Epidemiology and clinical aspects of sudden cardiac death in the young
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Incidence, causes, and outcome of out-of-hospital cardiac arrest in children: a comprehensive, prospective, population-based study in the Netherlands


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ABSTRACT

Objective
This study sought to determine comprehensively the incidence of pediatric out-of-hospital cardiac arrest (OHCA) and its contribution to total pediatric mortality, the causes of pediatric OHCA, and the outcome of resuscitation of pediatric OHCA patients.

Background
There is a paucity of complete studies on incidence, causes, and outcome of pediatric OHCA.

Methods
In this prospective, population-based study, OHCA victims younger than age 21 years in one province of the Netherlands were registered through both emergency medical services and coroners over a period of 4.3 years. Death certificate data on total pediatric mortality, survival status, and neurologic outcome at hospital discharge were also obtained.

Results
With a total mortality of 923 during the study period and 233 victims of OHCA (including 221 who died and 12 who survived), OHCA caused 24% (221 of 923) of total pediatric mortality. Natural causes of OHCA amounted to 115 cases (49%), with cardiac causes being most prevalent (N=90; 39%). The incidence of pediatric OHCA was 9.0 per 100,000 pediatric person-years (95% confidence interval, 7.8 to 10.3), whereas the incidence of pediatric OHCA from cardiac causes was 3.2 (95% confidence interval, 2.5 to 3.9). Of 51 resuscitated patients, 12 (24%) survived; among survivors, 10 (83%) had a neurologically-intact outcome.

Conclusions
OHCA accounts for a significant proportion of pediatric mortality, and cardiac causes are the most prevalent cause of OHCA. The vast majority of OHCA survivors have a neurologically-intact outcome.
INTRODUCTION
There is a paucity of complete studies on incidence and causes of pediatric out-of-hospital cardiac arrest (OHCA), and outcome of cardiopulmonary resuscitation (CPR) of pediatric OHCA victims. Reported pediatric OHCA incidences range widely (from 6.0 to 19.7 per 100 000 pediatric person-years),1-5 as do reported survival rates (from 0 to 19%).1-8 The only two studies on neurological outcome of pediatric OHCA reported a poor neurological outcome in less than half of those discharged from the hospital alive,1,6 and some researchers have even questioned whether CPR in children should be conducted at all, because neurological outcome and cost-effectiveness may be poor.5,9 Clearly, many questions have not been fully addressed. First, the large studies that aimed at identification of the incidence of pediatric OHCA only included OHCA cases in which emergency medical services (EMS) were involved,1,2 while excluding cases where EMS were not involved (coroners’ cases), thereby underestimating the incidence of OHCA and confounding efforts at determining the proportion of OHCA in total pediatric mortality. Second, few studies reported the contribution of the single (groups of) causes of OHCA, and these studies only included OHCA cases where EMS were involved.1-4,6 Consequently, it is unclear which causes are the most prevalent in pediatric OHCA, although this information may have important implications in prevention programs.

We conducted a comprehensive, prospective, population-based study in the Netherlands using EMS and non-EMS sources to identify cases of pediatric OHCA in order to determine: 1) the incidence of pediatric OHCA and its contribution to total pediatric mortality; 2) the causes of pediatric OHCA; 3) the outcome (overall and neurologic outcome) of CPR of pediatric OHCA victims.

METHODS
Setting
The investigation was a prospective population-based study of persons younger than 21 years who had OHCA between October 1, 2005 and February 1, 2010, in the North-Holland province of the Netherlands. This study region covers 2404 km² (urban and rural communities) and has a population of 2.4 million people, including 588 389 persons younger than 21 years (study population), of whom 28 069 were younger than one year (infants), 313 873 were 1 to 12 years of age (children), and 246 447 were 12 to 20 years of age (adolescents). We included all OHCA patients with whom EMS were involved (EMS cases), and those with whom coroners were involved (coroners’ cases). The Medical Ethics Review Board of the Academic Medical Center, Amsterdam, approved the study and gave a waiver for the requirement of (written) informed consent.

