Cardiac Arrest in Schools
Katayoun Lotfi, BS; Lindsay White, MPH; Tom Rea, MD, MPH; Leonard Cobb, MD; Michael Copass, MD; Lihua Yin, MBA; Linda Becker, MA; Mickey Eisenberg, MD, PhD

Background—The purpose of the present study is to improve understanding of the epidemiology of cardiac arrest in the school setting, with a special focus on the role of school-based automated external defibrillators.

Methods and Results—The investigation was a retrospective study of emergency medical service–treated, nontraumatic, out-of-hospital cardiac arrests in Seattle and King County, Washington, that occurred in schools between 1990 and 2005. Cases were identified with cardiac arrest location data from emergency medical service cardiac arrest registries. Patient characteristics, cardiac arrest characteristics, and outcome information were abstracted from the registries and incident report forms. During the study period, 97 cardiac arrests occurred in schools, accounting for 0.4% of all treated cardiac arrests and 2.6% of public location cardiac arrests. Of the 97 cases, 12 cardiac arrests were among students, 33 among faculty and staff, and 45 among adults not employed by the school (7 adults with indeterminate school association). School-based cardiac arrest occurred on average in 1 of 111 schools annually, with a greater annual incidence among colleges (1 cardiac arrest per 8 colleges) than high schools (1 per 125 high schools) or lower-level schools (1 cardiac arrest per 200 preschools through middle schools). The estimated annual incidence of cardiac arrest was 0.18 per 100 000 person-years among students and 4.51 per 100 000 person-years for school faculty and staff.

Conclusions—The present study characterizes school-setting cardiac arrest and provides a framework within which to consider preparation efforts and outcome expectations. (Circulation. 2007;116:1374-1379.)

Key Words: heart arrest ■ defibrillation ■ epidemiology ■ pediatrics

The death of a young student from sudden cardiac arrest stirs deep emotions within the family and the community and raises concerns about the vulnerability of other school-age children. Such events have increased awareness of school-based rescue actions that include cardiac arrest recognition and emergency activation, early cardiopulmonary resuscitation (CPR), early defibrillation, and timely advanced care, collectively termed the links in the chain of survival.1 Specifically, the increasing availability and successful dissemination of automated external defibrillators (AEDs) into some public settings has led groups to advocate for AEDs in every school.2–4 These advocacy efforts have prompted legislation in several states that requires AED placement in schools, as well as a US congressional bill promoting access to defibrillation on school grounds.2–6 However, population-based data on incidence, circumstances, patient characteristics, and outcome of cardiac arrest in the school setting are lacking.1

The purpose of the present study is to improve understanding of the epidemiology of cardiac arrest in the school setting, with a special focus on the role of school-based AEDs.
miles and includes urban, suburban, and rural areas with an overall population of 1.5 million per the 1990 US Census and 1.7 million per the 2000 US Census. Roughly 24% of the population is 18 years of age or younger. Study methods were approved by the University of Washington Institutional Review Board.

EMS System

The area is served by a 2-tiered EMS system that is activated by calling 9-1-1 and speaking with an emergency dispatcher. The first tier consists of firefighter–emergency medical technicians who are trained in basic life support and automated defibrillation. The second tier consists of paramedics who are trained in advanced life support. Both tiers are dispatched simultaneously in the case of a suspected cardiac arrest. In the city of Seattle, first-tier EMS providers typically arrive on scene an average of 3.7 minutes after dispatch. The second tier arrives on average 4 minutes after the first tier. In surrounding King County, first-tier EMS providers arrive on scene an average of 5 minutes after call receipt. The second tier arrives on average 5 minutes after the first tier.

