Incidence and Characteristics of Ventricular Fibrillation in Bystander-witnessed Out-of-hospital Cardiac Arrest with Cardiac Etiology in the City of Sendai, Japan

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Ventricular fibrillation (VF) in out-of-hospital cardiac arrest (OHCA) is a main target for resuscitation.

Methods and results: We analyzed Utstein-style data in Sendai City (population 1,020,000), Japan from January 2002 to March 2004. The incidence of OHCA overall was 62.3/100,000/year. The incidence of the bystander-witnessed VF was 2.5/100,000/year. In younger patients (20–65 years of age), the percentage of VF was 52% when cardiac origin was presumed by bystander witness, and ECG was recorded within 10 minutes from the collapse. In older patients (over 65 years of age), however, the percentage of VF was 21% when they were bystander-witnessed, and ECG was recorded within 10 minutes from the collapse. No VF was reported when the ECG was recorded more than 15 minutes after the collapse. The thirty-day survival rate was 21% in the bystander-witnessed VF cases with cardiac etiology, but 0% in the non-VF cases. The bystander CPR was significantly associated with improved 30-day survival rate. Conclusion: Younger age, male gender, and shorter collapse-to-ECG time are significantly associated with the appearance of VF in bystander-witnessed OHCA with cardiac etiology. Bystander CPR was significantly associated with the improvement in prognosis of those VF patients.


Key words: Utstein style, Resuscitation, Defibrillation, Brugada syndrome

Introduction

Out-of-hospital cardiac arrest (OHCA) is an important healthcare problem in Japan. Recent reports showed that the incidence of OHCA in the general population was comparable to that of west-
ern countries, and the incidence of sudden death in patients with heart failure was also nearly identical. It is well recognized that OHCA with ventricular fibrillation (VF) including pulseless ventricular tachycardia is the most important target for resuscitation, and early defibrillation is a key link for survival. Several public access defibrillator studies demonstrated that many patients were successfully resuscitated and survived after early defibrillation. However, Nishiuchi et al. reported that the percentage of VF in the bystander-witnessed OHCA with cardiac etiology in Japan was remarkably lower than that of western countries. The low percentage of VF is a serious problem in planning for the local emergency medical system that includes automated external defibrillators (AED). Therefore, we need to investigate the characteristics of VF. Particularly, what factors correlate to the fact that the first ECG demonstrates VF.

**Methods**

From January 2002, the emergency medical service (EMS) in Sendai City, Japan recorded OHCA cases according to the Utstein style. Sendai City is the largest city in the northeast area of Honshu Island, Japan and has an area of 788 km². The resident population is approximately 1,020,000, and the population over 65 years of age accounts for 15%. The total number of deaths from all causes was 5,554 in 2002, and those related to cardiac etiology represented 832 cases in the official death records. Ambulances with emergency life guard staff were dispatched from the 19 fire stations in response to emergency call from citizens. EMS was entirely public and operated by the city government. Emergency life-saving technicians were well trained for basic life support including the use of an AED. Sendai City Fire Bureau has educated approximately 160,000 citizens in cardiopulmonary resuscitation (CPR).

**Organization of the study**

We organized a task group called “RESCUED (Regional Survey of Cardiac UnExpected Death)” which included the representatives of Sendai City Fire Bureau, the local medical control directors and physicians in cardiovascular medicine and emergency medicine of Tohoku University Hospital. This study was a prospective observational study and was approved by the local ethics committee of Tohoku University Graduate School of Medicine. Utstein style data (from January 1st, 2002 to March 31st, 2004) were provided from the Sendai City Fire Bureau without private information including name, address (only name of the ward was provided) and birth date (only age was provided). Emergency life-saving technicians first applied AED when they encountered an unconscious patient without the signs of circulation, and evaluated the cardiac rhythm. According to the American Heart Association state-

![Figure 1](image.png)

**Figure 1** Summary of the out-of-hospital cardiac arrest (OHCA) patients of the present study. Cardiac etiology accounted for 47% of bystander witnessed OHCA patients. Ventricular fibrillation (VF) accounted for 23% of those bystander-witnessed OHCA.
cardiac rhythm was categorized into ventricular fibrillation (VF) and non-VF, with non-VF including asystole and pulseless electrical activity (PEA). Pulseless ventricular tachycardia was categorized as VF. The presence of bystander CPR was evaluated and recorded by the EMS staff. In some cases, only chest compression was performed without artificial breathing.

