How Sudden Is Sudden Cardiac Death?

Dirk Müller, MD, PhD; Rahul Agrawal, MD, PhD; Hans-Richard Arntz, MD, PhD

Background—Out-of-hospital sudden cardiac death (SCD) is a frequent cause of death. Survival rates remain low despite increasing efforts in medical care. Better understanding of the circumstances of SCD could be helpful in developing preventive measures and facilitating proper reactions to such a pending event.

Methods and Results—Information on cases of out-of-hospital SCD was collected in the Berlin, Germany, emergency medical system via a questionnaire. Bystander interviews were performed by the emergency physician on scene immediately after declaration of death or return of circulation. Of 5831 rescue missions, 406 involved patients with presumed cardiac arrest. Sixty-six percent had a known cardiac disease. In 72%, the arrest occurred at home, and in 67%, it occurred in the presence of an eyewitness. Information on symptoms immediately preceding the arrest was available in 80% (n=323) of all 406 patients and in 274 of those with witnessed arrest. Symptoms were identical in the 2 groups. Typical angina was present for a median of 120 minutes in 25% of the 274 patients with witnessed arrest and in 33% with a symptom duration of less than 1 hour.

Conclusions—SCD occurs most often at home in the presence of relatives and after a longer period of typical warning symptoms. Although the much-hailed use of public access defibrillation is supported by several studies, the present results raise the question of whether educational measures and targeted educational programs tailored for patients at risk and their relatives should have a higher priority. (Circulation. 2006;114:1146-1150.)

Key Words: death, sudden ▪ resuscitation ▪ myocardial infarction ▪ defibrillation

Sudden cardiac death (SCD) is one of the most frequent causes of death in industrialized countries. The yearly incidence is estimated to be ≈100 cases per 100 000 inhabitants.1 The initiation is apparently multifactorial and only partially understood. Recent studies have discussed chronobiological factors as possible trigger mechanisms. Circadian as well as weekly and seasonal variations in the occurrence of SCD have been reported.2-5 The influences of certain risk factors such as use of nicotine, caffeine, or specific drugs and other triggers such as psychological or physical stress and awakening have been identified.6 Although the fundamental role of coronary heart disease and other causes of SCD, such as long-QT syndrome, has been described comprehensively, every single event seemingly represents a sudden and unforeseeable situation.7

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Although some studies have investigated the demographic circumstances of SCD,8 including the patients’ medical history, important information on symptoms and the setting of the resuscitation (eg, witnesses, first responders) was not documented immediately on the scene but with a delay of days or even weeks,9 which could have led to rationalizing of the event. Moreover, resuscitation attempts for patients older than 75 years were excluded, which resulted in a further bias of the epidemiological background.

Knowledge of the preceding symptoms is essential for an effective and timely initiation of appropriate measures to prevent SCD. When a collapse has occurred, the question of whether the correct and recommended steps are taken is crucial. Exact information on the circumstances of SCD could be helpful in developing preventive measures. In addition, the location of the event, the role of eyewitnesses and first responders, the reaction of the environment, and the likely cause of collapse are important for developing tailored preventive programs and educational materials.

Methods

In the present prospective study, we investigated the conditions immediately preceding SCD. To avoid any denial, subsequent affirmation, or ratification of bystander actions, the information was collected on the scene by the emergency physician immediately after establishing the return of stable spontaneous circulation or after stopping resuscitation measures and declaring the victim dead.

Definition of SCD

For the present study, we defined SCD as sudden unexpected arrest of presumed cardiac origin in adults >18 years of age. The arrest should have occurred within 24 hours after onset of any symptoms that could retrospectively be interpreted as being of cardiac origin. Cases with a longer duration of symptoms and those with an arrest
of clearly noncardiac origin (eg, trauma, suicide, or known intoxication) were excluded from the analysis.