Data Collection

Since 1970, the Seattle Fire Department has maintained a registry of all cardiac arrests that received prehospital emergency medical treatment in the city of Seattle. King County EMS has maintained a similar registry of treated out-of-hospital cardiac arrests since 1976. The address for every cardiac arrest and an indication of whether the cardiac arrest occurred in a home or a public location is included in the registries. To identify cases of cardiac arrest that occurred in schools, all cardiac arrests taking place in a public location were extracted from the Seattle and King County registries. The medical incident report form for each of these cases was then individually reviewed to determine the exact cardiac arrest location. When the incident site was not clearly identified, the address was investigated via google.com, yellowpages.com, or wa.localschooldirectory.com, a World Wide Web site that contains information on all public and private schools in the state of Washington, to verify whether the event had occurred at a school.

The following data were abstracted for all public location cardiac arrests: date of incident, age, sex, witnessed status, bystander CPR, initial cardiac rhythm, hospital admission, survival to hospital discharge, and cause of the cardiac arrest. Survival to discharge and cardiac arrest cause were determined from available information, including incident report forms, hospital records, and death certificates. Cardiac causes were further classified into 1 of 4 categories: coronary artery disease alone, other structural cardiac causes, mixed coronary artery disease and other structural cardiac causes, and indeterminate cardiac origin. Other structural cardiac causes included valvular heart disease, congestive heart failure, and cardiomyopathy. Additional data were then abstracted from the incident report forms for the school cases, including dispatch and first-responder arrival times, location of cardiac arrest on campus, school affiliation of individual, whether a public access defibrillator (PAD) had been applied, and whether or not the individual was engaging in physical exertion during or immediately before the cardiac arrest. Physical exertion was defined as any activity that would likely cause an increase in heart rate. Examples include jogging, swimming, playing basketball, or climbing stairs. Walking or sitting was considered nonexertional.

School population information for Seattle and King County was retrieved from various sources to calculate incidence rates. Only full-time students, faculty, and staff were included in our calculations. We used data from the 1997 to 1998 school year because this year was the midpoint of the study. Student enrollment information for public and private preschools and for primary and secondary schools were obtained from the Washington State Office of Superintendent of Public Instruction Web site (www.k12.wa.us). This Web site only included preschools that were affiliated with a kindergarten or primary school. It did not include free-standing preschools. Faculty and staff data for all public schools were also available on this Web site; however, information on the number of faculty and staff in private schools was unavailable. Consequently, this number was estimated by applying the staff-to-student ratio in public schools to the number of private school students in Seattle and King County. Student, faculty, and staff head counts for higher-education institutions were acquired from the Integrated Postsecondary Education Data System on the National Center for Education Statistics Web site (nces.ed.gov/ipeds/pasp). Because this system combines both full-time and part-time students in their head counts for each school, each institution was contacted to provide the proportion of full-time students, which was in turn multiplied by the total student count during the 1997 to 1998 school year. Information on PAD availability in schools was obtained from the PAD registry, which was established by the Seattle Fire Department and King County EMS in 1999 to track PAD dissemination and use in the city of Seattle and surrounding King County.

Data Analysis

Statistical analyses were completed with SPSS version 11.5. We used descriptive statistics to examine the characteristics of cardiac arrests that occurred in school and other public locations. We compared characteristics between school and other public location arrests using χ² for categorical variables or t test for continuous variables. Fisher’s exact testing was used in cases in which the expected cell counts were <5. We calculated annual school-based incidence rates and incidence rates for school-affiliated individuals. Confidence intervals for incidence rates were computed by the Wilson method.8

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

Results

Between January 1, 1990, and December 31, 2005, 23 597 nontraumatic out-of-hospital cardiac arrests in Seattle and King County occurred that were treated by EMS (Figure 1). Of the 3773 cardiac arrests with specific public locations identified, 97 (2.6% of public cardiac arrests) took place in schools. Among persons 3 to 18 years of age, school-based cardiac arrests accounted for 13.1% (8/61) of public location cardiac arrests and 4.4% (8/183) of all cardiac arrests.

Incidence Rates

In Seattle and greater King County during the 16 years of study, 97 cardiac arrests occurred in a total of 641 schools: 39
cardiac arrests in 20 colleges, 19 cardiac arrests in 151 high schools, and 40 cardiac arrests in 519 middle schools, elementary schools, and preschools. Annual school-based incidence rates were similar for elementary, middle, and high schools but lower than rates at colleges (Table 1).