OHCA was categorized as cardiac etiology or non-cardiac etiology according to the Utstein guidelines. The assessment was first performed by the EMS staff, and was corrected based on examinations after hospitalization if required.

Data Analysis

Data were shown in mean ± standard deviation. The statistical comparison of incidence was performed by the χ²-test. Differences in the mean values of continuous parameters were tested by unpaired t-test. Factors associated with the fact that the first ECG demonstrated VF (i.e., appearance of VF), and 30-day in-hospital death in VF patients were tested by multivariate logistic regression analysis. P < 0.05 was considered statistically significant. Statistic calculation was performed by package software StatView 5.0 (SAS, Cary, NC).

Table 1

<table>
<thead>
<tr>
<th>Number of cases</th>
<th>Non-VF</th>
<th>VF</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male (%)</td>
<td>109 (56)</td>
<td>51 (89)</td>
<td>—</td>
</tr>
<tr>
<td>Age (mean ± SD)</td>
<td>73 ± 14</td>
<td>61 ± 13</td>
<td>p &lt; 0.0001</td>
</tr>
<tr>
<td>Number of those 20–65 years of age</td>
<td>44 (23)</td>
<td>34 (60)</td>
<td>p &lt; 0.0001</td>
</tr>
<tr>
<td>Call-to-arrival time (min)</td>
<td>8.4 ± 3.5</td>
<td>6.8 ± 2.0</td>
<td>p = 0.015</td>
</tr>
<tr>
<td>Collapse-to-ECG time (min)</td>
<td>11.7 ± 8.3</td>
<td>6.3 ± 3.6</td>
<td>p &lt; 0.0001</td>
</tr>
<tr>
<td>Bystander CPR provided (%)</td>
<td>75 (39)</td>
<td>28 (49)</td>
<td>p = 0.15</td>
</tr>
</tbody>
</table>

OHCA Out-of-hospital cardiac arrest, VF ventricular fibrillation, CPR cardiopulmonary resuscitation.

Table 2

<table>
<thead>
<tr>
<th>Number of cases</th>
<th>Non VF</th>
<th>VF</th>
<th>Percentage of VF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 20–65, collapse-to-ECG time ≤ 10 min</td>
<td>58</td>
<td>28</td>
<td>30</td>
</tr>
<tr>
<td>Age 20–65, collapse-to-ECG time &gt; 10 min</td>
<td>20</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>Age over 65, collapse-to-ECG time ≤ 10 min</td>
<td>97</td>
<td>77</td>
<td>20</td>
</tr>
<tr>
<td>Age over 65, collapse-to-ECG time &gt; 10 min</td>
<td>77</td>
<td>74</td>
<td>3</td>
</tr>
</tbody>
</table>

OHCA Out-of-hospital cardiac arrest.

Results

During 27 months of the study period, 1430 resuscitation-attempted OHCA patients were identified (62.3/100,000/year), excluding patients younger than 20 years of age. Figure 1 shows summary of the cases. There were 669 patients with cardiac etiology, and these accounted for 47% of the cases overall. Out of those 669 OHCA patients with cardiac etiology, 252 patients (38%) were witnessed by bystanders, and 70 patients (10%) were witness by EMS staff. Unfortunately, 347 patients (52%) were not witnessed. The OHCA patients with cardiac etiology mainly occurred in their residences (76%, 510/669) and in the other facilities (16%, 110/669, mainly nursing homes). The OHCA patients with cardiac etiology that occurred outside accounted for 7% (48/669). One patient lacked the location data.

