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Epidemiology of Pediatric Out-of-Hospital Cardiac Arrest at School

— An Investigation of a Nationwide Registry in Japan —

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Background: A better understanding of the epidemiology of pediatric out-of-hospital cardiac arrest (OHCA) occurring in school settings is important to establish an evidence-based strategy for prevention and better prognosis.

Methods and Results: The Stop and Prevent cardiac arrest, Injury, and Trauma in Schools (SPIRITS) is a nationwide prospective observational study linking databases from 2 nationally representative registries, the Injury and the Accident Mutual Aid Benefit System of The Japan Sport Council and the All-Japan Utstein Registry of the Fire and Disaster Management Agency. Using these databases, we described the detailed characteristics and outcomes of pediatric OHCA cases that occurred in school settings in Japan between 2009 and 2014. During the 6-year study period, 295 OHCA cases were confirmed. Overall incidence rate was 0.4 per 100,000 students per year. The majority of OHCA cases had a cardiac origin (71%), occurred during exercise (65%), were witnessed by bystanders (70%), and received bystander-initiated cardiopulmonary resuscitation (73%). In approximately one-third of cases the student was defibrillated by public-access automated external defibrillator (38%). The proportion of patients with 1-month survival and a favorable neurological outcome was 34% among all OHCA cases and 43% among OHCA cases of cardiac origin.

Conclusions: In Japan, approximately 50 pediatric cases of OHCA consistently occur yearly in school settings. The majority of students received basic life support from bystanders, and patients with OHCA of cardiac origin had a relatively good prognosis.

Key Words: Children; Out-of-hospital cardiac arrest; Schools; Students

Out-of-hospital cardiac arrest (OHCA) is a leading cause of death among adults in industrialized countries.¹ Although pediatric OHCA represents only a small subset of the overall OHCA incidents,^{2–5} it carries a huge negative societal impact in terms of productive years of life lost from premature death, the healthcare costs for survivors,⁶ and emotional burden for family members. Therefore, a better understanding of the detailed characteristics and outcomes of pediatric OHCA is important for planning and adopting evidence-based approaches for prevention and better prognosis.

Because school-age children spend a large part of their active daytime at school or in other public places,⁵ it is necessary to accumulate scientific data from the school settings. However, the low incidence of OHCA in this age group and the lack of an appropriate reporting system for OHCA cases may have hampered large-scale epidemiological investigations on this topic.^{2,3,7,8} Consequently, most of the existing epidemiological studies were limited by the small number of participants and/or limited target areas,⁹ and the characteristics of pediatric OHCA occurring in school settings have not been sufficiently understood.

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In Japan, the Fire and Disaster Management Agency (FDMA) launched a prospective, nationwide, population-based registry of OHCA in January 2005 (the All-Japan Utstein Registry), and it has been yielding a great amount of scientific knowledge on OHCA.^{4,10} Although the design of the All-Japan Utstein Registry was based on the Utstein-style template, which is internationally adopted,^{11,12} the Utstein reporting system does not include detailed information regarding the conditions of OHCA occurrence in schools, such as location and activity at the time of cardiac arrest. Therefore, combining this registry with other data sources would enable us to acquire missing information that may help prevent pediatric sudden cardiac death.

In the present study, we linked data from the All-Japan Utstein Registry with the Injury and the Accident Mutual Aid Benefit System of The Japan Sport Council (JSC),¹³ with the aim of determining the nationwide incidence, characteristics, and outcome of pediatric OHCA occurring in school settings in Japan.

Methods

Study Design of Stop and Prevent cardiac arrest, Injury, and Trauma in Schools (SPIRITS)

SPIRITS is a nationwide prospective observational study of pediatric cases of OHCA that occur in school settings in Japan. A database linking 2 nationally representative registries, the Injury and the Accident Mutual Aid Benefit System of the JSC and the All-Japan Utstein Registry of the FDMA, was developed for this study.