Among the cardiac arrests that occurred at schools, the affiliation between the patient and the school could not be determined for 7 of the cardiac arrests; all 7 of these cardiac arrests, however, involved persons older than 40 years. Of the 90 cases whose affiliation was known, 12 cardiac arrests occurred in students (8 students were 18 years of age or younger), 33 in faculty and staff, and 45 in adults not affiliated with the school. When stratified by student status, overall student incidence was 0.18 per 100 000 student school years, with similar estimates among elementary (0.18 per 100 000 person-school-years), middle school (0.19 per 100 000 person-school-years), high school (0.15 per 100 000 person-school-years), and college students (0.20 per 100 000 person-school-years). The incidence among faculty and staff was 25-fold greater and accounted for roughly 3-fold the number of cardiac arrests compared with students (Table 2). No school-based incidence estimate is possible for unaffiliated persons, although these accounted for 46% of all cardiac arrests.

**Characteristics of Cardiac Arrests at School**

Characteristics of the cardiac arrests that occurred in schools and those that occurred in all other public locations are shown in Table 3. Although the majority of cardiac arrests occurred in individuals older than 34 years of age, regardless of school or other public location, schools did have a greater proportion in the pediatric age group. Of the 8 students aged 3 to 18 years who experienced a cardiac arrest, 4 had a prior history of clinical cardiopulmonary disease or severe developmental disability. Similar to other public locations, most of the cardiac arrests in schools occurred in males (74%). Nearly all school cardiac arrests were attributed to cardiac causes, and approximately three fourths of the school cardiac arrests were witnessed (79%), received bystander CPR (74%), and presented with an initial cardiac rhythm of ventricular fibrillation or pulseless ventricular tachycardia (78%), which are greater proportions than observed in other public location cardiac arrests. Among school-based cardiac arrests due to cardiac causes, 56% were due to coronary artery disease alone, 25% to other structural causes, and 8% to a mix of coronary artery disease and other structural causes.

### Table 1. Incidence of Cardiac Arrest per School

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>No. of Cardiac Arrests (1990–2005)</th>
<th>No. of Schools</th>
<th>Incidence per School per Year (95% Confidence Interval)</th>
<th>No. of Schools to Generate 1 Cardiac Arrest per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>97</td>
<td>641</td>
<td>0.009 (0.008–0.012)</td>
<td>111</td>
</tr>
<tr>
<td>Preschool to 12th grade</td>
<td>58</td>
<td>621</td>
<td>0.006 (0.005–0.008)</td>
<td>167</td>
</tr>
<tr>
<td>Preschool to middle school</td>
<td>40*</td>
<td>519†</td>
<td>0.005 (0.004–0.007)</td>
<td>200</td>
</tr>
<tr>
<td>High school</td>
<td>19*</td>
<td>151†</td>
<td>0.008 (0.005–0.012)</td>
<td>125</td>
</tr>
<tr>
<td>College</td>
<td>39</td>
<td>20</td>
<td>0.122 (0.090–0.162)</td>
<td>8</td>
</tr>
<tr>
<td>Major university</td>
<td>27</td>
<td>1</td>
<td>1.69 (1.053–2.327)</td>
<td>0.6</td>
</tr>
<tr>
<td>Other colleges</td>
<td>12</td>
<td>19</td>
<td>0.040 (0.023–0.068)</td>
<td>25</td>
</tr>
</tbody>
</table>

*One cardiac arrest occurred at a school that served both primary and secondary grade levels and consequently was counted once in each category.
†A total of 49 schools served both primary and secondary grade levels and consequently were counted once in each category.