**Emergency System Structure**

The physician-manned mobile intensive care unit and the rescue helicopter, both located at our hospital, cover ~10% of the 3.5 million inhabitants of Berlin. A detailed description has been given elsewhere of the 2-tiered emergency system (EMS); a first-tier ambulance with emergency medical technicians on board equipped with automated external defibrillators (AEDs) and a second tier manned with an emergency physician. On the basis of a questionnaire evaluated in a pilot study, all available bystanders and witnesses of the arrest were interviewed on site by the emergency physician. This questionnaire was used to obtain data on the logistics of EMS and demographics, as well as the patient’s medical history, medication use, and any preceding signs or symptoms and their duration. The relationship of the witness to the victim of SCD was also documented. The follow-up of patients with successful resuscitation was continued until their in-hospital death or discharge. Furthermore, information on bystander resuscitation attempts was documented but without evaluation of its quality. The study protocol was approved by our institutional review board.

**Statistical Analysis**

All data were collected in the FileMaker Pro database (FileMaker Inc, Santa Clara, Calif). Statistical analysis was performed with Jump software (SAS Institute GmbH, Heidelberg, Germany). Statistical calculations were performed for continuous variables with the Mann-Whitney U test or Student t test where appropriate and the χ² test for discrete variables. Differences were assumed to be statistically significant for a confidence probability of P≤0.05. Ninety-five percent confidence intervals and odds ratios were calculated when appropriate.

The authors had full access to the data and take full responsibility for its integrity. All authors have read and agree to the manuscript as written.

**Results**

Our mobile intensive care unit and rescue helicopter performed 5831 missions in the course of 1 year. Of these, 569 pertained to patients with arrest and without vital signs, and 554 of those were presumed to have had an acute arrest due to cardiac causes. Fifteen patients had to be excluded because of nontraumatic, noncardiac causes of arrest (cerebral event, n=5; primary respiratory cause, n=5; drowning, n=2; intoxication, n=2; and malignant disease, n=1). In 148 of the 554 cases of nontraumatic causes of death, the emergency physician was called off by first-arriving emergency medical technicians equipped with an automated external defibrillator because of apparent signs of irreversible death. Only the age and sex of these patients were registered. In the remaining 406 patients, the emergency physician arrived on scene and completed the questionnaire. The following analysis is based on these 406 patients (Figure).

**Results of Resuscitation**

Of the 406 patients analyzed, 237 (58%) were male. The mean age of all patients was 71±14 years. Male patients were significantly younger (68±14 years, range 22 to 98 years) than female patients (76±12 years, range 25 to 98 years, P<0.0001). Details of site of the arrest, underlying arrhythmia documented in AEDs or manual defibrillators, and results of resuscitation attempts are shown in Table 1.

The cardiac arrest was witnessed or overheard in 274 cases (67%). Of these witnesses, 66% were relatives of the victim. Bystanders performed a resuscitation attempt in only 57 patients (14%). First registered arrhythmia in the patients with bystander cardiopulmonary resuscitation (CPR) was ventricular fibrillation in 22 (39%), pulseless electric activity in 19 (33%), and asystole in 16 (28%); the corresponding figures for the 349 patients without bystander CPR were 89 (25%), 86 (25%), and 174 (50%; P=0.017 for group comparisons).

With bystander CPR, 13 (23%) of 57 patients survived to discharge compared with only 13 (4%) of 349 patients without bystander CPR. First registered arrhythmia and resuscitation results

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**TABLE 1. SCD Details**

<table>
<thead>
<tr>
<th>Site of resuscitation</th>
<th>n</th>
<th>(%)</th>
</tr>
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<tbody>
<tr>
<td>At home</td>
<td>294</td>
<td>72</td>
</tr>
<tr>
<td>In public/at work</td>
<td>65</td>
<td>20</td>
</tr>
<tr>
<td>Other</td>
<td>31</td>
<td>8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>First registered arrhythmia and resuscitation results</th>
<th>n</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventricular fibrillation</td>
<td>149</td>
<td>37</td>
</tr>
<tr>
<td>Survival to hospital</td>
<td>74</td>
<td>74</td>
</tr>
<tr>
<td>Dead at the scene</td>
<td>49</td>
<td>49</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Asystole</th>
<th>n</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First documented rhythm</td>
<td>180</td>
<td>44</td>
</tr>
<tr>
<td>Survival to hospital</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Dead at the scene</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pulseless electrical activity</th>
<th>n</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First documented rhythm</td>
<td>77</td>
<td>19</td>
</tr>
<tr>
<td>Survival to hospital</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Dead at the scene</td>
<td>41</td>
<td>41</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Result</th>
<th>n</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declared dead without attempted resuscitation by emergency physician</td>
<td>102</td>
<td>25</td>
</tr>
<tr>
<td>Resuscitation ineffective</td>
<td>204</td>
<td>50</td>
</tr>
<tr>
<td>Admitted to hospital alive</td>
<td>100</td>
<td>25</td>
</tr>
<tr>
<td>Males</td>
<td>61</td>
<td>15</td>
</tr>
<tr>
<td>Females</td>
<td>39</td>
<td>9.6</td>
</tr>
<tr>
<td>Survived to discharge</td>
<td>26</td>
<td>6</td>
</tr>
<tr>
<td>Males</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>Females</td>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>