The Injury and Accident Mutual Aid Benefit System, which is directed by the School Safety Department of the JSC, provides benefits (medical expenses, disability compensation or death compensation) in cases of injury, illness, disease, accident, or death that occur among students and younger children under the supervision of schools or nurseries based on a contract (Injury and Accident Mutual Aid Benefit contract) between the JSC and school operators.¹³ The injuries and accidents under the supervision of schools refer to those that occur during class hours based on the school curriculum (including childcare hours at nurseries), as well as during extracurricular instruction hours, during breaks (including before class and after school), or on the way to and from school (or nurseries). The eligible school settings include nurseries (age 0–6 years), kindergartens (age 3–6 years), elementary schools (age 6–12 years), junior high schools (age 12–15 years), high schools (age ≥15 years), and technical colleges (age ≥15 years). The Injury and Accident Mutual Aid Benefit System covers most students and younger children attending these schools (85.9% nursery school children, 80.7% of kindergarteners, 99.9% of elementary school students, 99.9% of junior-high school students, 98.3% of high school students, and 99.4% of technical college students in 2014; approximately 17 million students and younger children in Japan), and approximately 1.1 million injuries/accident case data were reported annually from 73,000 schools nationwide.¹³

Details of the All-Japan Utstein Registry of the FDMA were previously described.¹⁴ Briefly, this is a population-based OHCA registry based on the international Utstein style^{11,12} and it covers a population of approximately 127 million people in Japan. Cardiac arrest is defined as the cessation of cardiac mechanical activity and confirmed by the absence of signs of circulation. Generally, prehospital

termination of resuscitation by emergency medical service (EMS) personnel is not allowed because do-not-resuscitate orders (or living wills) are prohibited in Japan; therefore, most OHCA patients treated by EMS personnel are transported to hospitals and recorded in this registry. All survivors of OHCA are followed for up to 1 month after the event by the EMS providers in charge to assess their prognosis. The data forms are filled out by EMS personnel, in consultation with the physician in charge of the patient. The information from the input data forms is transferred and integrated into the registration system via the FDMA database server. The data are then checked via the computer system and are confirmed by the FDMA. If incomplete data forms are found, EMS personnel in charge are asked to complete them.

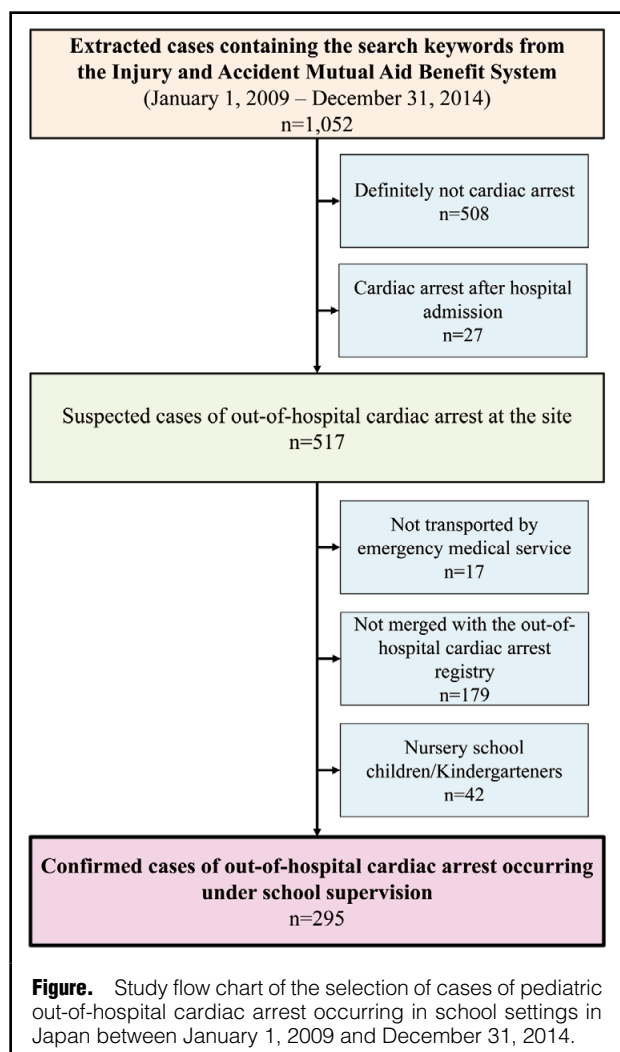
We merged these databases as follows. First, we extracted the data from the Injury and Accident Mutual Aid Benefit System for cases suggestive of cardiac arrest by text retrieval from the database, using search keywords that included the terms related to cardiac arrest. In this procedure, for example, “AED” and “CPR” were included in the search keywords, so cases that were definitely not victims of cardiac arrest were physically extracted (e.g., a case of a subject hitting his/her head on an “AED” cabinet; a subject who lost consciousness while participating in “CPR” training). Therefore, the data from extracted cases were carefully checked by several investigators, and subjects who were definitely not victims of cardiac arrest were excluded, as were those who suffered a cardiac arrest after hospital admission and those not transported to hospital by EMS (i.e., transported to hospital by family member/bystanders, non-EMS transporting vehicle, or air ambulance). The latter group was excluded because the subjects were not registered in the All-Japan Utstein Registry. Finally, the data from the remaining cases were merged with the All-Japan Utstein Registry by matching sex, age, prefecture, and date and time of the incidence.