### Table 2. School-Affiliated Incidence Stratified According to Grade Level

<table>
<thead>
<tr>
<th>Students</th>
<th>Cardiac Arrest Count (1990–2005)</th>
<th>No. of Students</th>
<th>Incidence per 100 000/y (95% Confidence Interval)</th>
<th>Faculty and Staff</th>
<th>Cardiac Arrest Count (1990–2005)</th>
<th>No. of Faculty/Staff</th>
<th>Incidence per 100 000/y (95% Confidence Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>12</td>
<td>411 282</td>
<td>0.18 (0.10–0.32)</td>
<td>33</td>
<td>45 680</td>
<td>4.51 (3.22–6.34)</td>
<td></td>
</tr>
<tr>
<td>Preschool to 12th grade</td>
<td>8</td>
<td>284 220</td>
<td>0.17 (0.09–0.35)</td>
<td>18</td>
<td>25 979</td>
<td>4.33 (2.74–6.85)</td>
<td></td>
</tr>
<tr>
<td>Preschool to 5th grade</td>
<td>4*</td>
<td>137 725</td>
<td>0.18 (0.07–0.47)</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>6th to 8th grade</td>
<td>2*</td>
<td>64 708</td>
<td>0.19 (0.05–0.70)</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>9th to 12th grade</td>
<td>2*</td>
<td>81 787</td>
<td>0.15 (0.04–0.56)</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>College</td>
<td>4</td>
<td>127 062</td>
<td>0.20 (0.08–0.51)</td>
<td>15</td>
<td>19 701</td>
<td>4.75 (2.88–7.85)</td>
<td></td>
</tr>
</tbody>
</table>

*In some circumstances, it was not clear what grade the student was in. In these situations, the student was placed in a category based on age. Students 3 to 11 years of age were counted in the Preschool to 5th-grade category. Students 12 to 14 years of age were counted in the 6th- to 8th-grade category. Students 15 to 18 years of age were counted in the 9th- to 12th-grade category.
disease and other structural causes, whereas 11% were of indeterminate cardiac cause. When stratified by age, coronary artery disease was a contributing cause in only 15% of cardiac arrests among persons aged ≤34 years and 72% among persons aged >34 years. Seven of the school-based cardiac arrests received lay-rescuer defibrillation. Survival to hospital discharge among cardiac arrests was 39% in school settings (46% for initial rhythm of ventricular fibrillation) compared with 27% in other public locations.

As reflected by a number of measures of timing, location, and circumstances, cardiac arrests were not concentrated at any particular time or any particular part of the school campus, nor were they associated with any single activity. Approximately half of the cardiac arrests (57%) took place in the afternoon between 12 PM and 6 PM. Another 24% occurred between 6 AM and noon, and the remaining 20% occurred between 6 PM and midnight. Approximately 29% took place indoors, 25% outdoors, 8% in a sports stadium, and 28% in an athletic facility, with 10% unknown. The patient had participated in physical exertion before the event in 34% and had no physical exertion in 55%, whereas exertion status was unknown in 11% of patients. Specifically among the student population, 6 of 12 cardiac arrests occurred in the setting of physical exertion. Twenty of the 52 cardiac arrest patients who were the general public or people of unknown affiliation were using an on-campus facility such as the library, basketball court, or track. Another third of these individuals were attending a school event or meeting being held on campus. Four patients were visiting friends or family at the school, and 3 were passing through the school grounds. Eight individuals were on campus for unknown reasons. Over the last 7 years of the study (1999–2005), 118 schools have implemented PAD programs, with the total count steadily increasing (Figure 2). During these final 7 years of observation, a PAD was used in 7 of 66 school-based cardiac arrests.