EMS cases
The Amsterdam Resuscitation Studies (ARREST) were set up to establish the genetic and environmental determinants of OHCA in the general population,10 and the determinants of outcome of OHCA.11 Data from all OHCA cases with EMS involvement in one contiguous representative region of the Netherlands (the study region) are collected and stored in the ARREST database. In a medical emergency, people dial the national emergency number. When the EMS dispatcher suspects OHCA, he or she dispatches two ambulances,11 and a first responder (firefighters, policemen, general practitioner) equipped with an automated external
defibrillator (AED). Ambulance personnel are equipped with a manual defibrillator and qualified to perform advanced life support. After each CPR attempt, EMS paramedics routinely send the continuous ECG and impedance recordings from their manual defibrillators to the study center by modem. ARREST study personnel, who visit the AED site shortly after OHCA, collect the AED electrocardiogram recording. The electrocardiograms are stored and analyzed with dedicated software (Code Stat Reviewer 7.0, Physio Control, Redmond, WA, USA). Rhythms are categorized as shockable (ventricular tachycardia [VT] and ventricular fibrillation [VF]) or non-shockable (asystole or electromechanical dissociation). Data items concerning the CPR procedure are collected according to the Utstein recommendations. All four EMS services in the study region participate in ARREST. EMS cases were collected from the ARREST database.

Coroners’ cases
When someone dies in The Netherlands, physicians are legally obliged to inspect the corpse and complete a death certificate. If the physician is unsure whether the patient died of natural causes, a coroner (physician) is contacted to inspect the corpse, determine the cause of death and judge (in consultation with the public prosecutor) whether judicial autopsy is required. All reports on corpse inspections performed by the coroners are digitally stored at the Departments of Forensic Medicine of the Public Health Services. This database contains personal details and date and cause of death. In case of a natural cause of death, details on the circumstances and temporal course of the event are also available. Eighty percent of all coroners in the study region participated in this study. Coroners’ cases were collected from this database.

Identification of OHCA cases
OHCA was defined as an out-of-hospital unexpected abrupt loss of consciousness with loss of vital signs (pulse, blood pressure, respiration) and resulting in death or, if successfully resuscitated, survival to hospital discharge, or out-of-hospital unexpected death of someone seen in a stable medical condition fewer than 24 hours previously. Perinatal sudden death and children known with a terminal disease were excluded. During the study period, all patients in the ARREST database younger than 21 years of age were retrieved and reviewed manually and independently by two researchers (A.B. and J.B.). A patient was included if he or she: 1) was resuscitated, that is, underwent CPR by EMS personnel, a defibrillation attempt with an AED by a first responder or bystander (such defibrillation attempts were always followed by subsequent treatment by EMS); or 2) was found dead by EMS personnel upon arrival and fulfilled the OHCA definition. In case of discrepancy between both researchers, a specialized physician (H.L.T) arbitrated. Two researchers (C.v.d.W. and Anneke Hendrix) reviewed all records in the coroners’ database of persons younger than 21 years to assess whether the definition of OHCA was met. In case of discrepancy, a specialized physician (A.A.M.W.) arbitrated. All cases were checked for duplicates within the ARREST and coroners’ databases.

Assessment of cardiac and noncardiac cause of OHCA
The included OHCA cases were classified based on the available medical information (by A.B., J.B., and C.v.d.W) as cardiac or noncardiac. OHCA was noncardiac when EMS rescuers, hospital physicians or coroners identified a natural, noncardiac cause (e.g., asphyxia, intracranial
hemorrhage) or nonnatural cause (e.g., traffic accident, drowning, suicide, violence); all other cases had a (presumed) cardiac cause and were considered cardiac OHCA.\textsuperscript{14,16}

**Death certificate data**

In addition to data from the ARREST database and the coroners’ database, we also retrieved death certificate data from Statistics Netherlands, a Dutch governmental institution that collects age- and gender-specific statistics of all deaths in The Netherlands (national mandatory reporting system).\textsuperscript{17} This allowed us to ascertain total pediatric mortality and to estimate the maximum number of potential OHCA cases. This served two purposes: 1) to establish the contribution of OHCA to total mortality in pediatric age groups; 2) to gain insight into the completeness of our data collection. Statistics Netherlands records anonymous information on the site and causes of death as indicated on the death certificates; in case of nonnatural causes of death, information from the police and the public prosecutor is also used. The causes of death are classified according to the International Classification of Diseases Death 10\textsuperscript{th} revision (ICD-10). Deceased children in the ICD-10 diagnostic categories pregnancy, childbirth and the puerperium (O00-O99), conditions originating in the perinatal period (P00-P96) and neoplasms (C00-D48) were excluded. Potential cardiac OHCA cases were all deaths in the ICD-10 categories that contained cardiovascular causes or unknown causes. Potential noncardiac OHCA cases were the remaining deaths in the ICD-10 categories that can occur suddenly (e.g., trauma, poisoning, drowning, suicide, and respiratory causes). We calculated the total number of potential cardiac OHCA cases by adding all out-of-hospital deaths in all ICD-10 categories that contained cardiovascular and unknown causes; to this, we added patients from the ARREST database who sustained cardiac OHCA, but eventually died in-hospital, because these patients were not classified as out-of-hospital death by Statistics Netherlands. An analogous addition was used to calculate the total number of potential noncardiac OHCA cases.