Etiology of Cardiac Arrest

In the All-Japan Utstein Registry, the etiology of arrest is presumed to be of cardiac origin unless evidence suggested external causes (e.g., trauma, hanging, drowning, drug overdose or asphyxia), respiratory diseases, cerebrovascular diseases, malignant tumors or any other noncardiac cause. Attribution of noncardiac or cardiac cause was made by the physicians in charge in consultation with the EMS personnel, in accordance with the Utstein-style international guidelines for cardiac arrest data reporting.^{11,12} In the Injury and the Accident Mutual Aid Benefit System, the name of the injury/disease is recorded according to the death certificate and/or the medical certificate. In this study, the etiology of cardiac arrest was determined by several investigators, including emergency physicians and pediatricians, using the information from diagnoses in both databases. After careful checking the data, the investigators discussed and determined the etiology of cardiac arrest for each patient.

Study Participants and Data Collection

All pediatric cases of OHCA at elementary school, junior high school, high school, and technical college in Japan, between January 1, 2009 and December 31, 2014, were enrolled in this study. We obtained the following data items from the SPIRITS database: date of occurrence, educational level, sex, activity at the time of cardiac arrest,



location of cardiac arrest, cardiac arrest witness, initiation of bystander-initiated cardiopulmonary resuscitation (CPR), public-access automated external defibrillator (AED) defibrillation, etiology of cardiac arrest, and outcome after OHCA.

Study Endpoints

Endpoints of this study included return of spontaneous circulation to prehospital level, 1-month survival, and 1-month survival with favorable neurological outcome after OHCA. Neurological status was assessed by the physician in charge, using the Glasgow-Pittsburgh cerebral performance category (CPC) scale: category 1, good performance; category 2, moderate disability; category 3, severe cerebral disability; category 4, coma/vegetative state; and category 5, death/brain death. The 1-month survival with favorable neurological outcome was then defined as CPC 1 or 2.^{11,12}

Statistical Analysis

The annual incidence rate (per 100,000 students per year) of OHCA was calculated separately for the 3 educational levels (i.e., elementary school, junior high school, and high school/technical college), and a Poisson regression model was applied for trend analysis. The patients' characteristics,

etiologies, and outcomes after OHCA were also evaluated by school type, and the χ^2 test was used to analyze statistical differences. All tests were 2-tailed and $P < 0.05$ was considered statistically significant. Statistical analyses were conducted using SPSS statistical package ver. 24.0J (IBM Corp., Armonk, NY, USA).

Ethics

The study protocol was approved by the Ethics Committee of Osaka University. The requirement for individual informed consent was waived.

Results

The **Figure** shows how patients with pediatric OHCA in a school setting in Japan were selected during the 6-year study period. Based on the Injury and Accident Mutual Aid Benefit System (≈ 6.6 million injuries/accident case data), 1,052 cases were extracted by text retrieval. As determined by the investigators, 508 subjects who were definitely not victims of cardiac arrest and 27 who suffered cardiac arrest after hospital admission were excluded. In addition, 17 subjects who were not transported to hospital by EMS, 179 cases that were not merged with the All-Japan Utstein Registry, and 42 cases of nursery school children/kindergarteners were excluded. Thus, a total of 295 cases were included in our analyses (49 elementary school students, 107 junior-high school students, and 139 high school/technical college students). Because a total of 4,852 OHCA cases in students aged 6–18 years were registered in the All-Japan Utstein Registry during the study period, the proportion of OHCA cases occurring in the school setting was roughly estimated to be 6.1% (295/4,852) of overall OHCA among school-age children in Japan.

