Table 1. Clinical characteristics and outcomes of out-of-hospital cardiac arrests in school children at or out of school

	Total	At school	Out of school	P value
No. of events, n	58	32 (55)	26 (45)	
Male gender, n (%)	37 (64)	20 (63)	17 (65)	1.00
Median age (interquartiles)	12 (11, 14)	13 (11, 14)	12 (9, 14)	0.24
Calendar year 07-09, n (%)	43 (74)	24 (75)	19 (73.1)	1.00
Bystander witness, n (%)	52 (90)	31 (97)	21 (81)	0.08
Nonfamily witness, n (%)	43 (74)	31 (97)	12 (46)	<0.001
Events in public locations, n (%)	48 (83)	32 (100)	16 (62)	<0.001
Initial VF, n (%)	48 (86)	28 (94)	20 (77)	0.13
Bystander's CPR, n (%)	43 (74)	27 (84)	16 (62)	0.07
AED use, n (%)	44 (76)	26 (81)	18 (69)	0.36
Bystander AED, n (%)	14 (24)	12 (38)	2 (8)	0.01
EMS AED, n (%)	30 (52)	14 (44)	16 (62)	0.20
Exercise-related, n (%)	38 (66)	27 (84)	11 (42)	0.001
Followed-up cases, n (%)	28 (48)	16 (50)	12 (46)	0.77
Favorable neurological outcome, n (%)	31 (53)	22 (69)	9 (35)	0.02
Survival at one month	42 (72)	23 (72)	19 (73)	1.00
Pre-hospital ROSC	33 (59)	20 (65)	13 (52)	0.42

Number among available data with the percentage in parenthesis was shown.
AED, automated external defibrillator; CPR, cardiopulmonary resuscitation; EMS, emergency medical service; ROSC, return of spontaneous circulation; VF, ventricular fibrillation.
Missing data on cases of initial VF at school (n=2) and pre-hospital ROSC at and out of school (1 each) were included, with percentages calculated based on the available data.

Table 2. Clinical and Outcome Parameters in Subgroups of Patients in the Japanese Pediatric Utstein Study

Parameter	Public location n=129	Private location n=101	P value
By presumed location of arrest			
Defibrillated by			
Bystander, n (%)	27 (21)	2 (2)	<0.001
EMS, n (%)	71 (55)	38 (38)	0.009
Favorable neurological outcome, n (%)	48 (37)	15 (15)	<0.001
Survival at 1 month, n (%)	62 (48)	22 (22)	<0.001
Prehospital ROSC, n (%)	46 (36)	20 (20)	0.008
Parameter	**Bystander n=29**	**EMS n=109**	**P value**
By bystander or EMS personnel who defibrillated the victim			
Collapse to CPR time, min	2.9±3.7	5.0±5.6	0.061
Collapse to AED time, min	3.3±3.7	12.9±5.8	<0.001
Favorable neurological outcome, n (%)	17 (59)	39 (36)	0.026
Survival at 1 month, n (%)	20 (69)	52 (48)	0.042
Prehospital ROSC, n (%)	19 (66)	39 (36)	0.004

Data are n (%). Family member-witnessed arrests were presumed to be in a private location; non-family member-witnessed arrests were presumed to be in a public location.
Abbreviations as in Table 1.

scale in which category 1 represents good cerebral performance; category 2, moderate cerebral disability; category 3, severe cerebral disability; category 4, coma or vegetative state; category 5, death.[23,28,29] CPC1–2 was regarded as a favorable neurological outcome.

Statistical Analysis

All statistical analyses were performed with the SPSS statistical package, version 16.0J (PASW Statistics 18.0). Continuous data are reported as median and interquartile ranges. The significance of any differences among 2 or more than 2 groups was assessed by the Mann-Whitney U test or by the Kruskal-Wallis test, followed by Mann-Whitney U test, adjusted for multiple comparisons. Categorical data are expressed as a value or frequency of occurrence. The difference of the proportions of categorical variables among groups was assessed by chi-square analysis. All tests were 2-tailed, and P<0.05 was considered to indicate statistical significance.

Results

The primary response rate in the present questionnaire survey was 57%; 58 elementary and middle school students (median age [interquartile range]: 12 years [11–14]; males: 64%) after an

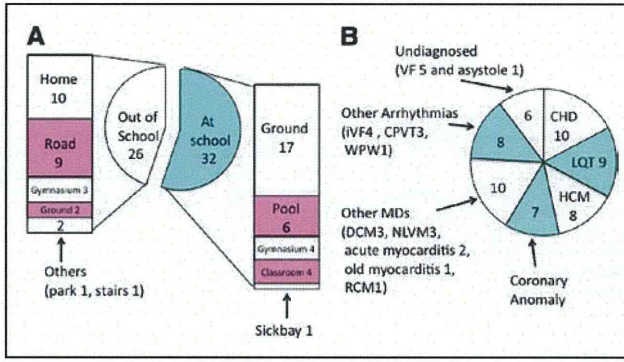

Figure 1. Location (**A**) of arrests and (**B**) cardiac etiology. CHD, congenital heart disease; CPVT, catecholaminergic polymorphic ventricular tachycardia; DCM, dilated cardiomyopathy; HCM, hypertrophic cardiomyopathy; iVF, idiopathic ventricular fibrillation; LQT, long QT syndrome; MD, myocardial disease; NLVM, noncompaction of left ventricular myocardium; RCM, restrictive cardiomyopathy; VF, ventricular fibrillation; WPW, Wolff-Parkinson-White syndrome.

OHCA with a definitive cardiac diagnosis (n=52) or of presumed cardiac origin (n=6) were recruited (**Table 1**): 52 (90%) were witnessed by bystanders (9 by family members and 43 by non-family members [30 by school teachers and 13 by others]); 48/56 patients (86%) had VF as the first documented rhythm (pulseless electrical activity in 2, asystole in 6, unknown in 2); 43 (74%) received bystander CPR (8 from family members and 35 from non-family members [27 from school teachers and 8 from others]); 44 (76%) received AED-based prehospital defibrillation (30 from EMS personnel and 14 from bystanders [11 from school teachers and 3 from other non-family members]). A total of 31 patients (53%) had a favorable neurological outcome, 42 (72%) survived 1 month after OHCA, and 33/56 (59%) had ROSC before arrival at the hospital. Among the patients initially defibrillated by a bystander, 11/14 (79%) exhibited a favorable neurological outcome. The proportion of prehospital ROSC was higher in patients with a favorable neurological outcome (26/29, 90%, P<0.001) than in those without a favorable neurological outcome (7/27, 26%). The proportion of prehospital ROSC tended to be higher in patients defibrillated by bystanders (11/13, 85%, P=0.11) than in those defibrillated by EMS personnel (18/30, 60%). The distribution of patients by school grade is illustrated in **Figure S1**. As a reference for this study, clinical and outcome parameters in subgroups of patients in an all-Japan population-level study of the same age population during the same study period are reported in **Table 2**.[6]

Characteristics of OHCA at School

Of the 58 patients, 32 (55%) had their OHCA at school (**Table 1**), which accounted for 67% of total public location arrests and comprised 31 non-family member-witnessed arrests and 1 unwitnessed arrest. Of the 43 non-family member-witnessed arrests, 31 occurred at school, 11 in other public locations, and 1 at home. Compared with an arrest out of school, an arrest at school was more likely to be witnessed by a non-family member (P<0.001), occur in a public location (P<0.001), be initially defibrillated by a bystander (P=0.01) but not by EMS, be witnessed by a bystander (P=0.08), and receive CPR from a bystander (P=0.07). In schools, teachers witnessed all 31 witnessed cases, treated all 27 cases resuscitated by a bystander, and defibrillated all 12 cases initially shocked by a bystander, except 1 case. An arrest at school was more likely to be exercise-related (84% vs. 42%, P=0.001), and to be in initial VF (94% vs. 77%, P=0.13) than out of school, but not associated with sex, age, calendar year, or pre-event follow-up status (50% vs. 46%, P=0.77). In schools, arrests at sports venues, including the ground, pool, and gymnasium, accounted for 84% of arrests, while arrests at sports venues out of school accounted for 19% (**Figure 1**). A total of 73% arrests out of school occurred at home or on the road, where AED devices are rarely located: among 9 arrests on the road, 6 students were traveling to or from school. Among all 14 events in patients initially defibrillated by a bystander, 11 occurred at sports venues and 1 at another location in school, while 2 were in public locations out of school. An arrest at school was associated with a higher proportion of favorable neurological outcome 1 month after OHCA than out of school (P=0.02) (**Table 1**).