Data are presented as n (%) unless otherwise indicated.
bystander CPR ($P<0.0001$). Significantly fewer bystander re-
suscitations were observed at home (32/294 [11%]) than at other
locations (25/96 [26%]; $P<0.001$). In addition, 5 cases of CPR
in domestic settings were performed by general practitioners
who were called to the patients’ location and were present at the
time of arrest. Correspondingly, the bystander CPR rate differed
depending on the rescuer’s relationship to the patient. The rate of
bystander CPR was 8% for related persons, 15% for acquainted
persons, and 23% for those with no personal relationship to the
patient.

Medical History and Character and Duration of
Symptoms Immediately Preceding Arrest
Information on the medical history was available in 352
patients (87%), and 106 (30%) had a history of coronary heart
disease documented by angiography. Of these, 16 patients
were reported to have had a previous episode of arrest and resuscitation. Symptoms of typical angina pectoris or intake
of antianginal medications that suggest the presence of
coronary heart disease were reported in 127 patients (36%).
Thirty of the remaining patients had a history of hypertension,
18 had diabetes mellitus, 19 were smokers, and 14 had
chronic obstructive pulmonary disease.

Information about character and duration of possible symp-
toms immediately preceding the arrest could be obtained in 80%
(n=323) of the patients (Table 2). The typical warning symptom
of angina pectoris was present in 88 patients (22%) for a median
of 120 minutes (range 20 to 630 minutes); dyspnea was present
in 61 patients (15%) for 30 minutes (range 10 to 375 minutes),
nausea or vomiting in 27 patients (7%) for 20 minutes (range
20 to 420 minutes), dizziness or syncope in 21 patients (5%) for
10 minutes (range 5 to 60 minutes), and other symptoms in 23
patients (6%) for 60 minutes (range 10 to 300 minutes). The
remaining 103 patients (25%) had no complaints. In the 274
patients with eyewitnessed or directly overheard arrest, angina
pectoris was reported for 120 minutes (range 15 to 495 minutes,
n=69 [25%]), dyspnea for 10 minutes (range 10 to 180 minutes,
n=47 [17%]), nausea or vomiting for 90 minutes (range 5 to 240
minutes, n=19 [7%]), dizziness or syncope for 10 minutes
(range 5 to 60 minutes, n=18 [7%]), and other symptoms for 60
minutes (range 10 to 270 minutes, n=23 [8%]). In addition, 71
patients did not complain of any symptoms, and in 31 patients
(11%), the symptoms and their duration were not known.

Distribution and duration of symptoms of patients with wit-
nessed arrest were not different from those of the other patients.
In 90% of all cases, symptoms lasted >5 minutes; in 20
patients (7.5%), they lasted between 2 and 5 minutes, and only
5 patients had symptoms for <2 minutes before they collapsed.
The median symptom duration was 50 minutes (range 17 to 200
minutes) for patients presenting with asystole, 20 minutes (range
10 to 270 minutes) for those with pulseless electrical activity,
and 30 minutes (range 15 to 180 minutes) for those with
ventricular fibrillation. Differences in duration among the 3
groups were not significant.