OHCA Incidence Rate

Table 1 shows the number and incidence rate of OHCA according to educational level. Overall, approximately 50 cases of OHCA were consistently identified yearly. The overall incidence rate was 0.4 cases per 100,000 students per year. This incidence rate is equivalent to an estimated annual risk for OHCA of 1.0 per 286,000 students per year, or 1.0 per 824 schools per year. Generally, a higher incidence rate was observed in the higher educational levels (0.1 cases per 100,000 among elementary school students and 0.6 cases per 100,000 among high school/technical college students). The incidence rate varied slightly during the study period; however, no statistically significant changes in the trend were found at any educational level.

Patients' Characteristics

Table 2 shows the patients' characteristics of confirmed OHCA cases according to educational level. The majority of all OHCA cases involved male students (71%, 209/295), occurred during exercise activities (65%, 193/295), was witnessed by bystanders (70%, 207/295), and received bystander-initiated CPR (73%, 215/295). Approximately one-third of them were defibrillated by public-access AEDs (38%, 111/295). A large proportion of the OHCA cases that were male students, occurred during exercise activities, and received public-access AED defibrillation increased in the more higher educational levels. **Table 3** shows the etiology of confirmed OHCA cases according to educational level. The majority of all OHCA cases were of cardiac origin (71%, 210/295), and in most cases was idio-

Table 1. Number and Incidence Rate of Out-of-Hospital Cardiac Arrests Occurring Under School Supervision in Japan (2009–2014)

| | Total | Year | | | | | | P for trend |
|--|-------|------|------|------|------|------|------|-------------|
| | | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | |
| Elementary school students | | | | | | | | |
| n | 49 | 5 | 11 | 8 | 10 | 7 | 8 | |
| Incidence rate* | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.839 |
| Junior-high school students | | | | | | | | |
| n | 107 | 14 | 26 | 13 | 12 | 21 | 21 | |
| Incidence rate* | 0.5 | 0.4 | 0.7 | 0.4 | 0.3 | 0.6 | 0.6 | 0.778 |
| High school / technical college students | | | | | | | | |
| n | 139 | 24 | 25 | 34 | 16 | 17 | 23 | |
| Incidence rate* | 0.6 | 0.7 | 0.7 | 0.9 | 0.4 | 0.5 | 0.6 | 0.470 |
| Total | | | | | | | | |
| n | 295 | 43 | 62 | 55 | 38 | 45 | 52 | |
| Incidence rate* | 0.4 | 0.3 | 0.4 | 0.4 | 0.3 | 0.3 | 0.4 | 0.874 |

*Incidence rate per 100,000 students per year.

Table 2. Characteristics of Out-of-Hospital Cardiac Arrests Occurring in School Settings in Japan

| | Total (n=295) | Elementary school students (n=49) | Junior-high school students (n=107) | High school / technical college students (n=139) | P value |
|---|------------------|---|---|--|---------|
| | n (%) | n (%) | n (%) | n (%) | |
| Male | 209 (70.8) | 23 (46.9) | 70 (65.4) | 116 (83.5) | <0.001 |
| Special support school* | 27 (9.2) | 4 (8.2) | 7 (6.5) | 16 (11.5) | 0.394 |
| Activity at the time of arrest | | | | | <0.001 |
| In class (with exercise) | 83 (28.1) | 17 (34.7) | 31 (29.0) | 35 (25.2) | |
| In class (without exercise) | 8 (2.7) | 4 (8.2) | 0 (0.0) | 4 (2.9) | |
| Extracurricular activities (with exercise) | 110 (37.3) | 6 (12.2) | 42 (39.3) | 62 (44.6) | |
| Extracurricular activities (without exercise) | 55 (18.6) | 16 (32.7) | 20 (18.7) | 19 (13.7) | |
| To/from school | 30 (10.2) | 6 (12.2) | 13 (12.1) | 11 (7.9) | |
| Other | 9 (3.1) | 0 (0.0) | 1 (0.9) | 8 (5.8) | |
| Location of arrest | | | | | <0.001 |
| Schoolyard | 131 (44.4) | 15 (30.6) | 48 (44.9) | 68 (48.9) | |
| School room | 32 (10.8) | 11 (22.4) | 8 (7.5) | 13 (9.4) | |
| Gymnasium | 44 (14.9) | 1 (2.0) | 17 (15.9) | 26 (18.7) | |
| Pool | 21 (7.1) | 12 (24.5) | 7 (6.5) | 2 (1.4) | |
| Other places inside school | 15 (5.1) | 4 (8.2) | 5 (4.7) | 6 (4.3) | |
| Street | 20 (6.8) | 2 (4.1) | 8 (7.5) | 10 (7.2) | |
| Dormitory | 14 (4.7) | 2 (4.1) | 5 (4.7) | 7 (5.0) | |
| Other places outside school | 18 (6.1) | 2 (4.1) | 9 (8.4) | 7 (5.0) | |
| Witness of arrest | | | | | 0.076 |
| Bystanders | 207 (70.2) | 30 (61.2) | 70 (65.4) | 107 (77.0) | |
| EMS | 25 (8.5) | 3 (6.1) | 12 (11.2) | 10 (7.2) | |
| Not witnessed | 63 (21.4) | 16 (32.7) | 25 (23.4) | 22 (15.8) | |
| Initiation of bystander CPR | 215 (72.9) | 37 (75.5) | 72 (67.3) | 106 (76.3) | 0.264 |
| Public-access AED defibrillation | 111 (37.6) | 8 (16.3) | 42 (39.3) | 61 (43.9) | 0.003 |