Cardiac Etiology and Circumstances of OHCA in School Children

Figure 1 depicts the diagnosis of the cardiac disorders. Among all 58 arrests, 52 (90%), comprising 41 of 42 survivors and 11 of 16 non-survivors, were diagnosed. Of these 52 diagnosed cases, structural and nonstructural heart disease accounted for 67% and 33%, respectively. Cardiac etiology according to exercise status and follow-up status is shown in **Figure 2**. Arrests that occurred during or just after exercise accounted for 66%, events that occurred at rest or during walking accounted for 26%, and events that occurred during sleeping accounted for 7%. All arrests in the coronary anomaly and catecholaminergic polymorphic ventricular tachycardia (CPVT) categories were exercise-related, whereas 50% of cases of congenital heart disease (CHD) and of hypertrophic cardiomyopathy (HCM) were exercise-related. Cases of follow-up for chronic heart disease before the event accounted for 48%. All 10 CHD cases, 6 of the 8 HCM cases, 5 of the 8 other myocardial diseases, excluding 2 acute myocarditis cases, and 4 of the 9 cases of long QT syndrome were followed up. No cases of coronary anomaly, CPVT, or idiopathic VF were followed up. The proportion of these 3 diseases, which can exhibit apparently normal resting ECG, accounted for 47% of the total cases with no pre-event follow-up (**Figure 2**). There was a tendency toward a lower proportion of exercise-related events in followed cases (54% vs. 77%, P=0.06) than in unfollowed cases (**Table 3**). OHCAs among the unfollowed cases of arrests at school, which were almost always exercise-related (94%), were frequently associated with these 3 diseases which could exhibit apparently normal resting ECG (63%) (**Table 3**). Among 27 exercise-related cases of arrests at

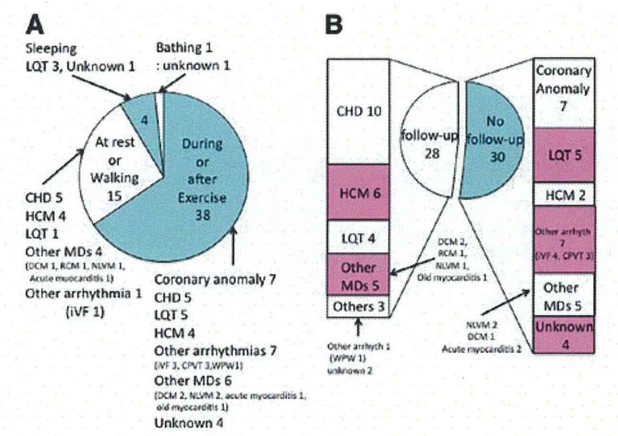

Figure 2. Cardiac etiology by (**A**) exercise status and (**B**) follow-up status. CHD, congenital heart disease; CPVT, catecholaminergic polymorphic ventricular tachycardia; DCM, dilated cardiomyopathy; HCM, hypertrophic cardiomyopathy; iVF, idiopathic ventricular fibrillation; LQT, long QT syndrome; MD, myocardial disease; NLVM, noncompaction of left ventricular myocardium; RCM, restrictive cardiomyopathy; VF, ventricular fibrillation; WPW, Wolff-Parkinson-White syndrome.

Table 3. Cardiac Disease and Exercise Status by Location and Follow-up of Arrest

	At school (n=32)	Out of school (n=26)
Follow-up (28)	(n=16)	(n=12)
	Exercise-related (n=12)	Exercise-related (n=3)
	HCM (4), CHD (3), LQT (3), Other MD (3: DCM 1, NLVM 1, old myocarditis 1), Other arrhythmia (1: WPW), Unknown (2)	CHD (7), HCM (2), LQT (1), Other MD (2: DCM 1, RCM 1)
No follow-up (n=30)	(n=16)	(n=14)
	Exercise-related (n=15)	Exercise-related (n=8)
	Coronary anomaly (5), HCM (2), LQT (2), Other arrhythmia (5: iVF 3, CPVT 2), Other MD (1: DCM), Unknown (1)	LQT (3), Coronary anomaly (2), Other MD (4: NLVM 2, acute carditis 2), Other arrhythmia (2: iVF 1, CPVT 1), Unknown (3)

CHD, congenital heart disease; CPVT, catecholaminergic polymorphic ventricular tachycardia; DCM, dilated cardiomyopathy; HCM, hypertrophic cardiomyopathy; iVF, idiopathic ventricular fibrillation; LQT, long QT syndrome; MD, myocardial disease; NLVM, noncompaction of left ventricular myocardium; RCM, restrictive cardiomyopathy; WPW, Wolff-Parkinson-White syndrome.

school, the likelihood of defibrillation by bystanders was similar between the followed cases and ostensibly healthy students (42% vs. 40%, P=0.93) (data not shown). The clinical and outcome parameters according to disease category and cardiac etiology according to the time of day and location of arrest are described in detail in Table S1, Figure S2 and the text.

Discussion

According to previous Japanese Utstein registry studies, which included all age groups, it is adolescents and younger school-age children who are most likely to be defibrillated by a bystander and have a favorable neurological outcome.[6,22] However, the specific locations of arrests and circumstances of events related to PAD are unknown. In the present survey, we demonstrated that elementary and middle school students were more likely to benefit from defibrillation by bystanders after OHCA and exhibited a more favorable neurological outcome for arrests occurring in schools than in other locations, suggesting that school campuses might be a specific location that is highly efficient for CPR with defibrillation by bystanders. The majority of arrests in schools were exercise-related, occurred at sports venues, and were witnessed and resuscitated by teachers, which could support prioritization of the placement of AED in these locations and the focused training of school teachers, especially those in charge of physical exercise, in CPR with AED. Patients with associated chronic cardiac disease in the pre-event follow-up accounted for half of the arrests at school, suggesting that such a subgroup may be at high risk for OHCA at school.

OHCA at School in the Era of PAD

In the present study, we demonstrated that an arrest in children at school was associated with a high proportion of AED use by bystanders and a favorable neurological outcome; this is in contrast with the low rate of defibrillation by bystanders out of school. These findings are consistent with our concomitant pediatric Utstein study, in which there was a high rate of AED use by bystanders (21%) and a favorable neurological outcome (37%) after OHCA occurred in a public location, although the specific location of arrests was not determined in that study.[6] These findings are also consistent with a recent sharp decline of the incidence of sudden cardiac death in children under school supervision in the Japan Sport Council database, although the incidence of OHCA or the number of bystander's using AEDs is unknown.[30] The advantage of school campuses for emergency preparedness is consistent with a population-based Seattle/King County study in which arrests on school campus were characterized by a higher rate of witnessed arrest (79%), bystander CPR (74%), and survival to hospital discharge (39%), although that study mainly focused on the adult population with few cases initially defibrillated by a bystander.[2] It is also consistent with a questionnaire study of US high-school athletes, in which 93% (13/14) received AED defibrillation and 64% (9/14) survived to hospital discharge, although the non-athlete population was not addressed in that study.[15] Therefore, the outcome in schools could be comparable to that in other specific public locations, including casinos, airlines, and airports, where the favorable effect of PAD has been highly appreciated.[11–14] The high rate of initial VF in the present study was consistent with that in 2 other school-based studies [Seattle/King study (78%) and the US high-school study (83%)], as well as in our pediatric Utstein study (71% in public location arrests).[2,6,15] In addition, the proportion of VF did not vary significantly with the underlying disease category in the present study, suggesting the therapeutic potential of early defibrillation overall in children after arrests at school.

The non-athletic level of exercise in schools,[2,5] as well as strenuous exercise such as by competitive athletes in high school or university, or by young adults,[15,21,31,32] has been considered a trigger for OHCA. As the proportion of exercise-related arrests was higher in than out of school in the present study, even regular exercise by elementary and middle school students at school poses a risk for an arrest in such children; sports venues were a high-risk location of arrests in schools; however, bystander CPR and defibrillation performed by teachers in such a situation worked reasonably well. These findings support prioritization of AED placement accessible to these locations in schools and focused training of school teachers, especially those in charge of physical exercise, in CPR with AED.

Cardiac Etiology and Circumstances of OHCA in School Children

Cardiac disorders related to sudden cardiac death in school children have been extrapolated from pathology-based studies of young athletes and non-athletes up to the age of 35 in Italy, the USA, and the UK.[5,32–34] In those studies, structural heart disease, including HCM (4–36%), coronary anomaly (≤17%), myocarditis (3–12%), and arrhythmogenic right ventricular cardiomyopathy (≤14%), was the predominant cause of arrests; 6–29.2% of arrests were unexplained, and presumed to be caused by arrhythmia.[5,32–34] The relatively high proportion of CHD in the present study was consistent with the findings in the recent King County study, which included non-athletic children with chronic diseases (21–23%).[5] The inclusion of specific arrhythmic disorders in the present study was newly derived from clinically diagnosed aborted sudden death cases recruited nationwide. Thus, this study presents the cardiac etiology of OHCAs in a specific school-age population, which could be relevant to the understanding of arrests in such students.

Because we have demonstrated that approximately half of all arrests, and of those at school, occurred in students with a pre-event follow-up of cardiac disease, as in a previous school-based study,[2] the recognition of such a high-risk group may have implication in emergency responses at school. Despite a lower proportion of exercise-related events in followed cases, which may be explained by the effect of withdrawal from exercise in such cases or the exercise-related characteristics of the disease,[32–36] 'pre-event awareness of diseases', including HCM and long QT syndrome, could aid in alerting school staff to otherwise unpredictable events in schools. Conversely, as OHCA in ostensibly healthy children at school was mostly exercise-related, the secondary prevention of cardiac death by using AED at sports venues may play an essential role. Although the likelihood of defibrillation by bystanders was in fact similar between the followed cases and ostensibly healthy children among the exercise-related cases of arrests at school in the present study, the recognition of a high-risk patient, as well as a high-risk situation and venue, may be relevant to optimizing the outcome of OHCA at school in the future.