To assess the 1-hour definition of SCD, the data were
analyzed for the 116 patients with eyewitnessed arrest and a
symptom duration of <1 hour. We found no differences with
regard to age and sex distribution or presenting arrhythmias and
character of symptoms (Table 2) in this subgroup compared with
the entire group of patients with information on symptoms and
the 274 patients with eyewitnessed arrest. Even if stratified by
the first documented arrhythmia, there were no differences in
duration and character of symptoms.

Discussion
SCD is one of the most frequent causes of death in industrialized
countries. Patients with a very high risk for SCD, which may be
offset by an implantable defibrillator, ie, survivors of myo-
cardial infarction with a low ejection fraction or patients with
severe congestive heart failure, and a few with known geneti-
cally transmitted diseases represent only a very small percentage
of the total population at risk for SCD. The hypothesis that the majority of cases of SCD will
seemingly occur at random in an apparently healthy or at least
very low-risk population is, however, not supported by the
findings of the present investigation. In the present study, the
majority of the patients in an unselected population had a history
of documented cardiac disease or at least typical symptoms of
coronary heart disease or relevant risk factors that exposed them
to an obviously increased risk. The 66% of patients with
documented or suspected cardiac disease in the present study is
higher than that observed by others. This is most likely
explained by the inclusion of older patients in the present study
who were more likely to have ischemic heart disease. To date,
there are no reliable algorithms available for assessing the individual risk of SCD in this population.

The most frequent arrhythmia precipitating SCD is presumed to be a tachyarrhythmic event in 80% to 90% of cases, with predominantly ventricular fibrillation against the background of coronary heart disease, even though the number of patients found in ventricular fibrillation by EMS personnel appears to have been decreasing in recent years. Patients with ventricular fibrillation have a much better prognosis than those with asystole or pulseless electrical activity; ventricular fibrillation can only be treated definitively, however, with adequate use of a defibrillator within an appropriate time window. It has been shown that ventricular fibrillation can be prolonged by basic life support, which functions as a bridge until rescuers arrive with a defibrillator. In addition, ongoing CPR has an influence on the wavelet characteristics of fibrillation, which increases the probability of successful defibrillation that results in the return of spontaneous circulation. Moreover, a recent study revealed that a few minutes of CPR preceding defibrillation may lead to more survivors among patients with a longer period of untreated arrest due to ventricular fibrillation. Correspondingly, in the present study, the percentage of patients in ventricular fibrillation with preceding bystander CPR was significantly higher than the percentage of those without bystander CPR, and the rate of successful resuscitation after bystander CPR (24/57, 42%) was higher than that of patients without bystander CPR (76/349, 22%). The same applied to the discharge rate from hospital (13/57, 23%) with bystander CPR than that without bystander CPR (13/349, 4%). The low overall survival rate to discharge of only 6% in the present study is in agreement with other studies performed in settings with similar demographic structures.

In most cases, ventricular fibrillation is triggered by an acute ischemic coronary event, or a trigger is an integral part of ischemic heart disease. Indeed, in some patients, SCD is the first and only event of that disease. Effective primary prevention of ischemic heart disease would best prevent SCD; this cannot be fully achieved, however, owing to a lack of resources and compliance. Most patients in the present study had definite or suspected cardiac disease. The results of the present study show that even if the majority of patients with SCD and their relatives were aware of the disease, they were unaware of the inherent risk for SCD and were thus apparently caught unprepared by the fatal event. Relatives could have been informed about warning symptoms and could have learned to react appropriately in an emergency situation.

The present study shows that SCD occurs “suddenly out of the blue,” without any premonitory symptoms, in only a few cases. These results are principally in line with those of DeVreede-Swagemakers et al. The patients observed by us in the present study tolerated their symptoms for a median time of 60 minutes (range 10 to 380 minutes) before collapse occurred. In 80% of the cases, the complaints were presumably of cardiovascular origin. Even this high percentage with symptoms before arrest may have been underestimated, because some patients may have actually had symptoms that they did not mention to a bystander. It could be speculated that the majority of arrests in the present patient population could have been avoided, or at least, more patients could have been successfully resuscitated, if they had received earlier treatment, which could have been achieved by early recognition of symptoms and a subsequent call for help.