*Schools for disabled children. AED, automated external defibrillator; CPR, cardiopulmonary resuscitation; EMS, emergency medical service.

pathic ventricular fibrillation (45%, 134/295), followed by hypertrophic cardiomyopathy (4%, 13/295), commotio cordis (3%, 9/295), long QT syndrome (1%, 4/295), and Wolff-Parkinson-White syndrome (1%, 4/295). The proportion of OHCA of cardiac origin gradually increased in the higher educational levels (51% among elementary school students and 81% among high school/technical college students).

Outcomes After OHCA

Table 4 shows the outcomes after OHCA according to the origin of cardiac arrest and educational level. The proportion of patients with 1-month survival with a favorable neurological outcome was 34% (100/295) among all patients, 43% (90/210) among patients with OHCA of cardiac origin and 12% (10/85) among those of noncardiac origin.

Table 3. Etiology of Out-of-Hospital Cardiac Arrests Occurring in School Settings in Japan

| | Total (n=295) | Elementary school students (n=49) | Junior-high school students (n=107) | High school / technical college students (n=139) |
|---|------------------|---|---|--|
| | n (%) | n (%) | n (%) | n (%) |
| Cardiac origin | 210 (71.2) | 25 (51.0) | 73 (68.2) | 112 (80.6) |
| Idiopathic ventricular fibrillation | 134 (45.4) | 10 (20.4) | 47 (43.9) | 77 (55.4) |
| Hypertrophic cardiomyopathy | 13 (4.4) | 1 (2.0) | 6 (5.6) | 6 (4.3) |
| Commotio cordis | 9 (3.1) | 0 (0.0) | 4 (3.7) | 5 (3.6) |
| Long QT syndrome | 4 (1.4) | 2 (4.1) | 1 (0.9) | 1 (0.7) |
| Wolff-Parkinson-White syndrome | 4 (1.4) | 0 (0.0) | 1 (0.9) | 3 (2.2) |
| Presumed cardiac origin (no definite diagnosis) | 46 (15.6) | 12 (24.5) | 14 (13.1) | 20 (14.4) |
| Noncardiac origin | 85 (28.8) | 24 (49.0) | 34 (31.8) | 27 (19.4) |
| All trauma | 37 (12.5) | 4 (8.1) | 20 (18.7) | 13 (9.3) |
| Fall | 13 (4.4) | 2 (4.1) | 9 (8.4) | 2 (1.4) |
| Hanging | 6 (2.0) | 1 (2.0) | 5 (4.7) | 0 (0.0) |
| Traffic accident | 2 (0.7) | 0 (0.0) | 0 (0.0) | 2 (1.4) |
| Other trauma | 16 (5.4) | 1 (2.0) | 6 (5.6) | 9 (6.5) |
| Drowning | 15 (5.1) | 8 (16.3) | 4 (3.7) | 3 (2.2) |
| Suffocation | 9 (3.1) | 5 (10.2) | 1 (0.9) | 3 (2.2) |
| Respiratory disease | 6 (2.0) | 2 (4.1) | 1 (0.9) | 3 (2.2) |
| Cerebrovascular disease | 6 (2.0) | 3 (6.1) | 3 (2.8) | 0 (0.0) |
| Aortic disease | 5 (1.7) | 0 (0.0) | 3 (2.8) | 2 (1.4) |
| Other noncardiac origin | 7 (2.4) | 2 (4.1) | 2 (1.9) | 3 (2.2) |