**Survival analysis**

With the aim of establishing the outcome of CPR by EMS, we analyzed only OHCA cases that truly could be resuscitated cases by excluding OHCA victims who were found dead by EMS personnel upon arrival, but in whom CPR was still initiated (e.g., for the parents’ comfort). Survival status and neurologic outcome at hospital discharge were obtained by contacting the hospital of admission. We estimated the cerebral performance category of each patient by reviewing the hospital charts: good cerebral performance, 1; moderate cerebral disability, 2; severe cerebral disability, 3; coma or vegetative state, 4; and death, 5.\textsuperscript{18} A cerebral performance category score of 1 or 2 was classified as neurologically-intact outcome.

**Statistical analyses**

Descriptive statistics are reported as mean ± standard deviation, median (25\textsuperscript{th}, 75\textsuperscript{th} percentile), or number (percent) as indicated. Comparisons for continuous variables were made with an analysis of variance. Likelihood-ratio chi-square analyses were used when discrete variables were compared across groups. The incidence rates were calculated per 100 000 pediatric person-years. The age category and sex-specific rates were calculated; these rates were adjusted by age and sex to the European Union population. All statistical tests were two tailed, and a P <0.05 was considered statistically significant. All statistics were performed in SPSS (version 16.0 for Mac, Chicago, IL, USA).
## RESULTS

### Patient characteristics and incidence of OHCA

During the study period of four years and four months, 443 possible pediatric OHCA cases were identified. Of these, 210 did not meet the inclusion criteria because there was no loss of vital signs when EMS arrived (N=142), the event occurred in the perinatal period (N=56), or the event occurred in a patient with a terminal illness (N=12). Thus, 233 persons fulfilled the definition of OHCA, including 221 who eventually died and 12 who survived. Of these 233 cases, 83 were EMS-only cases, 100 coroners-only cases and 50 were registered by both sources. With a total mortality of 923, the 221 OHCA victims who died amounted to 24% of total mortality in this age group. Fifty-two percent of all OHCA cases were adolescents, and 70% were males (Table 1). Most OHCA cases occurred at the place of residence (N=111, 51%) or on the streets (N=81, 38%). Ninety persons had cardiac OHCA. Among adolescents who had cardiac OHCA, 32% were engaged in exercise or sports at the time of OHCA. The adjusted incidence per 100 000 pediatric person-years of OHCA was 9.0 (95% CI, 7.8 to 10.3), while that of cardiac OHCA was 3.2 (95% CI, 2.5 to 3.9) (Table 2). The incidence of cardiac OHCA was highest amongst infants and similar among children and adolescents. According to the death certificate data, the total number of potential pediatric cardiac OHCA cases in the study period and study region was 103; of these, we registered 90 (87%) cases. The total number of potential pediatric noncardiac OHCA cases was 144, of which we registered 143 (99%).

Figure 1 shows the single causes of pediatric OHCA. Half of the 233 OHCA cases (N=115, 49%) were due to natural causes. OHCA from cardiac causes was the most prevalent cause of OHCA (N=90, 39%). Traffic accidents were the most prevalent cause among nonnatural causes (N=60, 26%).