Patients were more likely to survive when the arrest happened in public places where the EMS has faster access. Moreover, resuscitation attempts were initiated significantly more frequently in that setting by bystanders, predominantly by nonrelated persons, than in a domestic setting with relatives as eyewitnesses. This unexpected finding may be explained in part by the fact that relatives are emotionally involved in the event and act under shock. Moreover, the likelihood of an eyewitness trained in basic life support being present is likely to be greater in public places than in private settings. In contrast to the present results, DeVreede-Swagemakers et al found a much higher percentage of resuscitation attempts by bystanders at home and in other places. It cannot be ruled out that their findings were due to the retrospective interviews performed days to weeks after the event and not immediately on scene. The witness perception and answers may have thus been influenced by mechanisms of repression and palliation.

Our observations again point to a highly important dilemma: the vast majority of SCDs occur in an apartment or residence with a low bystander resuscitation rate and a longer delay in the arrival of a defibrillator than in public places. It is not realistic to assume that an AED will be on hand for immediate defibrillation in every household. The efficacy of AEDs without the support of CPR must be questioned, because delay in defibrillation is typical for most patients who collapse at home. This underscores the great importance of training in CPR and explains the limited overall efficiency of public access defibrillation programs in fighting SCD. Not only did the domestic setting have an adverse effect on the rate of basic life support, but with regard to premonitory symptoms, patients at home tolerated their symptoms for an extremely long time before collapse: The median was 75 minutes at home (range 15 to 585 minutes) versus only 20 minutes (range 10 to 300 minutes) in public.

The present study has important limitations. We allowed a long symptom duration of 24 hours for the definition of SCD here. The application of stricter definitions than those used in the present study did not change the results (Table 2). Next, the information we acquired pertains to an urban German population. The results may thus not be generally applicable to other regions. Third, because there are no standards, we developed our own questionnaire, which was proved to work in a pilot study. A selection bias also cannot be excluded, because we only considered patients observed in the EMS. There was no further information on the group with irreversible death signs not seen by the emergency physician. Additionally, a cardiac cause of arrest could only be verified in patients admitted to hospital and not in those who died at the scene, because no autopsy was performed in those patients. Finally, even though witness reports could not be verified, misinformation is quite improbable, because the interviews were made immediately at the scene to avoid attenuation.

In conclusion, our data show that “sudden cardiac death” is not nearly as sudden in most cases as the term may suggest. Warning symptoms that precede SCD are present for a surprisingly long time in many patients. These symptoms are misinterpreted, suppressed, or denied despite the presence of a preexisting cardiac disease or cardiac risk factors. Because SCD mainly
occurs in domestic settings and in the presence of relatives, it is of the utmost importance to give detailed information not only to the patient at risk but also to the relatives. All should know how to recognize warning symptoms and react accordingly. Relatives are the most probable witnesses and should therefore learn to perform basic life support. Programs that aim at the use of AEDs and early defibrillation mainly focus on public places. They cannot substitute for the necessity of instructing patients and relatives about warning symptoms and adequate measures in these types of emergency situations. Money invested in training and education instead of AED programs might well lead to earlier recognition, more rapid contact of the EMS, and a higher percentage of bystander CPR and thus to a higher probability of survival in patients with SCD.

**Disclosures**

None.

**References**


2. Kloner RA, Poole WK, Perritt RL. When throughout the year is coronary death most likely to occur? A 12-year population-based analysis of more than 220 000 cases. Circulation. 1999;100:1630–1634.


**CLINICAL PERSPECTIVE**

The term “sudden death” suggests that death occurred without warning. Prevention efforts have largely focused on optimizing out-of-hospital resuscitation networks and selecting high-risk patients for interventions. Most sudden deaths are associated with coronary artery disease and possibly ischemia, which would be expected to cause symptoms. The present study prospectively investigated the circumstances preceding the so-called sudden cardiac death from standardized interviews. The main finding was that the cardiac arrest was often preceded by symptoms of heart disease for more than an hour and that many patients had known cardiac disease before the fatal event. These findings suggest that educating the public, patients, and relatives to recognize and respond to symptoms of heart disease holds promise for reducing mortality attributed to sudden death.
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