Study Limitations

First, this was a retrospective, nonpopulation-based study, which may affect the interpretation of the findings. However, the present findings are consistent with our concomitant pediatric population-based Utstein study, in which we demonstrated a high rate of bystander AED use and favorable neurological outcomes after OHCA occurring in public locations.[6,22] Second, specific information on the scope of the budgetary barriers and logistic issues (ie, the locations of AEDs, training schedule for teachers) involved in implementing and refining AED/CPR programs at the national level in Japan is unavailable. Third, cardiac etiology of OHCA in followed and unfollowed patients in the present study could be influenced by the school ECG screening in Japan, although the role of the school ECG screening system was not specifically addressed.[27] Fourth, the present study focused on the issue in children, not adults, in schools.[2,16] Fifth, there might be unmeasured confounding factors (ie, quality of bystander's CPR) that might influence outcomes.[6,23,37]

Conclusions

OHCA in school children is a rare event, but one of great public concern. The present study is the first to characterize cardiac arrest in ordinary elementary and middle school children in or out of school in the era of PAD, which could be relevant to the recognition of high-risk groups, the efficient placement of AEDs and the focused training of staff (CPR with AED use) in schools. The present findings warrant population-based studies on the role of CPR with AED use and related circumstances of events in schools.[8,10,22]

Acknowledgments

We thank the participating physicians for graciously enrolling their patients, and Dr Naoki Shimizu of the Tokyo Metropolitan Children's Medical Center and Dr Kenji Koshimizu of the Saitama Medical Center for their kind suggestions at the planning stage of this project.

Funding Sources

This study was supported by grants from the Ministry of Education, Culture, Sports, Science, and Technology (21590558), the Ministry of Health, Labour, and Welfare (H-18-myocardium-01) (2010–145), and the Miyata Pediatric Heart Disease Research Fund.

Disclosures

We declare that we have no conflicts of interest.

References

1. Kovach J, Berger S. Automated external defibrillators and secondary prevention of sudden cardiac death among children and adolescents. *Pediatr Cardiol* 2012; **33:** 402–406.
2. Lotfi K, White L, Rea T, Cobb L, Copass M, Yin L, et al. Cardiac arrest in schools. *Circulation* 2007; **116:** 1374–1379.
3. Bardai A, Berdowski J, van der Werf C, Blom MT, Ceelen M, van Langen IM, et al. Incidence, causes, and outcomes of out-of-hospital cardiac arrest in children: A comprehensive, prospective, population-based study in the Netherlands. *J Am Coll Cardiol* 2011; **57:** 1822–1828.
4. Atkins DL, Everson-Stewart S, Sears GK, Daya M, Osmond MH,

Advance Publication by-J-STAGE

Warden CR, et al. Epidemiology and outcomes from out-of-hospital cardiac arrest in children: The Resuscitation Outcomes Consortium Epistry-Cardiac Arrest. *Circulation* 2009; **119:** 1484–1491.
5. Meyer L, Stubbs B, Fahrenbruch C, Maeda C, Harmon K, Eisenberg M, et al. Incidence, causes, and survival trends from cardiovascular-related sudden cardiac arrest in children and young adults 0 to 35 years of age: A 30-year review. *Circulation* 2012; **126:** 1363–1372.
6. Mitani Y, Ohta K, Yodoya N, Otsuki S, Ohashi H, Sawada H, et al. Public-access defibrillation improved the outcome after out-of-hospital cardiac arrests in school-age children: A nationwide, population-based, Utstein registry study in Japan. *Europace* 2013; **15:** 1259–1266.
7. Donoghue AJ, Nadkarni V, Berg RA, Osmond MH, Wells G, Nesbitt L, et al. Out-of-hospital pediatric cardiac arrest: An epidemiologic review and assessment of current knowledge. *Ann Emerg Med* 2005; **46:** 512–522.
8. Kaltman JR, Thompson PD, Lantos J, Berul CI, Botkin J, Cohen JT, et al. Screening for sudden cardiac death in the young: Report from a national heart, lung, and blood institute working group. *Circulation* 2011; **123:** 1911–1918.
9. Corrado D, Pelliccia A, Bjornstad HH, Vanhees L, Biffi A, Borjesson M, et al. Cardiovascular pre-participation screening of young competitive athletes for prevention of sudden death: Proposal for a common European protocol Consensus Statement of the Study Group of Sport Cardiology of the Working Group of Cardiac Rehabilitation and Exercise Physiology and the Working Group of Myocardial and Pericardial Diseases of the European Society of Cardiology. *Eur Heart J* 2005; **26:** 516–524.
10. Hazinski MF, Markenson D, Neish S, Gerardi M, Hootman J, Nichol G, et al. Response to cardiac arrest and selected life-threatening medical emergencies: The medical emergency response plan for schools: A statement for healthcare providers, policymakers, school administrators, and community leaders. *Circulation* 2004; **109:** 278–291.
11. Hallstrom AP, Ornato JP, Weisfeldt M, Travers A, Christenson J, McBurnie MA, et al. Public-access defibrillation and survival after out-of-hospital cardiac arrest. *N Engl J Med* 2004; **351:** 637–646.
12. Valenzuela TD, Roe DJ, Nichol G, Clark LL, Spaite DW, Hardman RG. Outcomes of rapid defibrillation by security officers after cardiac arrest in casinos. *N Engl J Med* 2000; **343:** 1206–1209.
13. Caffrey SL, Willoughby PJ, Pepe PE, Becker LB. Public use of automated external defibrillators. *N Engl J Med* 2002; **347:** 1242–1247.
14. Page RL, Joglar JA, Kowal RC, Zagrodzky JD, Nelson LL, Ramaswamy K, et al. Use of automated external defibrillators by a U.S. airline. *N Engl J Med* 2000; **343:** 1210–1216.
15. Drezner JA, Rao AL, Heistand J, Bloomingdale MK, Harmon KG. Effectiveness of emergency response planning for sudden cardiac arrest in United States high schools with automated external defibrillators. *Circulation* 2009; **120:** 518–525.
16. Swor R, Grace H, McGovern H, Weiner M, Walton E. Cardiac arrests in schools: Assessing use of automated external defibrillators (AED) on school campuses. *Resuscitation* 2013; **84:** 426–429.
17. Report on a study on social system development to improve survival from emergency cardiovascular disease using automated external defibrillator [Marukawa's report; in Japanese] http://kouroukaken-kyukyusosei.info/wpm/archivepdf/21/2_11a.pdf. (accessed 23 June, 2011).
18. Japanese Foundation for Emergency Medicine. A search for information on placement of AEDs (in Japanese). http://www.qqzaidan.jp/AED/aed.htm. (accessed 23 June, 2011).
19. National survey on AED placement at schools (in Japanese). http://www.mext.go.jp/a_menu/gakkouanzen/syousai/__icsFiles/afieldfile/2009/06/17/1267499_2.pdf. (accessed 23 July, 2011).
20. Young KD, Gausche-Hill M, McClung CD, Lewis RJ. A prospective, population-based study of the epidemiology and outcome of out-of-hospital pediatric cardiopulmonary arrest. *Pediatrics* 2004; **114:** 157–164.
21. Drezner JA, Rogers KJ. Sudden cardiac arrest in intercollegiate athletes: Detailed analysis and outcomes of resuscitation in nine cases. *Heart Rhythm* 2006; **3:** 755–759.
22. Kitamura T, Iwami T, Kawamura T, Nitta M, Nagao K, Nonogi H, et al. Nationwide improvements in survival from out-of-hospital cardiac arrest in Japan. *Circulation* 2012; **126:** 2834–2843.
23. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Hiraide A. Nationwide public-access defibrillation in Japan. *N Engl J Med* 2010; **362:** 994–1004.
24. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Nadkarni VM, et al. Conventional and chest-compression-only cardiopulmonary resuscitation by bystanders for children who have out-of-hospital cardiac arrests: A prospective, nationwide, population-based cohort study. *Lancet* 2010; **375:** 1347–1354.
25. Mitamura H. Public access defibrillation: Advances from Japan. *Nat Clin Pract Cardiovasc Med* 2008; **5:** 690–692.
26. Ministry of international Affairs and Communications. Ambulance service and emergency responses in 2010 (in Japanese). http://www.fdma.go.jp/neuter/topics/houdou/2212/221203_1houdou/01_houdoushiryou.pdf). (accessed 23 June, 2011).
27. Tanaka Y, Yoshinaga M, Anan R, Nomura Y, Oku S, Nishi S, et al. Usefulness and cost effectiveness of cardiovascular screening of young adolescents. *Med Sci Sports Exerc* 2006; **38:** 2–6.
28. Cummins RO, Chamberlain DA, Abramson NS, Allen M, Baskett PJ, Becker L, et al. Recommended guidelines for uniform reporting of data from out-of-hospital cardiac arrest: The Utstein Style. A statement for health professionals from a task force of the American Heart Association, the European Resuscitation Council, the Heart and Stroke Foundation of Canada, and the Australian Resuscitation Council. *Circulation* 1991; **84:** 960–975.
29. Jacobs I, Nadkarni V, Bahr J, Berg RA, Billi JE, Bossaert L, et al. Cardiac arrest and cardiopulmonary resuscitation outcome reports: Update and simplification of the Utstein templates for resuscitation registries. A statement for healthcare professionals from a task force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Councils of Southern Africa). *Circulation* 2004; **110:** 3385–3397.
30. Yoshinaga M. Prevalence of sudden death and out-of-hospital cardiac arrest in infants, children, and adolescents: What does it imply? *Circ J* 2013; **77:** 2475–2476.
31. Drezner JA, Chun JS, Harmon KG, Derminer L. Survival trends in the United States following exercise-related sudden cardiac arrest in the youth: 2000–2006. *Heart Rhythm* 2008; **5:** 794–799.
32. Corrado D, Basso C, Rizzoli G, Schiavon M, Thiene G. Does sports activity enhance the risk of sudden death in adolescents and young adults? *J Am Coll Cardiol* 2003; **42:** 1959–1963.
33. de Noronha SV, Sharma S, Papadakis M, Desai S, Whyte G, Sheppard MN. Aetiology of sudden cardiac death in athletes in the United Kingdom: A pathological study. *Heart* 2009; **95:** 1409–1414.
34. Maron BJ, Doerer JJ, Haas TS, Tierney DM, Mueller FO. Sudden deaths in young competitive athletes: Analysis of 1866 deaths in the United States, 1980–2006. *Circulation* 2009; **119:** 1085–1092.
35. Denjoy I, Lupoglazoff JM, Guicheney P, Leenhardt A. Arrhythmic sudden death in children. *Arch Cardiovasc Dis* 2008; **101:** 121–125.
36. Basso C, Maron BJ, Corrado D, Thiene G. Clinical profile of congenital coronary artery anomalies with origin from the wrong aortic sinus leading to sudden death in young competitive athletes. *J Am Coll Cardiol* 2000; **35:** 1493–1501.
37. Japanese Circulation Society Resuscitation Science Study Group. Chest-compression-only bystander cardiopulmonary resuscitation in the 30:2 compression-to-ventilation ratio era: Nationwide observational study. *Circ J* 2013; **77:** 2742–2750.