### Survival and neurologic outcome of resuscitation of OHCA patients

The EMS were involved in 133 (57%) of the 233 pediatric OHCA patients. Of these patients, 73 OHCA cases were the result of cardiac causes, including four that were witnessed by EMS personnel. Table 3 shows the characteristics of resuscitated patients. Infants were most likely to have OHCA at home (97% vs. 61% in children and 41% in adolescents; P<0.001). An AED was more frequently used in adolescents (32% vs. 6% in children and 3% in infants; P=0.02). Adolescents also had the highest percentage of shockable initial rhythm (82% vs. 33% in children and 3% in infants; P<0.001). Although CPR was initiated in 69 OHCA victims, only 51 (14 infants, 17 children, 20 adolescents) truly could be resuscitated. The overall survival to hospital discharge of these 51 patients was 24% (12 of 51). The survival rates were not statistically significantly different between groups (29% [4 of 14] in infants, 12% [2 of 17] in children, 30% [6 of 20] in adolescents; P=0.37). The overall proportion of neurologically intact outcome among OHCA survivors was 83% (75% [3 of 4] in infants, 100% [2 of 2] in children, 83% [5 of 6] in adolescents).

## DISCUSSION

Every year, nine out of 100 000 children in The Netherlands have OHCA. Cardiac causes account for three, and noncardiac causes for six OHCA cases per 100 000 pediatric person-years. Cardiac causes are the most prevalent single cause of pediatric OHCA (39%), followed by traffic accidents (26%). The overall survival of resuscitated pediatric OHCA patients is 24%; the vast majority of survivors (83%) are discharged with neurologically intact function.
Table 1. Characteristics of out-of-hospital cardiac arrest from cardiac and non-cardiac causes.

<table>
<thead>
<tr>
<th>Variable</th>
<th>All causes (N=233)</th>
<th>Cardiac causes (N=90)</th>
<th>Non-cardiac causes (N=143)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>10.8 ± 7.7</td>
<td>7.4 ± 7.6</td>
<td>13.0 ± 7.0</td>
</tr>
<tr>
<td>&lt;1 years</td>
<td>45 (19)</td>
<td>35 (39)</td>
<td>10 (7)</td>
</tr>
<tr>
<td>1-12 years</td>
<td>66 (28)</td>
<td>25 (28)</td>
<td>41 (29)</td>
</tr>
<tr>
<td>12-20 years</td>
<td>122 (52)</td>
<td>30 (33)</td>
<td>92 (64)</td>
</tr>
<tr>
<td>Male</td>
<td>162 (70)</td>
<td>61 (68)</td>
<td>100 (70)</td>
</tr>
<tr>
<td>Ethnicity known</td>
<td>218 (94)</td>
<td>87 (97)</td>
<td>131 (92)</td>
</tr>
<tr>
<td>Caucasian</td>
<td>170 (78)</td>
<td>68 (78)</td>
<td>102 (78)</td>
</tr>
<tr>
<td>Non-Caucasian</td>
<td>48 (22)</td>
<td>19 (22)</td>
<td>29 (22)</td>
</tr>
<tr>
<td>Arabic</td>
<td>17 (8)</td>
<td>3 (3)</td>
<td>14 (11)</td>
</tr>
<tr>
<td>Black</td>
<td>10 (5)</td>
<td>7 (8)</td>
<td>3 (2)</td>
</tr>
<tr>
<td>Turkish</td>
<td>11 (5)</td>
<td>5 (6)</td>
<td>6 (5)</td>
</tr>
<tr>
<td>Other</td>
<td>10 (5)</td>
<td>4 (5)</td>
<td>6 (5)</td>
</tr>
<tr>
<td>Site of OHCA known</td>
<td>216 (93)</td>
<td>89 (99)</td>
<td>127 (89)</td>
</tr>
<tr>
<td>Place of residence</td>
<td>111 (51)</td>
<td>67 (75)</td>
<td>44 (35)</td>
</tr>
<tr>
<td>On street</td>
<td>81 (38)</td>
<td>9 (10)</td>
<td>72 (57)</td>
</tr>
<tr>
<td>Public place</td>
<td>9 (4)</td>
<td>4 (4)</td>
<td>5 (4)</td>
</tr>
<tr>
<td>Sports or recreational facility</td>
<td>12 (6)</td>
<td>7 (8)</td>
<td>5 (4)</td>
</tr>
<tr>
<td>Other</td>
<td>3 (1)</td>
<td>2 (2)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Activity at the time of OHCA*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infants, activity known,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At rest</td>
<td>29 (100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>During exercise/sport</td>
<td>0 (0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children, activity known</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At rest</td>
<td>17 (65)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>During exercise/sport</td>
<td>16 (94)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adolescents, activity known</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At rest</td>
<td>22 (76)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>During exercise/sport</td>
<td>15 (68)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Values are represented as mean ± standard deviation or number (percentage).
OHCA indicates out-of-hospital cardiac arrest.
*Only analyzed for OHCA from cardiac cause.