We focused on bystander-witnessed OHCA cases with cardiac etiology in the present study. Table 1 summarizes the basic characteristics. We identified 57 patients who showed VF at the first ECG recording after collapse. The incidence of bystander-witnessed OHCA cases with cardiac etiology was 11.0/100,000/year, and the incidence of the bystander-witnessed VF was 2.5/100,000/year. Of the 57 VF patients, patients were more likely to be male and younger. The time from the collapse-to-ECG was clearly shorter in patients with VF than in those with non-VF. Bystander (non-EMS staff) CPR was done in 39% of non-VF patients and 49% of VF patients. Bystander CPR was frequently performed in the nursing home (95%, 21/22), but less frequently done at home (35%, 62/176) and other sites (43%, 23/54, mostly public places).

Table 2 shows the number of VF and non-VF cases categorized by age and collapse-to-ECG time. The percentage of VF in the younger patients with short collapse-to-ECG time (≤ 10 minutes) was 52% (30/58) and significantly higher than those of the other groups (4–21%). Also, in the older patients, the percentage of VF was higher when collapse-to-ECG time was short, but it was significantly lower than...
that of younger patients with short collapse-to-ECG time. Most VF cases were observed when collapse-to-ECG time ≤ 10 minutes, and no VF was found when the collapse-to-ECG time was more than 15 minutes.

Figure 2 shows the percentage of VF in bystander-witnessed OHCA with cardiac etiology according to the collapse-to-ECG time by 3-minute intervals. In the older patients, the percentage of VF appeared to be less than 30% even when the collapse-to-ECG time was 3 min or less. In the younger patients, however, the percentage of VF was 63% when the collapse-to-ECG time was 3 min or less. Table 3 shows odds ratio and 95% confidence interval of factors, which may be associated with the VF appearance in bystander-witnessed OHCA with cardiac etiology. Male gender, younger age, and short collapse-to-ECG time were significantly associated with the VF appearance.

The 30-day survival rate in bystander-witnessed OHCA with cardiac etiology is summarized in Table 4. The 30-day survival (17 cases) was observed only in patients with VF (57 cases). In these VF patients, only bystander CPR was significantly associated with 30-day survival (odds ratio 3.70, 95% confidence interval 1.08–12.67). Age (odds ratio 1.05 per 1 year, 95% confidence interval 0.96–1.05), male (odds ratio 0.77, 95% confidence interval 0.12–5.12), and collapse-to-ECG time (odds ratio 0.97 per 1 hour, 95% confidence interval 0.82–1.15) could not be significantly associated. The successful recovery (discharged home) rate in the 30-day
survived patients was 47.0% (8/17).

Figure 3 shows the distribution of the VF episodes according to the time of day (X axis) and age (Y axis) plane. The VF episodes in older patients are sparsely distributed from 21:00 to 06:00 (17%, 4/23). On the other hand, the VF episodes in younger patients showed a relatively dense distribution from 21:00 to 06:00 (47%, 16/34). Thus, the distribution of VF episodes from 21:00 to 06:00 was significantly more dominant in younger patients as shown in Table 5. It was not easy to recognize the underlying heart diseases in the nocturnal VF of younger patients. Of the 4 survivors from among those 16 VF patients, one patient was diagnosed as Brugada syndrome after recovery, and one as acute coronary syndrome, one as hypertrophic cardiomyopathy, and one whose diagnosis was unknown.

Discussion

The incidence of OHCA overall was 62.3/100,000/year and comparable to that of previous reports including those from Japan, Europe, and U.S.1,11–15) The incidence of the bystander-witnessed OHCA with cardiac etiology was 11.0/100,000/year and identical to that of Osaka City,1) but relatively lower than those of the reports from Europe. The incidence of VF in those patients was 2.5/100,000/year and nearly identical to that of Osaka City,1) but considerably lower than those in reports from Europe and U.S.11–15)

Percentage of VF in OHCA with cardiac etiology

The percentage of VF in bystander-witnessed OHCA with cardiac etiology was 23% overall. In younger patients, the VF percentage was 63% when collapse-to-ECG time was 3 minutes or less (Figure 3). In the older patients, however, the VF percentage was 25% even when collapse-to-ECG time was 3 minutes or less. No VF was found when the collapse-to-ECG time was 15 minutes or more. Multivariate logistic analysis showed that age, male gender, and the collapse-to-ECG time were significantly associated with the appearance of VF, and bystander CPR was significantly associated with improved 30-day mortality in VF patients. We cannot confirm reports that bystander CPR prolonged the duration of VF.18,19) Nagao et al. reported that bystander CPR was not associated with hospital discharge although their data included 61% non-VF patients.20)