Supplementary Files

Supplementary File 1

Methods.

Figure S1. Distribution of patients by school grade.

Figure S2. (A) Cardiac etiology by the time of day of arrest.

Table S1. Clinical and outcome parameters by disease category (n=52)

Please find supplementary file(s);
http://dx.doi.org/10.1253/circj.CJ-13-1162

Europace Advance Access published April 19, 2013

Europace
doi:10.1093/europace/eut053

CLINICAL RESEARCH

Public access defibrillation improved the outcome after out-of-hospital cardiac arrest in school-age children: a nationwide, population-based, Utstein registry study in Japan

Yoshihide Mitani[1]*, Kunio Ohta[2], Noriko Yodoya[1], Shoichiro Otsuki[1], Hiroyuki Ohashi[1], Hirofumi Sawada[1], Masami Nagashima[3], Naokata Sumitomo[4], and Yoshihiro Komada[1]

[1]Department of Pediatrics, Mie University Graduate School of Medicine, 2-174 Edobashi, Tsu City, Mie Prefecture 514-8507, Japan; [2]Department of Pediatrics, Kanazawa University Graduate School of Medicine, 13-1 Takaramachi, Kanazawa City, Ishikawa Prefecture 920-8641, Japan; [3]Department of Pediatric Cardiology, Aichi Children's Health and Medical Center, 1-2 Osakada, Morioka-Machi, Obu City, Aichi Prefecture 474-8710, Japan; and [4]Department of Pediatrics, Nihon University Itabashi Hospital, 30-1 Otaniguchiuemachi, Itabashi Ward, Tokyo 173-8610, Japan

Received 14 November 2012; accepted after revision 12 February 2013

185

Aims The purpose of this study was to determine whether implementation of public access defibrillation (PAD) improves the outcome after out-of-hospital cardiac arrest (OHCA) in school-age children at national level.

Methods and results We conducted a prospective, nationwide, population-based Japanese Utstein registry study of consecutive OHCA cases in elementary and middle school children (7–15 years of age) who had a bystander-witnessed arrest of presumed cardiac origin during 2005–09 and received pre-hospital resuscitation by emergency responders. The primary endpoint was a favourable neurological outcome 1 month after an arrest. Among 230 eligible patients enrolled, 128 had ventricular fibrillation (VF) as an initial rhythm. Among these 128 patients, 29 (23%) children received a first shock by a bystander. Among these 29 patients, the proportion of the favourable neurological outcome after OHCA was 55%. During the study period, the proportion of patients initially shocked by a bystander among eligible patients increased from 2 to 21% ($P = 0.002$ for trend). The proportion of patients with a favourable neurological outcome after OHCA increased from 12 to 36% overall ($P = 0.006$). The collapse to defibrillation time was shorter in bystander-initiated defibrillation when compared with defibrillation by emergency responders (3.3 ± 3.7 vs. 12.9 ± 5.8 min, $P < 0.001$), and was independently associated with a favourable neurological outcome after OHCA [$P = 0.03$, odds ratio (OR) per 1 min increase, 0.90 (95% confidence interval 0.82–0.99)]. A non-family member's witness was independently associated with VF as the initial rhythm [$P < 0.001$, OR 4.03 (2.08–7.80)].

Conclusion Implementation of PAD improved the outcome after OHCA in school-age children at national level in Japan.

Keywords Cardiopulmonary resuscitation • Sudden unexplained death • School health • Public access defibrillation • School-age children

Introduction

Sudden cardiac death in elementary and middle school children is a rare but tragic event, which has tremendous impact on the family, school, communities, and health-care providers, and which may be relevant to cardiopulmonary resuscitation (CPR)/automated external defibrillator (AED) programmes in the public environment surrounding these children.[1,2] Recently, implementation of public

* Corresponding author. Tel: +81 59 231 5024; fax: +81 59 231 5213, Email: ymitani@clin.medic.mie-u.ac.jp

What's new?

- This is the first population-based study, which specifically addressed the impact of public access defibrillation on the outcome of out-of-hospital cardiac arrests (OHCAs) in elementary and middle school children.
- Among 230 eligible patients, 128 (56%) had ventricular fibrillation (VF) as an initial rhythm. Among these 128 patients, 29 (23%) children received a first shock by a bystander. Among these 29 patients, the proportion of the favourable neurological outcome after OHCA was 55%.
- During the study period 2005–09, the proportion of patients initially shocked by a bystander among eligible patients increased from 2 to 21%. The proportion of patients with a favourable neurological outcome after OHCA increased from 12 to 36% overall.
- A non-family member's witness was independently associated with VF as the initial rhythm. The collapse to defibrillation time was independently associated with a favourable neurological outcome, the survival at 1 month, and the pre-hospital return of spontaneous circulation after OHCA.

access defibrillation (PAD) improved outcomes among adults after out-of-hospital cardiac arrest (OHCA) in public locations, by reducing the time interval from the patient's collapse to defibrillation.[3–6] However, the impact of PAD on the outcome after OHCA in such school-age children was unclear. This question is challenging two-fold. First, paediatric patients of different ages have diverse aetiologies of OHCA; relatively poor survival has been reported in this heterogeneous group of patients.[7,8] The reported incidence of ventricular fibrillation (VF) as an initial rhythm in paediatric OHCA is lower than that reported in adults, and the effectiveness of early defibrillation programmes even for paediatric patients in VF arrest has been questioned.[7,8] Secondly, although school-age children are reported to spend a large part of their active daytime in public locations,[9] it is uncertain whether PAD programme, if any, would be effective for ordinary children in the children's public environment, including schools.[2,9–11] Recently, VF was found to be present in a higher percentage of high school-age athletes with sudden arrest, and recent small series have noted improved survival when early defibrillation with CPR was provided for such patients in high schools.[11–13] However, the limited deployment of AED devices in elementary and middle schools, and other public locations, a small sample size of OHCA in this age population in local studies, and the lack of an appropriate reporting system of OHCA, may have hampered any investigations involving the epidemiological basis of the benefit of PAD for OHCA in such school-age children.[11,12,14,15]

In Japan in July 2004, the Ministry of Health, Labour and Welfare approved AED use by citizens. By 2009, the number of AED devices in public places increased to 203 924 (106.6/100 000 population).[16,17] Of note, up to 28.9% of public access AED devices in Japan were placed in schools; by 2009, AEDs were placed in 72% of elementary schools and 89.8% of middle schools.[18,19] In January 2005, the Fire and Disaster Management Agency of Japan launched a prospective, nationwide, population-based, Utstein-style registry involving consecutive OHCA victims in all the age groups.[20] A recent study, using the Utstein registry database, demonstrated that there was a temporal increase in public access AED application and improved outcomes after OHCA in adults at the national level.[20] However, the impact of the national PAD programme on outcomes of OHCA in elementary and middle school children has not been reported. We therefore investigated whether PAD may have an impact on the outcome after OHCA in such school-age children at the national level, by using the Japanese Utstein registry database.[20,21]