Table 4. Outcomes After Out-of-Hospital Cardiac Arrests Occurring in School Settings in Japan

| | Total | Elementary school students | Junior-high school students | High school / technical college students | P value |
|--|----------------|-------------------------------|--------------------------------|---|---------|
| | n/N (%) | n/N (%) | n/N (%) | n/N (%) | |
| Cardiac origin | | | | | |
| Prehospital return of spontaneous circulation | 88/210 (41.9) | 8/25 (32.0) | 33/73 (45.2) | 47/112 (42.0) | 0.513 |
| 1-month survival | 105/210 (50.0) | 9/25 (36.0) | 38/73 (52.1) | 58/112 (51.8) | 0.329 |
| 1-month survival with favorable neurological outcome | 90/210 (42.9) | 7/25 (28.0) | 32/73 (43.8) | 51/112 (45.5) | 0.271 |
| Noncardiac origin | | | | | |
| Prehospital return of spontaneous circulation | 20/85 (23.5) | 6/24 (25.0) | 10/34 (29.4) | 4/27 (14.8) | 0.402 |
| 1-month survival | 20/85 (23.5) | 9/24 (37.5) | 8/34 (23.5) | 3/27 (11.1) | 0.086 |
| 1-month survival with favorable neurological outcome | 10/85 (11.8) | 4/24 (16.7) | 5/34 (14.7) | 1/27 (3.7) | 0.147 |
| Total | | | | | |
| Prehospital return of spontaneous circulation | 108/295 (36.6) | 14/49 (28.6) | 43/107 (40.2) | 51/139 (36.7) | 0.376 |
| 1-month survival | 125/295 (42.4) | 18/49 (36.7) | 46/107 (43.0) | 61/139 (43.9) | 0.675 |
| 1-month survival with favorable neurological outcome | 100/295 (33.9) | 11/49 (22.4) | 37/107 (34.6) | 52/139 (37.4) | 0.161 |

Discussion

Our study described the nationwide incidence rate, detailed characteristics, and outcomes of pediatric OHCA occurring in various school settings in Japan. Because the epidemiological characteristics of pediatric OHCA occurring in school settings are not yet sufficiently understood, the knowledge gained from our study will contribute additional essential information to the development of preventive strategies, informing of policy makers and helping

physicians consider the mechanism and treatment of OHCA in greater depth.

Our results show that the majority of OHCA cases had a cardiac origin; however, the rhythm and structural disorders that could be found using electrocardiography or echocardiography accounted for only a small subset of all causes of OHCA (i.e., hypertrophic cardiomyopathy, long QT syndrome, and Wolff-Parkinson-White syndrome). Previous studies also suggested that many cases of cardiac arrest occur in people without known underlying health

problems, and a definitive cause of cardiac arrest cannot be found even after autopsy in some cases.^{15–17} Thus, identification of individuals at risk of cardiac arrest is currently challenging. In order to provide appropriate treatment to prevent the onset of OHCA, more effective school-based screening strategies should be established in the future.

We found that approximately 50 cases of pediatric OHCA consistently occurred each year in school settings in Japan, and the proportion of OHCA cases occurring in school settings was estimated to be approximately 6.1% of all pediatric OHCA. Although the proportion was slightly higher than in a previous report from the USA, which suggested that 4.4% of all cases of pediatric OHCA occurred at school,^{18,19} our result suggested that pediatric OHCA occurring in school settings account for a small portion of the overall pediatric OHCA burden in Japan. We also estimated that the incidence rate of overall OHCA was 0.4 per 100,000 students per year. According to a systematic review, the incidence rate of cardiac arrest among students at school reported in several studies from various settings, ranged from 0.17 to 4.4 per 100,000 students per year.⁹ Although comparing the incidence rate of OHCA occurring in schools across countries is important, the existing studies on this topic show a wide variation among student populations, outcome measures, environmental factors, age cutoff, duration of the study, and patient selection criteria.⁹ Therefore, our study cannot be directly compared with previous studies. Because we focused on OHCA occurring under the supervision of schools in accordance with the Japanese Injury and Accident Mutual Aid Benefit System,¹³ our study included OHCA occurring at other places in addition to school campuses ($\approx 13\%$ of all cases). Therefore, the OHCA incidence rate reported in our study may be slightly higher compared with other studies.