Comparison with other studies
Because different studies use various definitions for OHCA and include various age cut-offs, comparison of incidences between studies is difficult. We provide an overall incidence, an incidence for OHCA from cardiac causes, and an incidence for OHCA from noncardiac causes, both unadjusted and adjusted for age and gender of the European Union population. While our
Table 2. Incidences of out-of-hospital cardiac arrest from cardiac and non-cardiac causes.

|                      | All causes  
|----------------------|------------|
|                      | (N=233)    | Cardiac causes  
|                      | (N=90)     | Non-cardiac causes  
|                      | (N=143)    |
| Overall              | 9.0 (7.8-10.3) | 3.2 (2.5-3.9) | 5.8 (4.9-6.8) |
| Age <1 years         | 33.8 (23.1-44.5) | 25.8 (16.4-35.2) | 8.0 (2.8-13.2) |
| Age 1-12 years       | 4.8 (3.6-6.0) | 1.6 (0.9-2.3) | 3.2 (2.2-4.2) |
| Age 12-20 years      | 11.7 (9.5-13.8) | 2.7 (1.7-3.7) | 9.0 (7.1-10.8) |

Data are expressed as number per 100 000 pediatric person-years (95% confidence interval). All incidences are adjusted by age/sex to the European Union population.

Table 3. Operational characteristics of resuscitated victims of out-of-hospital cardiac arrest from cardiac causes according to age group.

| Variable                     | All  
|------------------------------|------|
|                              | (N=69) | Age <1 years  
|                              | (N=29) | Age 1-12 years  
|                              | (N=18) | Age 12-20 years  
|                              | (N=22) | P   |
| Witnessed collapse           | 41 (59) | 11 (38) | 14 (78) | 16 (73) | 0.03 |
| Bystander CPR                | 52 (75) | 19 (66) | 14 (78) | 19 (86) | 0.53 |
| Collapse at home             | 48 (70) | 28 (97) | 11 (61) | 9 (41) | <0.001 |
| AED connected                | 9 (13) | 1 (3) | 1 (6) | 7 (32) | 0.02 |
| Time between emergency call  | 12.1 (8.8-14.8) | 12.2 (9.8-13.9) | 11.1 (8.4-15.3) | 12.0 (9.0-15.6) | 0.99 |
| and EMS arrival, min         |       |       |       |       |     |
| Shockable initial rhythm     | 25 (36) | 1 (3) | 6 (33) | 18 (82) | <0.001 |

Values are represented as number (percentage) or median (interquartile range). AED indicates automated external defibrillator; CPR, cardiopulmonary resuscitation; EMS, emergency medical services.

OHCA definition is comparable to the large population-based study by Kitamura et al., we found somewhat higher incidences of total pediatric OHCA (9.0 vs. 8.0 per 100 000 pediatric person-years) and cardiac OHCA (3.2 vs. 2.3 per 100 000 pediatric person-years). It is conceivable that these differences are because we also included coroners’ cases and studied a somewhat wider age range (subjects aged up to 20 years). We also found a higher OHCA incidence than two other recent population-based studies from the USA and Canada. These differences may be explained by disparities in definitions, because we included all causes of OHCA, whereas those studies excluded some nonnatural causes. Moreover, differences in socioeconomic and ethnic composition may be relevant. For example, the incidence of OHCA among adults in different states of the USA and Canadian sites ranges from 76 to 159 per 100 000 persons, compared to an incidence of 60 per 100 000 persons in The Netherlands. Finally, the proportion of OHCA among infants varies among populations and affects the overall incidence of pediatric OHCA. In our study, infants contribute 39% of all OHCA cases, comparable to other studies. Chugh et al. reported a higher proportion of infants (76%). The reason for this discrepancy is unknown, but sudden infant death syndrome is up to 5.7 times more prevalent in the USA than in The Netherlands. Biologic differences and behavioral factors are thought to cause this disparity.
We report an overall percentage of 36% of VT and VF in our cases, and an even higher percentage in adolescents (82%). Other prospective studies reported a lower percentage of VT and VF, ranging from 3% to 9%, whereas one retrospective study reported an incidence of 19%. The presence of VT and VF as initial rhythm is correlated with a witnessed collapse, bystander CPR, use of an AED, and time to arrival of the ambulance. In comparison to other studies, patients in our study were more likely to have a witnessed collapse, receive bystander CPR, and be treated with an AED. Because VT/VF as initial rhythm has been associated with a better survival, one would expect a low survival among infants (VT and VF: 3%) and a high survival among adolescents (VT and VF: 82%). However, the survival to discharge did not support this expectation, being similar in infants and adolescents (29% and 30%, respectively). This apparent inconsistency between the low proportion of VT and VF and the relatively high survival rates was also observed in a large, prospective, observational study of in-hospital cardiac arrests, in which the survival rates in children with VT and VF as an initial rhythm were comparable to those found in asystole (29% and 22%, respectively).