Methods

Study design

The All-Japan registry of the Fire and Disaster Management Agency of Japan is a prospective, nationwide, population-based registry of OHCA, which is based on the standardized Utstein style, as reported in detail previously.[20,21] Briefly, this cohort enrolled all consecutive patients who suffered OHCA all over Japan, and were treated by emergency medical service (EMS) personnel and transported to hospitals. Specific enrolment process was described in Supplementary material online, Supplementary methods.[20,21] Among these patients, who had OHCA during January 2005–December 2009, we identified eligible patients who were 7–15 years of age, because we would include school-age students in compulsory education, which corresponds to the elementary and middle schools in Japan: high school students were thereby excluded. We identified those school-age victims with bystander-witnessed OHCA of presumed cardiac origin occurring during the entire day. Cardiac arrest was defined as the cessation of cardiac mechanical activity as confirmed by the absence of signs of circulation.[22–24] The arrest was presumed to be of cardiac origin unless it was caused by non-cardiac (respiratory disease, malignant tumours, and central nervous system disorders), external (trauma, hanging, drowning, drug overdose, and asphyxia) , or any other non-cardiac factors.[22–24] The data form was filled out by the EMS personnel in co-operation with the physicians in charge of the patients, and the data were integrated into the registry system on the database server. The working group for All-Japan Utstein registry designed the study protocol; collected and managed the data; and the authors analysed the data and wrote the manuscript. The protocol for analyses was approved by the Ethics Committee of Mie University Graduate School of Medicine.

Study setting

Emergency medical service and training system in Japan was previously reported in detail.[20,21] Briefly, Japan has an area of ~378 000 km², and its population was 127 million, including 3 666 839 male and 3 496 405 female 7–12-year-old children (elementary school students), and 1 871 134 male and 1 780 230 female 13–15-year-old children (middle school students) in 2005.[25] Placement of AEDs in public locations was driven by either public or private initiatives.[17] The cumulative number of public access AEDs, excluding those in medical facilities and EMS institutions, as estimated from sales of AEDs, increased from 9906 to 203 924 during the 5-year study period (see Supplementary material online, *Table*).[16] A total of 96.5% of public access AEDs are located in public locations (28.9% in schools, 20.6% in workplaces, 8.8% in nursing homes, 5.7% in sports facilities, 4.8% in cultural facilities, 2.6% in public transportation facilities, and 25.1% in other public locations), 1.4% in residential areas, and 2.1% in others.[18] From 2007 to 2009, the percentage of elementary or middle schools equipped with at least one AED device increased from 18.1 to 72.9% in elementary schools and from 38.3 to 89.8% in middle schools (see Supplementary material online, *Table*).[19] School teachers and other staff were trained in CPR programmes by EMS providers or other instructors, under the guidance of local school boards, in which paediatric and adult PADs were generally recommended for children at 7 years of age and older, respectively, in accordance with the Japanese CPR guidelines.[26] In Japan, ~1.4–1.5 million citizens per year participated in the CPR/AED training programmes, generally provided by local fire departments.[27]

Data collection

Procedure of data collection was described previously.[20,21] Briefly, registry data were prospectively collected in accordance with the Utstein-style reporting guidelines for OHCA, which is a standardized form (uniform definitions, terminology, and recommended data sets) for clinical investigators to report human resuscitation studies.[20,21,23,24] Specific data sets and data collecting process were described in Supplementary material online, Supplementary methods.[20,21,23,24] In the present Japanese Utstein reporting system, a patient initially shocked by a bystander was defined as one in which a public access AED was used and the shock was delivered; if the public access AED was applied but the shock was not delivered, the patient was not included in this category.[20,21] In this analysis, an OHCA witnessed by non-family members was presumed to be an event in a public location, because of a lack of data with respect to specific locations in the registry; when a bystander delivered shocks with an AED, the initial rhythm of the patient was regarded as VF, including pulseless ventricular tachycardia.

Endpoints

The primary endpoint was survival at 1 month with minimal neurological impairment, which was defined as a Glasgow–Pittsburg cerebral performance category of 1 (good performance) or 2 (moderate disability).[23,24] Secondary endpoints were survival at 1 month and return of spontaneous circulation (ROSC) before arrival at the hospital.

Statistical analysis

The age-stratified annual incidence of OHCA was calculated with the use of 2005 census data.[25] Continuous variables between two groups were assessed by the unpaired *t*-test. Trends in categorical and continuous variables were analysed with the use of univariate regression models and linear tests, respectively, in overall and subgroups of eligible patients, determined by the relation of bystanders to the victims (family or non-family member). The planned subgroup analysis was intended to determine the impact of PAD on trends in outcome parameters of arrest in presumed public locations (non-family member-witnessed arrests) in comparison with the non-public location arrest (family member-witnessed arrests). Univariate and multivariable logistic regression analyses were performed to assess the factors associated with VF as the initial rhythm, and outcome parameters. Adjusted and unadjusted odds ratios with their 95% confidence intervals and *P* values were reported. Potential confounding factors adjusted for VF as the initial rhythm included the calendar year, the age, gender, the relation of the bystander to the patient (family or non-family member), the type of CPR initiated by a bystander (compression-only or conventional CPR), and the time from the witnessed collapse to the EMS arrival, in accordance with previous reports.[20,21,28] Potential confounding factors for outcome parameters included VF as an initial rhythm, bystander's AED use at the first shock, and the time from the witnessed collapse to the first shock, in addition to the potential confounders for VF, in accordance with previous reports.[20,21,28] All statistical analyses were performed with the use of the SPSS statistical package, version 16.0J (SPSS). Data were reported as mean ± standard deviation. All tests were two-tailed, and *P* values of <0.05 were considered to indicate statistical significance.

Results

Among 2072 OHCA children, 522 were of presumed cardiac origin; 230 of 522 arrests were witnessed by bystanders (*Figure 1*). Among a total of 230 eligible patients, 128 (56%) children had VF as the initial rhythm. Among these 128 patients, 29 (23%) children received a first shock by bystanders using a public access AED before the arrival of EMS personnel and 96 (75%) children received a first shock by EMS personnel (32 with a monophasic and 64 with a biphasic defibrillator). In addition, among 102 patients without VF as the initial rhythm, none received bystander's defibrillation, but 13 (13%) received a shock by EMS personnel following CPR. Among 128 children with VF as the initial rhythm, 53 (41%) survived with a favourable neurological outcome, 67 (52%) survived 1 month after the arrest, and 55 (43%) had pre-hospital ROSC. Among the subset of 29 school-age children with OHCA who received initial AED shock by bystanders, 16 (55%) survived with favourable neurologic outcome, 19 (66%) survived 1 month after the arrest and 19 (66%) had prehospital ROSC. Among 102 patients without VF as the initial rhythm, 8 (8%) survived with favourable neurological outcome, 15 (15%) survived 1 month after the arrest and 11 (11%) had pre-hospital ROSC. The time interval from collapse to the initiation of CPR was shorter in bystander-initiated CPR than EMS-initiated CPR (3.2 ± 4.9 vs. 8.9 ± 6.8 min, $P < 0.001$). The interval from collapse to the initiation of AED use was shorter in bystander-initiated AED use than EMS-initiated one (3.3 ± 3.7 vs. 12.9 ± 5.8 min, $P < 0.001$). Clinical and outcome parameters in the overall, family and non-family member witnessed arrests were reported in *Table 1*. The population-based age-stratified incidence of bystander-witnessed OHCA of presumed cardiac origin in children was constant during the study period (see Supplementary material online, *Table*).

Trends in clinical and outcome parameters

During the study period (*Table 2*), the proportion of patients initially shocked by a bystander's AED among total patients increased from 2% in 2005 to 21% in 2009 ($P = 0.002$). Such a temporal increase was observed in non-family member-witnessed arrests, from 4% in 2005 to 37% in 2009 ($P = 0.001$), but not in family member-witnessed arrests. The collapse to AED time tended to become shorter only in non-family member-witnessed arrests, from 11.1 min in 2005 to 8.3 min in 2009 ($P = 0.07$). The proportion of any other categorical and continuous variables investigated in either subgroup of patients did not change significantly (see Supplementary material online, *Appendix 1*). As the outcome parameters (*Figure 2*), the proportion of patients with a favourable neurological outcome among total patients increased from 12% in 2005 to 36% in 2009 ($P = 0.006$). Such a temporal improvement was observed only in non-family member-witnessed arrests, from 9% in 2005 to 53% in 2009 ($P = 0.001$). The proportion of survival at 1 month after OHCA ($P = 0.008$) and ROSC before arrival at the hospital ($P = 0.046$) increased only in non-family member-witnessed arrests, from 17 and 17% in 2005 to 53 and 42% in 2009, respectively. Trends in specific values in all the clinical and outcome parameters investigated in overall and subgroups of patients were reported (see Supplementary material online, *Appendix 1*).

