
</tbody>
</table>

HR for trend: 0.84 (0.78, 0.91) 0.80 (0.76, 0.85) 0.79 (0.74, 0.85) 0.79 (0.75, 0.84)

* Deaths is abbreviated D. Person years is abbreviated P-Y. Hazard ratio is abbreviated HR. Confidence interval is abbreviated CI.
Rate is per 100 person-years.
Hazard ratio is adjusted for age and gender.
Cause of death was unavailable for 36 persons. These persons were excluded from the cause-specific analyses.

Figure 2. Age-adjusted mortality due to heart disease according to time period.*
persons discharged from the hospital after SCA. The finding suggests that in total, each demographic group is benefiting from improvements in therapies, although the distribution of specific therapies might differ by gender or age. Therefore, although this temporal improvement in survival across various demographic groups is encouraging, it might incur more cost. Among Medicare beneficiaries resuscitated for ventricular fibrillation cardiac arrest, initial hospital cost associated with care of survivors also rose steadily during the 10-year period from 1986 to 1995, primarily due to the increased number of procedures.

This study has several limitations. We were unable to assess temporal changes in various underlying health conditions, health behaviors, and treatments that would provide a better understanding of the temporal pattern of improved survival observed in this cohort. Although the temporal trends in all-cause mortality are certain, the temporal trend of cause-specific mortality (ie, cardiac) might be subject to bias if cause-of-death coding changed systematically over time. It is unlikely, however, that such a bias would account for the marked differences in temporal trends observed between cardiac and noncardiac causes of death. The investigation did not assess neurological or functional status of the survivors. However, neurological status of survivors is generally satisfactory. Moreover, poor neurological status typically predicts poor outcome, making it unlikely that the survivors...
during the more recent time periods had poorer neurological status than did survivors from the earlier time periods. Although the results might be representative of the experience of other communities, the findings report 1 community’s experience and might not necessarily be generalizable. These limitations should be balanced against the strengths of the study: the large size of the cohort, the substantial duration and extent of follow-up, and the community-based composition of the cohort.

In this cohort of persons resuscitated and discharged alive from the hospital after resuscitation from SCA, long-term survival increased substantially and steadily over time due to a temporal trend of decreasing cardiac mortality. To continue this trend, future studies should identify circumstances or clinical groups in which proven effective treatments are underutilized as well as investigate new therapies that might benefit the survivor of SCA.

Acknowledgment
We are indebted to the emergency dispatchers, fire fighters—emergency medical technicians, and paramedics of King County for their ongoing vital role in prehospital emergency care.

References
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