Consistent with previous reports,^{20–24} our study revealed that the majority of OHCA in school settings occurred during exercise activities. The proportion of OHCA occurring during exercise increased in the higher educational levels. Therefore, the increased frequency of exercise-related events in these types of schools may account for the observed difference in the incidence rate according to educational level. Importantly, a large proportion of the OHCA occurring during exercise activities of junior high school, high school, and technical college students happened after normal school hours. In Japan, although club activities after class are not mandatory, many students belong to a club directed by a school. Sports club activities occupy large amounts of time in Japanese students' lives, and many students go to school even on weekends and during vacation to practice sports. Therefore, introducing resuscitation training as part of school education would be helpful to improve treatment of OHCA occurring during sports club activities, especially as bystanders are most likely to be other students.²⁵ In addition, implementation of a systematic screening program to identify at-risk individuals and appropriate limitation of exercise activity would be an effective strategy for reducing the incidence and mortality of cardiac arrest. In Italy, a pre-participation athletic screening successfully reduced the incidence of sudden cardiovascular death in athletes by 89% from 3.6 per 100,000 person-years to 0.4 over a 26-year period.²⁶ In Japan, a nationwide, school-based screening program for heart diseases in 1st, 7th, and 10th graders started in 1994; participation is mandatory and this program could have contributed to the reduction in the number of sudden car-

diac deaths among students in recent years.²⁷

Our study also suggested that patients with OHCA of cardiac origin had a relatively good prognosis, and it was better than the average for overall OHCA outcomes in Japan.²⁸ It is likely that school-age children are physiologically fit, which improves their chances of survival after an OHCA.²⁹ In addition, the fact that a considerable number of OHCA cases were witnessed by bystanders, received bystander CPR, and were treated with a public-access AED greatly contributed to the improved outcomes. These proportions in our study were much higher than those for overall OHCA in Japan.²⁸ However, in this study, we did not directly assess the effectiveness of such basic life support and dissemination of AEDs in schools, because of the small numbers of study subjects. Prospective registration of OHCA cases into our SPIRITS database for the purpose of conducting comprehensive investigations on this topic is an issue to be addressed in the future.²⁷

Study Limitations

This study has several inherent limitations. First, we were unable to obtain information on several factors that would be associated with the occurrence of cardiac arrest and/or its prognosis. This information includes past medical history, medication, intensity and duration of exercise at the time of cardiac arrest, frequency of habitual exercise, quality of bystander-initiated CPR, and other life habits. The potential variability in post-arrest care, such as hemodynamic support, induced hypothermia, and coronary interventional therapies, could not also be addressed because of the lack of information on these aspects in the database. Second, in the All-Japan Utstein Registry, the etiology of many cases may be determined to be of cardiac origin after excluding other possibilities. Autopsy was not performed for all cases of sudden cardiac death, and the reported autopsy rate in 2014 was only 2.4% of all death cases in Japan.³⁰ Therefore, in this study, the etiology of cardiac arrest was determined by emergency physicians and pediatricians, by complementing the diagnostic information from the Injury and the Accident Mutual Aid Benefit System. However, there is still a possibility that unmeasured inherited functional or structural cardiac diseases and cardiac electrical disorders existed as the underlying cause of cardiac arrests, similar to those reported in previous studies.^{31–34} Third, among the suspected cases of OHCA at the sites, 179 cases were not merged with the All-Japan Utstein Registry. In most cases, it would be because they did not have a cardiac arrest, and so the EMS personnel did not register them in the All-Japan Utstein Registry. Because most bystanders were non-medical professionals, it is difficult for them to correctly judge whether a victim had a cardiac arrest at the site. However, in some cases, there is the possibility that there were input errors in the items for data-linkage, which could lead to underestimation of OHCA cases. Moreover, exclusion of subjects who were not transported to hospital by EMS would also cause underestimation of OHCA incidence.

Conclusions

Using a nationwide registry, we described the detailed characteristics and outcomes of pediatric OHCA occurring in Japanese school settings between 2009 and 2014. In Japan, approximately 50 pediatric cases of OHCA consistently occur each year in school settings and most of them

occurred during exercise, were witnessed by bystanders, and had a cardiac origin. In general, pediatric patients with OHCA of cardiac origin had a good prognosis. Additional efforts to disseminate knowledge of basic life support training and the establishment of effective school-based screening strategies will both prevent the occurrence and improve the survival of cardiac arrest in school children.

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