Multivariable analysis

In multivariable analysis (*Table 3*), a non-family member's witness [$P < 0.001$, adjusted odds ratio (OR) 4.03 (2.08–7.80)] was independently associated with the presence of VF as the initial rhythm. The collapse to AED time, either by a bystander or an emergency responder [$P = 0.03$, OR per 1 min increase, 0.90 (0.82–0.99)], and female gender [$P = 0.008$, 3.20 (1.35–7.56)] were independently associated with a favourable neurological outcome. The collapse to AED time was the only variable independently associated with the survival at 1 month [$P = 0.045$, 0.92 (0.85–0.99)] and pre-hospital ROSC [$P = 0.001$, 0.82 (0.73–0.92)]. Results of univariate analysis were reported in the see Supplementary material online, *Appendix 2*.

Discussion

Although the epidemiological data related to the impact of disseminating PAD programmes on OHCA in elementary and middle school children were limited,[7,8] the present Utstein registry study would supply evidence supporting that implementation of PAD programmes increases the likelihood of early defibrillation by bystanders, and improves the outcome after OHCA in such school-age children. These findings may underscore the benefit of PAD in the prevention of sudden cardiac death in school-age children.

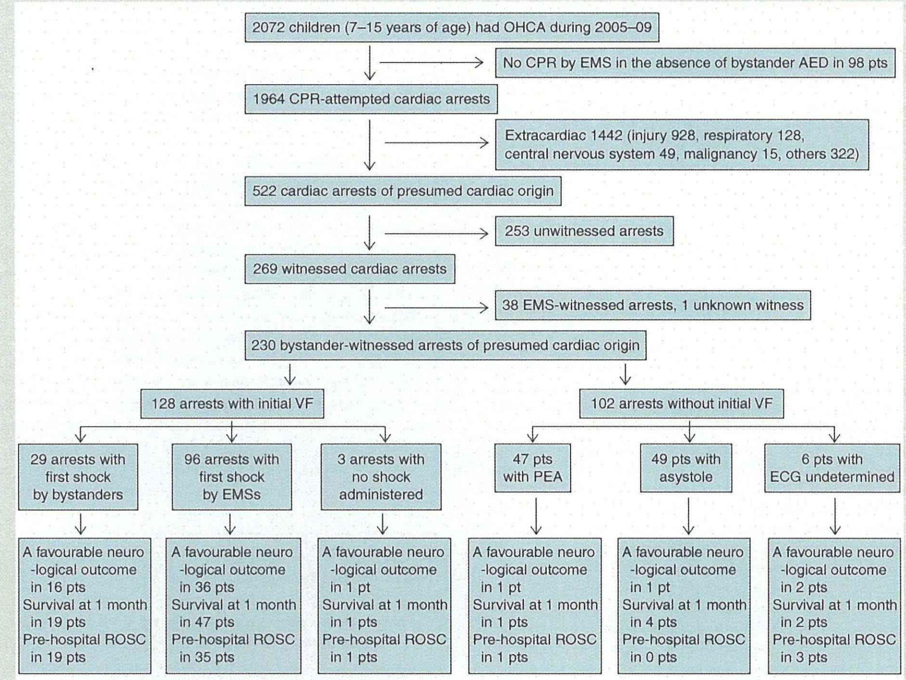

Figure 1 Study profile. OHCA, out-of-hospital cardiac arrest; CPR, cardiopulmonary resuscitation; EMS, emergency medical service; AED, automated external defibrillator; VF, ventricular fibrillation; PEA, pulseless electrical activity; ECG, electrocardiography; ROSC, return of spontaneous circulation; pts, patients.

Table 1 Clinical and outcome parameters

Parameters	Total (n = 230)	Family witnessed (101)	Non-family witnessed (129)
Age, years of age	12.2 ± 2.5	11.3 ± 2.7	12.8 ± 2.1
Male gender, n (%)	145 (63)	63 (62)	82 (64)
Ventricular fibrillation, n (%)	128 (56)	37 (37)	91 (71)
CPR initiated by bystanders, n (%)	161 (70)	55 (55)	106 (82)
Conventional CPR, n (%)	102 (64)	30 (55)	72 (69)
Collapse to CPR time (min)	4.9 ± 6.1	5.3 ± 6.3	4.6 ± 6.0
Shock initiated, n (%)			
by bystanders	29 (13)	2 (2)	27 (21)
by EMS	109 (47)	38 (38)	71 (55)
Collapse to AED time (min)	10.9 ± 6.7	13.1 ± 7.0	10.0 ± 6.4
Collapse to EMS arrival (min)	34.6 ± 17.2	35.0 ± 16.5	34.3 ± 17.7
Favourable neurological outcome, n (%)	63 (27)	15 (15)	48 (37)
Survival at 1month, n (%)	84 (37)	22 (22)	62 (48)
Prehospital ROSC, n (%)	66 (29)	20 (20)	46 (36)

Favourable neurological outcome denotes cerebral performance category 1 or 2 at 1 month.
Conventional CPR indicated chest compression with rescue breathing, as a type of bystander-initiated CPR. Percentages were calculated on the basis of the available data in overall or each subgroup of arrests (family or nonfamily witnessed). Plus–minus values are means ± SD.
CPR, cardiopulmonary resuscitation; EMS, emergency medical service; AED, automated external defibrillator; ROSC, return of spontaneous circulation.

Table 2 Trends in clinical parameters

Variables	2005	2006	2007	2008	2009	P value for trend
Type of bystanders, (n)						
Total	41	46	51	48	44	
Family member	18	18	21	19	25	0.27
Non-family member	23	28	30	29	19	
CPR initiated by bystanders, n (%)						
Total	26 (63)	33 (72)	36 (72)	37 (77)	29 (66)	0.65
Family member	8 (44)	9 (50)	12 (60)	12 (63)	14 (56)	0.35
Non-family member	18 (78)	24 (86)	24 (80)	25 (86)	15 (79)	0.90
Shock initiated by bystanders, n (%)						
Total	1 (2)	1 (2)	10 (20)	8 (17)	9 (21)	0.002
Family member	0 (0)	0 (0)	0 (0)	0 (0)	2 (8)	0.99
Non-family member	1 (4)	1 (4)	10 (33)	8 (28)	7 (37)	0.001
Shock initiated by EMS, n (%)						
Total	18 (44)	24 (52)	26 (51)	19 (40)	22 (50)	0.94
Family member	6 (33)	3 (17)	10 (48)	7 (37)	12 (48)	0.14
Non-family member	12 (52)	21 (75)	16 (53)	12 (41)	10 (53)	0.22
Collapse to AED time (min)						
Total	11.8 ± 4.8	12.5 ± 5.4	10.4 ± 7.2	10.2 ± 6.2	10.3 ± 8.4	0.22
Family member	13.5 ± 7.2	14.3 ± 4.6	13.3 ± 4.4	12.7 ± 3.0	12.6 ± 10.3	0.71
Non-family member	11.1 ± 3.2	12.2 ± 5.5	9.2 ± 7.8	9.4 ± 6.8	8.3 ± 5.9	0.07

Percentages were calculated on the basis of the available data in overall or each subgroup of arrests (family or non-family witnessed) in the respective year. Plus-minus values are means ± SD.
CPR, cardiopulmonary resuscitation; EMS, emergency medical service; AED, automated external defibrillator.

187

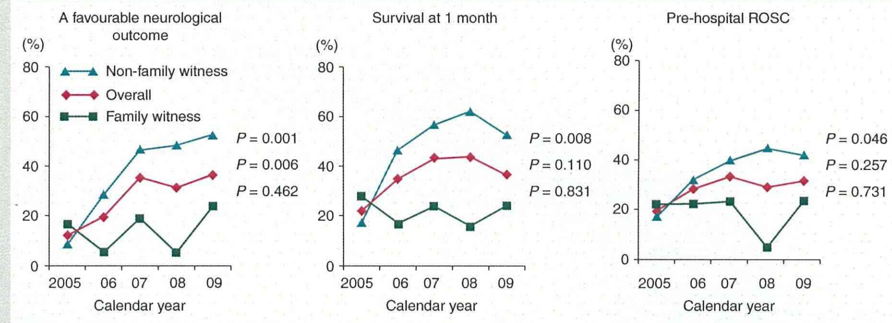

Figure 2 Trends in outcome parameters in arrests, by the relationship of a bystander to the victim. P values are for trend; ROSC, return of spontaneous circulation.