In another study of 47 pediatric OHCA victims, 24 presented with bradycardia and 12 of those survived to hospital discharge. Although other studies showed a poor neurologic outcome after CPR, all but two survivors in our study were discharged with neurologically intact function. The outcomes observed in our study were better than those reported in two recent studies by Kitamura et al. and Atkins et al. Again, the higher rates of bystander CPR and bystander witnessed collapse could have contributed to the better outcomes found in our study. Resuscitation attempts in children are rare; of all OHCA patients in the ARREST registry in whom resuscitation was attempted, only 1.3% (51 of 4014) were under the age of 21. We observed a survival rate of 24% (12 of 51) among OHCA patients under the age of 21, which was not different.
from that among adult OHCA patients in the ARREST registry (688 of 3844, 17.9%; J. Berdowski, A. Bardai, M.T. Blom, H.L. Tan, R.W. Koster, unpublished data, October 2010).

Study strengths
A major strength of our study is that it was designed to establish the incidence, determinants and outcome of OHCA in the general population, allowing comprehensive and accurate data collection of all cases from the site of cardiac arrest until discharge from the hospital, including neurologic outcome in OHCA survivors. Our study is the first study that aims at establishing the contribution of OHCA to total pediatric mortality. Estimation of the incidence of OHCA within a particular region can be hampered by the fact that individuals who reside outside of this region may experience OHCA in the study region and vice versa. In a pediatric population, this confounder is probably less important, as children travel less (far) than adults. Only 7% of children in this study resided outside the study region. Other studies on the incidence of OHCA do not comment on this potential confounder.

Study limitations
Because only a national mandatory reporting system for OHCA, not present in The Netherlands, would ensure capture of all OHCA cases, we might have missed some cases. The incidences that we reported for OHCA which are based on EMS and coroners’ databases may thus underestimate the true OHCA incidence, in particular, because not all coroners in the study region contributed to the study. Yet, by analyzing data from a national mandatory reporting system for all mortality in The Netherlands (Statistics Netherlands), we verified that the number of cases that we might have missed was relatively small. We identified 90 cardiac OHCA cases, including 7 cardiac OHCA cases that survived to hospital discharge, while Statistics Netherlands reported 92 potential cardiac OHCA cases (excluding surviving OHCA victims). Similarly, we found 143 noncardiac OHCA cases, while Statistics Netherlands reported 137 potential noncardiac OHCA cases (excluding surviving OHCA victims). These findings indicate that our reported incidences are close to the actual incidences.

Second, the cause of OHCA was considered cardiac when evidence for a noncardiac or nonnatural cause was absent, as recommended, and reported by others. Because this cardiac category is a diagnosis by exclusion, this may lead to an overestimation of the proportion of cases that were considered to be due to cardiac causes. This definition may particularly be problematic in case of OHCA in infants (sudden infant death syndrome). Only 33% of infant OHCA cases were alive when EMS arrived, allowing a diagnostic workup, while autopsy data were absent in virtually all cases (autopsy is not mandatory in The Netherlands). Thus, the cause of OHCA was unknown in most infants, and classified as cardiac, according to our definition. Yet, sudden infant death syndrome is believed to often result from respiratory causes.

CONCLUSIONS
In this prospective, population-based study, we established that OHCA accounts for 24% of total pediatric mortality and that cardiac causes are the most prevalent causes of OHCA. The vast majority of survivors of pediatric OHCA have a neurologically intact outcome.
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