### Table 3. Comparison of Cardiac Arrests on School Campus With Those in All Other Public Locations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cardiac Arrest on School Campus (n=97), % (n)</th>
<th>All Other Public Locations (n=3676), % (n)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>0–18 y</td>
<td>8 (8)</td>
<td>2 (62)</td>
<td>...</td>
</tr>
<tr>
<td>19–34 y</td>
<td>7 (7)</td>
<td>7 (259)</td>
<td>...</td>
</tr>
<tr>
<td>35–59 y</td>
<td>41 (40)</td>
<td>41 (1526)</td>
<td>...</td>
</tr>
<tr>
<td>≥60 y</td>
<td>43 (42)</td>
<td>49 (1811)</td>
<td>...</td>
</tr>
<tr>
<td>Unknown</td>
<td>0 (0)</td>
<td>1 (48)</td>
<td>...</td>
</tr>
<tr>
<td>Male sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiac origin of arrest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Witnessed cardiac arrest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bystander CPR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial rhythm VF/VT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Admitted to the hospital</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survival to hospital discharge</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

VF/VT indicates ventricular fibrillation/ventricular tachycardia.
*Percentages do not always total 100% because of rounding.

### Discussion

In this population-based, retrospective cohort study, school-based cardiac arrests accounted for 0.4% of all treated out-of-hospital cardiac arrests and 2.6% of public location cardiac arrests. School-based cardiac arrest occurred on average in ∼1 of 111 schools annually, with a greater incidence among colleges (1 cardiac arrest per 8 colleges) than among high schools (1 per 125 high schools) or lower-level schools (1 cardiac arrest per 200 preschools through middle schools). Only ∼10% of school-based cardiac arrests occurred among students, half of whom (6/12) had previously identified cardiopulmonary disease or severe developmental disability. Among the remaining 90% of cardiac arrests, approximately one third were school employees. Cardiac arrests occurred across a range of times, circumstances, and within-school locations. By 2005, 18% of all schools in this community had implemented a PAD program.

Schools have been identified as a relevant location to consider emergency preparedness planning, specifically cardiac arrest care. In the present study, which occurred in a large and diverse metropolitan setting, school-based cardiac arrests accounted for a small fraction of public location.
cardiac arrests. Nonetheless, the links in the chain of survival can be lifesaving. Ideally, school-based sites, persons, or circumstances could be identified that would optimally direct school-based emergency activation, CPR, and AED programs in a manner that balances resources with the potential to save lives from cardiac arrest. Site-based incidence at high schools was higher than at primary schools and increased substantially from high schools to colleges. However, this increase was driven in large part by the major university campus in the community, which experienced almost 2 cardiac arrests on campus each year. In contrast, the incidence rate at other, more modest-sized colleges was substantially less and was more comparable to that of the high school site.

Although the incidence of cardiac arrest increases with age, little is known about pediatric versus adult risk in the school setting and how this influences the composition of school-based cardiac arrests. Prior studies have focused on incidence among high school and college athletes and have resulted in estimates of 0.5 per 100,000 student-years. In the present study, risk was estimated among all students. The lower incidence observed in the present study (0.18 per 100,000 student-years) might be explained in part by the association between physical exertion and elevated cardiac arrest risk. Importantly, however, approximately half of student cardiac arrests were not associated with physical exertion or sports participation, and student risk was relatively constant across the different school levels (elementary school, middle school, high school, and college). Interestingly, even though students (elementary, middle school, and high school) spend 15% of their time in school, school-based cardiac arrests accounted for <5% of cardiac arrests in this age group. However, as noted above, we identified only 12 cardiac arrests among students over a 16-year period, and little can be concluded about the diurnal variation in incidence rates.

Incidence among (adult) school staff was 25-fold greater than that among students. Given the additional contribution of other adults not employed by the school, ∼90% of cardiac arrests in schools occurred among adults. The finding supports the assertion that school-based CPR and AED programs will benefit faculty and staff members, as well as visitors to the school who, because of their age, are at greater risk of cardiac arrest than the students. We caution, however, that schools can by no means be considered as sites for high occurrence rates of cardiac arrest.

Finally, no time periods during the day, locations within the school, or circumstances could be identified that might be used to definitively direct or allocate CPR or AED resources. Although some cardiac arrests occurred during athletic events or school performances, cardiac arrests also occurred in the classroom, school hallways, and parking lots.