Table 3 Multivariable analyses of factors associated with ventricular fibrillation as the initial rhythm and outcome parameters

Variable	Ventricular fibrillation Adjusted OR (95% CI)	Favourable neurological outcome Adjusted OR (95% CI)	Survival at 1 month Adjusted OR (95% CI)	Pre-hospital ROSC Adjusted OR (95% CI)
Year (per 1-year increase)	1.09 (0.87–1.37)	1.19 (0.87–1.63)	0.97 (0.73–1.30)	0.80 (0.58–1.10)
P value	0.46	0.29	0.86	0.17
Age≥13 years	1.83 (0.96–3.48)	1.79 (0.76–4.20)	1.60 (0.72–3.54)	1.60 (0.67–3.80)
P value	0.07	0.18	0.25	0.29
Female gender	0.76 (0.39–1.47)	3.20 (1.35–7.56)	1.80 (0.79–4.10)	2.17 (0.91–5.19)
P value	0.41	0.008	0.16	0.08
Non-family witnessed	4.03 (2.08–7.80)	1.53 (0.58–4.03)	1.68 (0.70–4.02)	0.86 (0.32–2.29)
P value	<0.001	0.39	0.27	0.76
CPR				
Not bystander-initiated	reference	reference	reference	reference
Bystander-initiated				
Conventional	0.76 (0.35–1.65)	1.01 (0.34–3.00)	1.24 (0.45–3.43)	0.90 (0.29–2.78)
P value	0.49	0.98	0.68	0.86
Compression only	0.79 (0.34–1.83)	1.55 (0.51–4.71)	1.08 (0.38–3.06)	1.77 (0.58–5.46)
P value	0.58	0.44	0.88	0.32
Collapse–EMS time (per 1 min increase)	0.99 (0.97–1.37)	1.00 (0.98–1.03)	1.00 (0.98–1.03)	1.01 (0.99–1.04)
P value	0.30	0.74	0.89	0.33
Ventricular fibrillation as the initial rhythm		2.03 (0.43–9.46)	1.30 (0.34–4.91)	0.76 (0.18–3.20)
P value		0.37	0.70	0.71
Bystander's AED		0.49 (0.12–2.02)	0.59 (0.15–2.23)	0.61 (0.14–2.76)
P value		0.32	0.43	0.53
Collapse–AED time (per 1-min increase)		0.90 (0.82–0.99)	0.92 (0.85–0.99)	0.82 (0.73–0.92)
P value		0.03	0.045	0.001

Favourable neurological outcome denotes cerebral performance category 1 or 2 at 1 month.
OR, odds ratio; ROSC, return of spontaneous circulation; EMS, emergency medical service; CPR, cardiopulmonary resuscitation; AED, automated external defibrillator.

Impact of public access defibrillation on out-of-hospital cardiac arrest in school-age children

Between 2005 and 2009 in Japan, there was a remarkable increase in the availability of AED in public spaces surrounding school children, including schools.[16–19] During this period, there was an increase in the proportion of OHCA in which the victim was initially shocked by a bystander, and this was temporally associated with an improvement in the neurological outcome in children with OHCA. In subgroup analyses, (i) temporal trends in these parameters were evident in non-family member-witnessed arrests, but not in family member-witnessed arrests, (ii) similar trends in secondary outcome parameters were observed in non-family member-witnessed arrests, and (iii) trends in other clinical parameters were not affected in either subgroup of patients during the same period. Therefore, trends in relevant variables, together with multivariable analysis data, consistently support that introduction of PAD programmes would increase the likelihood of early defibrillation by bystanders, and improve the outcomes of school-age children after public location arrest. Such an impact of PAD on OHCA in school-age children is consistent with that reported in adults.[20] In an adult study (≥18 years of age) by using the same Japanese Utstein registry data during 2005–07, 32% of patients with bystander-witnessed OHCA of presumed cardiac origin with initial rhythm of VF who received bystander AED shock delivery had a favourable neurological outcome.[20] In the present study during the corresponding years 2005–07 (data not shown), 58% (7/12) of children who received bystander-initiated shock had a favourable neurological outcome. In other adult studies, the survival rate of OHCA patients initially shocked by a bystander was ~60%.[3,4,6,13] Thus, the survival to 1 month with good neurological outcome of school-age children who experience witnessed OHCA with bystander CPR and AED shock delivery appears to equal or surpass that reported in adults. The more favourable outcome in this paediatric population may result from the higher rate of bystander CPR, and the shorter collapse to CPR and collapse to AED shock delivery intervals than those observed in adults with OHCA during the same period in Japan. This may be explained in part by factors in the school environment, such as constant visual observation of the children and focused training of teachers and staff.

188

Frequency of ventricular fibrillation as the initial rhythm in out-of-hospital cardiac arrest in school-age children

The frequency of VF in OHCA in children has been debated for a decade, and has been negatively influenced by the young age (<1 year of age), and traumatic and respiratory aetiologies.[7,8,14,15] In the present study, as high as 56% of bystander-witnessed arrests of presumed cardiac origin in school-age children were associated with VF. This is consistent with the results in local studies (in King county of USA, and in a province of the Netherlands), in which the frequency of VF has been positively associated with the advanced age (≥8 years of age), witnessed arrest, and cardiac aetiology, and a half of arrest patients had an initial rhythm of VF among adolescents aged 13–18 years with witnessed arrest.[11,29] In our study, we could further demonstrate that the non-family member-witnessed arrest was independently associated with VF as the initial rhythm, which is consistent with the results in an adult study.[28] The relatively low proportion of initial VF in adolescent OHCA in ROC study may be related to the difference of witness status, aetiology, and the reporting system.[14] The present study suggests that the relatively high proportion of initial VF in bystander-witnessed OHCAs of presumed cardiac origin in public locations in school-age children may confer an epidemiological basis for early defibrillation in this age population.

Limitations

Several limitations could be acknowledged in this study, in addition to those, as described previously.[20,21] First, the proportion of OHCA patients in schools among total eligible samples is unknown, because of the lack of data with respect to school as a specific location in the registry. Secondly, there might be unmeasured confounding factors (i.e. quality of bystander's CPR) that might influence the association between bystander's defibrillation and outcomes. Thirdly, information on in-hospital treatment (ie, hypothermia) is unavailable, which might affect survival after OHCA. Fourthly, it is unknown whether the present information can be generalized to other communities with different emergency response programmes at schools and other public locations surrounding children,[18,19] or different EMS systems.[20] Fifthly, the present investigation is not a cost-effectiveness analysis, although a previous study of cardiac arrests in high schools indicated that PAD may be cost-effective in schools.[12] Sixthly, specific data on the scope of the budgetary barriers and logistic issues (i.e. the locations of AED placement, training schedule for teachers) in implementing and refining AED/CPR programmes at the national level in Japan is unavailable.[17]

Conclusions

Although the impact of PAD has been largely elusive in overall children of different ages after etiologically diverse OHCAs in their public environmnent,[7,8] the present study would supply evidence which could dissect an epidemiological basis of the benefit of PAD in school-age children after bystander-witnessed OHCA of presumed cardiac origin. We believe that these findings are relevant to medical emergency response and CPR/AED programmes in the public environment surrounding school-age children.[1,2]

Supplementary material

Supplementary material is available at *Europace* online.

Acknowledgement

We thank the emergency medical personnel and participating physicians in Japan, and the Fire and Disaster Management Agency and Institute for Fire Safety and Disaster Preparedness of Japan, for generously gifting their Utstein database.

Conflict of interest: none declared.

Funding

This study was supported by grants from the Ministry of Education, Culture, Sports, Science, and Technology (21590558 to K.O., 24791056 to H.O.), the Ministry of Health, Labour, and Welfare (H-18-myocardium-01 to K.O., 2010-145 to N.K.), and Miyata Pediatric Heart Disease Research Fund (to Y.M.).