VF in younger patients during the nighttime

The present study indicated that the appearance of VF during the nighttime (21:00–06:00) was dependent on the age class. In younger patients (≤ 65 years of age), 47% of the VF episodes occurred at night. In older patients, however, only 17% of the VF episodes occurred during the night (p = 0.043).

The age-dependent difference in the distribution of the VF episodes over the day-time can be caused by a low incidence of VF in older patients, a high incidence in younger patients, or both. Peckova et al.21) reported that the incidence of VF during 0:00–06:00 was smallest in U.S. However, they did not show the age-dependent difference in the circadian distribution of the VF. Kida et al.22) reported that OHCA in Japan more often occurs in daytime, although they did not examine ECGs after collapse.

We must consider at least two potential background factors concerning the nighttime VF in younger population, which are acute coronary syndrome, and Brugada syndrome. Out of 4 survivors, one had acute coronary syndrome and one had Brugada syndrome. Concerning Brugada syndrome, Nademanee et al.23) reported that the Brugada-type ECG pattern was found in 16 out of 27 survivors from probable sudden unexpected death syndrome (SUD) in Thailand. Although SUD was observed mainly in the south-east Asia including Japan, it showed that not only age and sex, but collapse-to-ECG time were significantly associated with the appearance of VF. The percentage of VF in the younger patients was 63% within 3 minutes after the collapse. Holmberg et al. from Sweden reported a higher percentage of VF in witnessed-VF with cardiac etiology at an estimated 80–85% immediately after the collapse.

The duration of VF is an important issue for the appearance of VF in bystander witnessed OHCA with cardiac etiology. Holmberg et al. reported that 50–60% of bystander-witnessed OHCA retained VF for 20 minutes after the collapse. In the present study, however, no VF was found 15 minutes or more after the collapse. Duration of VF appeared to be shorter, although no direct evidence was available from the present study. Bystander CPR was significantly associated with improved 30-day mortality in VF patients, although it was not associated with the appearance of VF. We cannot confirm reports that bystander CPR prolonged the duration of VF.18,19)
remains unknown how many patients died from Brugada/SUD syndrome in Japan. Large scale screening by ECG revealed that Brugada type was found in 0.7%, 24 0.15%, 25 and 0.16%. 26 Atarashi et al. 26 reported that the 3-year sudden death mortality was 1.5% in asymptomatic patients. Therefore, it can be speculated that the incidence of sudden death from Brugada/SUD is 0.8–3.5/100,000/year, which was potentially related VF in younger patients during nighttime.

**Limitations and Clinical implications**

This is an EMS records-based study, and some OHCA cases might be processed by local physicians. Therefore, the incidence of OHCA overall may be somewhat underestimated. Although the total number of OHCA cases in the present study might be relatively small for performing statistical analysis, the incidence of OHCA was nearly identical to those of other reports, 11,11–15 and the incidence of bystander-witnessed VF with cardiac etiology and the 30-day survival rate were nearly identical to those of larger studies in Japan. 11 Therefore, we believe that the data collection and EMS system for OHCA in Sendai were not inferior. Careful interpretation is needed to generalize the present data because the data were from one city. However, it is noted that the EMS system should be improved based on the area study.

The present study confirmed the importance of the early access and resuscitation in OHCA patients. The early defibrillation by emergency life-saving technicians and/or bystander citizens will improve the outcome of OHCA with cardiac etiology. We definitely need to continue the study to evaluate these measures and create a new plan. The improvement should have a substantial social impact.

In conclusion, younger age, male gender, and shorter collapse-to-ECG time are significantly associated with the appearance of VF in bystander-witnessed OHCA with cardiac etiology. Bystander CPR was significantly associated with the improved prognosis of those VF patients.

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**References**