The study has limitations. Incidence estimates did not account for part-time students, faculty, and staff, and thus, the student- and staff-specific risk results may modestly overestimate incidence. The study included only cardiac arrest patients who received prehospital emergency medical treatment by EMS and so would have excluded patients who did not receive a 9-1-1 response. Any untreated cases would increase the true incidence, although we believe such a circumstance is quite unlikely. Moreover, any untreated cases would presumably be unlikely to benefit from improvements in the links in the chain of survival. Although the present study includes a large population who reside in large, mid-sized, and small communities that are served by a variety of schools, the findings may not be generalizable to other communities or school settings, particularly when contrasting the lay-rescuer AED experience in states in which AEDs are legally mandated. The present investigation was not a cost-effectiveness analysis. A previous study of cardiac arrest in high schools that used derived information to estimate incidence indicated that an AED program may be cost-effective if 5 patients require its services over 5 years in a school district of 26,000 students. The present study indicates a low school-specific incidence that suggests programmatic blanket coverage of all schools would not meet traditional levels of cost-effectiveness.

So, what are the implications of the study findings given current guidelines on school-based preparedness for cardiac arrest? Certainly, school-based training in emergency activation and CPR is worthwhile, because these skills provide potential benefit throughout the community and not just at school.

How should school-based AED programs be considered? Importantly, a large majority of school cardiac arrests are witnessed and present with ventricular fibrillation, such that early defibrillation is relevant. Current guidelines recommend consideration of a lay-rescuer AED program if (1) a cardiac arrest is likely to occur at least once every 5 years, or (2) students or staff exist who are at especially elevated risk of cardiac arrest, or (3) a low likelihood that EMS can provide definitive care (shock) within 5 minutes of collapse is coupled with a high likelihood that the lay-rescuer program could provide a shock within 5 minutes. The results of the present study suggest that rarely will the school-specific incidence estimate meet or exceed the guideline of 0.2 cardiac arrests per year. Among student cardiac arrests, 4 of 8 pediatric cardiac arrests had prior clinical cardiopulmonary disease or severe developmental disabilities, so that directing AED resources and training on the basis of individual clinical history may be appropriate. The third consideration requires an understanding of the probable EMS response and the challenges to a school-based lay-rescuer AED program. For example, although the site-based incidence at the major college campus was quite high, the area of response is substantial and would clearly require multiple public access AEDs and responders. Other meaningful considerations exist that hinge on personal, emotional, financial, and legal concerns and influence the decision to implement and maintain an AED program. Undoubtedly a variety of these considerations influenced decisions to implement AED programs in the schools in the present investigation, in which the prevalence of such programs has steadily increased to roughly 18%, and 7 cardiac arrests (of 66 school cardiac arrests since 1996) have been treated by school-based lay-rescuer use of an AED.

The present study characterizes cardiac arrest in the school setting and provides a framework in which to consider preparation efforts and outcome expectations. Future efforts
should continue to assess the health and cost consequences of specific programs and innovations implemented in the school setting.

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Disclosures
None.

References

CLINICAL PERSPECTIVE
Schools have been identified as a relevant location to consider emergency preparedness planning, particularly for cardiac arrest care. More specifically, schools have been identified as desirable locations for automated external defibrillator placement. However, population-based data on incidence, circumstances, patient characteristics, and outcome of cardiac arrest in the school setting are lacking. The present study helps address these issues by reporting a 16-year experience of cardiac arrest at schools from a large metropolitan community. During the study period, 97 cardiac arrests occurred in schools, accounting for 0.4% of all treated out-of-hospital cardiac arrests and 2.6% of public location cardiac arrests. Approximately 90% of these cardiac arrests occurred among adults. School-based cardiac arrest occurred on average in 1 of 111 schools annually, with a greater annual incidence among colleges (1 cardiac arrest per 8 colleges per year) than among high schools (1 per 125 high schools per year) or lower-level schools (1 cardiac arrest per 200 lower-level schools per year). These data suggest that cardiac arrest is a rare occurrence in school. Those most likely to benefit from a school-based automated external defibrillator program would be faculty, staff, and adult visitors to the school.
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