References

1. Hazinski MF, Markenson D, Neish S, Gerardi M, Hootman J, Nichol G *et al.* Response to cardiac arrest and selected life-threatening medical emergencies: the medical emergency response plan for schools: a statement for healthcare providers, policymakers, school administrators, and community leaders. *Circulation* 2004;**109**:278–91.
2. Cave DM, Aufderheide TP, Beeson J, Ellison A, Gregory A, Hazinski MF *et al.* Importance and implementation of training in cardiopulmonary resuscitation and automated external defibrillation in schools: a science advisory from the American Heart Association. *Circulation* 2011;**123**:691–706.
3. Valenzuela TD, Roe DJ, Nichol G, Clark LL, Spaite DW, Hardman RG. Outcomes of rapid defibrillation by security officers after cardiac arrest in casinos. *N Engl J Med* 2000;**343**:1206–9.
4. Page RL, Joglar JA, Kowal RC, Zagrodzky JD, Nelson LL, Ramaswamy K *et al.* Use of automated external defibrillators by a U.S. Airline. *N Engl J Med* 2000;**343**: 1210–6.
5. Hallstrom AP, Ornato JP, Weisfeldt M, Travers A, Christenson J, McBurnie MA *et al.* Public-access defibrillation and survival after out-of-hospital cardiac arrest. *N Engl J Med* 2004;**351**:637–46.
6. Caffrey SL, Willoughby PJ, Pepe PE, Becker LB. Public use of automated external defibrillators. *N Engl J Med* 2002;**347**:1242–7.
7. Donoghue AJ, Nadkarni V, Berg RA, Osmond MH, Wells G, Nesbitt L *et al.* Out-of-hospital pediatric cardiac arrest: an epidemiologic review and assessment of current knowledge. *Ann Emerg Med* 2005;**46**:512–22.
8. Young KD, Gausche-Hill M, McClung CD, Lewis RJ. A prospective, population-based study of the epidemiology and outcome of out-of-hospital pediatric cardiopulmonary arrest. *Pediatrics* 2004;**114**:157–64.
9. Nitta M, Iwami T, Kitamura T, Nadkarni VM, Berg RA, Shimizu N *et al.* Age-specific differences in outcomes after out-of-hospital cardiac arrests. *Pediatrics* 2011;**128**:e812–20.
10. Lotfi K, White L, Rea T, Cobb L, Copass M, Yin L *et al.* Cardiac arrest in schools. *Circulation* 2007;**116**:1374–9.
11. Bardai A, Berdowski J, van der Werf C, Blom MT, Ceelen M, van Langen IM *et al.* Incidence, causes, and outcomes of out-of-hospital cardiac arrest in children. A comprehensive, prospective, population-based study in the Netherlands. *J Am Coll Cardiol* 2011;**57**:1822–8.
12. Berger S, Whitstone BN, Frisbee SJ, Miner JT, Dhala A, Pirrallo RG *et al.* Cost-effectiveness of project ADAM: a project to prevent sudden cardiac death in high school students. *Pediatr Cardiol* 2004;**25**:660–7.
13. Drezner JA, Rao AL, Heistand J, Bloomingdale MK, Harmon KG. Effectiveness of emergency response planning for sudden cardiac arrest in United States high schools with automated external defibrillators. *Circulation* 2009;**120**:518–25.
14. Atkins DL, Everson-Stewart S, Sears GK, Daya M, Osmond MH, Warden CR *et al.* Epidemiology and outcomes from out-of-hospital cardiac arrest in children: the Resuscitation Outcomes Consortium Epistry-Cardiac Arrest. *Circulation* 2009; **119**:1484–91.
15. Zideman DA, Hazinski MF. Background and epidemiology of pediatric cardiac arrest. *Pediatr Clin North Am* 2008;**55**:847–859, ix.
16. Report on a study on social system development to improve survival from emergency cardiovascular disease using automated external defibrillator (Marukawa's report)(in Japanese)(23 June 2011). http://kouroukaken-kyukyusosei.Info/wpm/archivepdf/21/2_11a.Pdf
17. Mitamura H. Public access defibrillation: Advances from Japan. *Nat Clin Pract Cardiovasc Med* 2008;**5**:690–2.
18. Japanese Foundation for Eemergency Medicine: A search for information on placement of AEDS (in Japanese) (23 June 2011). http://www.Qqzaidan.Jp/aed/aed.Htm
19. *National Survey on AED Placement at Schools* (in Japanese) (23 July 2011). http://www.Mext.Go.Jp/a_menu/gakkouanzen/syousai/__icsfiles/afieldfile/2009/06/17/1267499_2.Pdf
20. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Hiraide A. Nationwide public-access defibrillation in Japan. *N Engl J Med* 2010;**362**:994–1004.
21. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Nadkarni VM *et al.* Conventional and chest-compression-only cardiopulmonary resuscitation by bystanders for children who have out-of-hospital cardiac arrests: a prospective, nationwide, population-based cohort study. *Lancet* 2010;**375**: 1347–54.
22. Zaritsky A, Nadkarni V, Hazinski MF, Foltin G, Quan L, Wright J *et al.* Recommended guidelines for uniform reporting of pediatric advanced life support: the pediatric Utstein style. A statement for healthcare professionals from a task force of the American Academy of Pediatrics, the American Heart Association, and the European Resuscitation Council Writing Group. *Circulation* 1995;**92**: 2006–20.
23. Cummins RO, Chamberlain DA, Abramson NS, Allen M, Baskett PJ, Becker L *et al.* Recommended guidelines for uniform reporting of data from out-of-hospital cardiac arrest: the Utstein style. A statement for health professionals from a task force of the American Heart Association, the European Resuscitation Council, the Heart and Stroke Foundation of Canada, and the Australian Resuscitation Council. *Circulation* 1991;**84**:960–75.
24. Jacobs I, Nadkarni V, Bahr J, Berg RA, Billi JE, Bossaert L *et al.* Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries: a statement for healthcare professionals from a task force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand Resuscitation Council, Heart and Stroke Foundation of Canada, Inter-American Heart Foundation, Resuscitation Councils of Southern Africa). *Circulation* 2004;**110**:3385–97.
25. *Vital Statistics of Japan 2005*. Tokyo: Health and welfare statistics association, 2011 (in Japanese) (23 June 2011). http://www.Stat.Go.Jp/data/kokusei/2005/index.Htm.
26. *Japanese Guidelines for Emergency Care and Cardiopulmonary Resuscitation*. Tokyo: Health Shuppansha; 2007.
27. Ministry of International Affairs and Communications. *Ambulance Service and Emergency Responses in 2010*. (in Japanese) (23 June 2011). http://www.Fdma.Go.Jp/neuter/topics/houdou/2212/221203_1houdou/01_houdoushiryou.Pdf).
28. Weisfeldt ML, Everson-Stewart S, Sitlani C, Rea T, Aufderheide TP, Atkins DL *et al.* Ventricular tachyarrhythmias after cardiac arrest in public versus at home. *N Engl J Med* 2011;**364**:313–21.
29. Moler FW, Donaldson AE, Meert K, Brilli RJ, Nadkarni V, Shaffner DH *et al.* Multicenter cohort study of out-of-hospital pediatric cardiac arrest. *Crit Care Med* 2011; **39**:141–9.

Appendix 1 Trends in all the clinical and outcome parameters investigated in family and nonfamily member witnessed arrests.

Variables	2005	2006	2007	2008	2009	p value for trend
Type of bystanders--n						
Total	41	46	51	48	44	
Family member	18	18	21	19	25	.27
Nonfamily member	23	28	30	29	19	
Age--years of age						
Total	11.8±2.5	11.8±2.8	12.6±2.1	12.3±2.5	12.3±2.5	.22
Family member	11.4±2.5	9.6±2.6	11.8±2.4	11.5±2.7	12.0±2.7	.07
Nonfamily member	12.0±2.5	13.3±1.8	13.2±1.6	12.8±2.3	12.5±2.2	.71
Male gender--n (%)						
Total	26(63)	29(63)	35(69)	28(58)	27(61)	.69
Family member	10(56)	10(56)	17(81)	11(58)	15(60)	.82
Nonfamily member	16(70)	19(68)	18(60)	17(59)	12(63)	.44
Ventricular fibrillation --n (%)						
Total	20(49)	22(48)	33(65)	25(52)	28(64)	.16
Family member	7(39)	2(11)	8(38)	7(37)	13(52)	.10
Nonfamily member	13(57)	20(71)	25(83)	18(62)	15(79)	.31
CPR initiated by a bystander--n (%)						
Total	26(63)	33(72)	36(72)	37(77)	29(66)	.65

Family member	8(44)	9(50)	12(60)	12(63)	14(56)	.35
Nonfamily member	18(78)	24(86)	24(80)	25(86)	15(79)	.90
Collapse to CPR time--min						
Total	4.9±6.5	4.5±6.0	4.6±7.0	5.2±4.9	5.3±6.1	.56
Family member	4.7±6.5	7.7±3.2	3.4±5.3	5.9±4.9	6.4±8.4	.52
Nonfamily member	4.7±5.3	4.1±6.7	4.8±7.8	4.8±4.2	4.3±4.6	.93
Conventional CPR--n(%)						
Total	20(77)	22(67)	23(68)	23(62)	14(48)	.04
Family member	5(63)	7(78)	7(58)	6(50)	5(36)	.08
Nonfamily member	15(83)	15(63)	16(73)	17(68)	9(60)	.29

Shock initiated						
by bystanders--n (%)						
Total	1(2)	1(2)	10(20)	8(17)	9(21)	.002
Family member	0(0)	0(0)	0(0)	0(0)	2(8)	.99
Nonfamily member	1(4)	1(4)	10(33)	8(28)	7(37)	.001
by EMS--n (%)						
Total	18(44)	24(52)	26(51)	19(40)	22(50)	.94
Family member	6(33)	3(17)	10(48)	7(37)	12(48)	.14
Nonfamily member	12(52)	21(75)	16(53)	12(41)	10(53)	.22

Collapse to AED time--min						
Total	11.8±4.8	12.5±5.4	10.4±7.2	10.2±6.2	10.3±8.4	.22
Family member	13.5±7.2	14.3±4.6	13.3±4.4	12.7±3.0	12.6±10.3	.71
Nonfamily member	11.1±3.2	12.2±5.5	9.2±7.8	9.4±6.8	8.3±5.9	.07
Collapse to EMS arrival--min						
Total	42.1±17.2	32.8±12.0	30.8±10.9	32.3±10.7	37.0±20.7	.42
Family member	37.8±13.5	32.4±12.9	30.9±7.9	30.4±7.2	41.1±25.3	.36
Nonfamily member	44.9±33.5	33.0±11.6	30.7±12.6	33.6±12.5	31.5±10.8	.06
Favorable neurological outcome--n (%)						
Total	5(12)	9(20)	18(35)	15(31)	16(36)	.006
Family member	3(17)	1(6)	4(19)	1(5)	6(24)	.46
Nonfamily member	2(9)	8(29)	14(47)	14(48)	10(53)	.001
Survival at one month--n (%)						
Total	9(22)	16(35)	22(43)	21(44)	16(36)	.11
Family member	5(28)	3(17)	5(24)	3(16)	6(24)	.83
Nonfamily member	4(17)	13(46)	17(57)	18(62)	10(53)	.008
Prehospital ROSC-n (%)						
Total	8(20)	13(28)	17(33)	14(29)	14(32)	.26
Family member	4(22)	4(22)	5(24)	1(5)	6(24)	.73
Nonfamily member	4(17)	9(32)	12(40)	13(45)	8(42)	.046