Several minutes of circulatory arrest causes irreversible brain damage and therefore first aid by bystanders and emergency personnel plays an important role in emergency medicine. In Japan, trained emergency medical technicians (paramedic) were authorized in 1992 to provide some additional device-aid procedures other than conventional life support techniques to the patients of out-of-hospital cardiac arrest.1 From 1992 Nagoya City Government has been posting licensed paramedics at fire stations and since 1997 every emergency team of the city had at least one paramedic. Taking advantage of this transition period, we collected data from official emergency medical service records and evaluated demographic, chronological, and clinical factors for survival of the patients of sudden cardiac arrest.

Methods

Emergency Medical Service System

Nagoya City is located in the center of Japan with a population of 2.16 million and an area of 326 km². The city is divided into 16 administrative wards, each of which has one or more fire stations equipped with ambulance vehicles available throughout 24 h. An ambulance team consists of 3 crews on board and the work shift is uniformly repeated in a 6-day cycle: on 24-h duty, recess, on 24-h duty, recess, holiday, and recess. Officially trained paramedics are exclusively allowed to perform defibrillation with an automated external defibrillator,2 alternative airway device insertion, and intravenous access with lactated Ringer’s solution, under the physicians’ remote direction, in addition to basic cardiac life support procedures.1

Study Subjects

A total of 115,525 patients asked ambulance transportation during the period of April 1, 1994 through March 31, 1996 in the city. Among them, 1,726 experienced cardiac arrest at the time of ambulance arrival and received basic and additional cardiac life support. Excluding 126 patients suffering from end-stage malignant neoplasm or diseases of extrinsic origin, we enrolled 1,600 patients with unexpected and intrinsic out-of-hospital cardiac arrest.

Data Collection

Emergency personnel were to record the patients’ condition and life support procedures in a prescribed form similar to the Utstein style3 for every dispatch. This template contained the sex and age of the patients, location of the events, date and time of emergency call, interval from call to arrival at the scene (call-response interval), duration of staying at the scene and interval from departure from the scene to arrival at the emergency department of a hospital (response – hospital interval, in total), clinical status at the scene, treatment by bystanders and emergency personnel, license of the emergency personnel, and tentative diagnosis available throughout 24 h. An ambulance team consists of 3 crews on board and the work shift is uniformly repeated in a 6-day cycle: on 24-h duty, recess, on 24-h duty, recess, holiday, and recess. Officially trained paramedics are exclusively allowed to perform defibrillation with an automated external defibrillator,2 alternative airway device insertion, and intravenous access with lactated Ringer’s solution, under the physicians’ remote direction, in addition to basic cardiac life support procedures!
made by the physicians at the hospital. Vital status of each hospitalized patient at 1 week and 1 month later (‘still in hospital,’ ‘discharged alive,’ or ‘dead’) was referred to the hospital medical chart and reported to the relevant fire station by the doctor in charge.

With institutional approval, we extracted data from the compiled reports for the 2 fiscal years of 1994 and 1995 during which the paramedic system had been promoted. All data were treated anonymously, according to the national ethical guideline for epidemiological research published in June 2002.

**Statistical Analysis**

Sex and age of the patients, location of the events, date and time of emergency call, call–response interval, response–hospital interval, clinical status at the scene, treatment by bystanders, license of the emergency personnel, and tentative diagnosis were described epidemiologically. The difference in mean values was examined by the unpaired t-test and frequency distribution by chi-square test. These factors were then analyzed in associations with 1-month survival. Unidirectional frequency trend was verified by the Cochran-Armitage trend test, and goodness of fit...
of survival rate to trigonometric function by chi-square test. Multivariate logistic regression was applied to evaluate independent contribution of the factors of interest to 1-month survival, treating all potential explanatory variables as dichotomous. Odds ratios (OR) for 1-month survival and their 95% confidence intervals (CI) were calculated. SAS statistical package version 6.1.1 (SAS Institute Inc, Cary, NC, USA) was used, and p values were two-sided.

**Results**

**Overall Incidence and Fatality**

Cardiopulmonary resuscitations in acute intrinsic events were performed more frequently in males (975) than in females (625) (p<0.001), and mean age of 68.8±17.4 years in male patients was lower than that of 72.0±17.1 years in females (p<0.001). The overall incidence rate was calculated as 37.2 per 100,000 population per year.

The outcome cascade of the patients is illustrated in Fig.1. Among 1,600 patients, 29 (1.8%) were judged as dead at the scene and the remainder were transported to hospitals. Death was confirmed for 307 patients (19.2%) on arrival at emergency rooms, and rescue procedures were continued thereafter for the other 1,264. Only 86 (5.4%) and 45 (2.8%) patients survived for 1 week and 1 month, respectively. Unfortunately their functional status was not recorded.

**Demographic Factors**

Survivors to 1-month were 27 men (mean age, 56.3±24.0 years) and 18 women (60.4±21.1 years). The proportion of 1-month survivors (survival rates) was 2.8% and 2.9% for
males and females, respectively. Mean age and survival rate did not significantly differ between the sexes.

Fig 2 shows the number of the patients and their survival rate according to age. The age distribution was appreciably shifted to the elderly. The survival rate was as high as 9.8% in the patients under 20 years of age, with a marked decreasing trend to 0.8% in the patients aged 80 years or older (trend p=0.004).

Chronological Factors

Events needed to resuscitate were most frequent in January (208 patients) followed by December, February, and March (153–167 patients), while less frequent in August (94 patients) and from June though October (102–106 patients). When divided by season (Fig 3), 414 life-threatening events occurred in spring (March to May), 309 in summer (June to August), 354 in autumn (September to November), and 523 in winter (December to February) (p<0.001). The survival rate was somewhat lower in spring (2.2%) and summer (1.9%) compared with autumn (3.4%) and winter (3.4%) (p=0.47, Fig 3).

Variation by day of the week of the events requiring cardiopulmonary resuscitation is shown in Fig 4. Events were seemingly more common on the weekend (260 patients on Saturday and 250 patients on Sunday) than weekdays (203–231 patients per day) (p=0.07). The survival rate peaked at 4.8% on Sunday and bottomed out at 0.5% on Thursday, forming a distinct sine curve.

Fig 5 presents the circadian variation of resuscitation by 3-h interval. Two peaks in number of 243 and 269 were found at 09.00–12.00 and 18.00–21.00h, respectively, with a nadir of 108 at 03.00–06.00h. Survival tended to be
poorer at 00.00–03.00, 03.00–06.00, and 06.00–09.00 h (0.8%, 1.9%, and 1.8%, respectively), compared with daytime and evening hours (2.2–4.5%), though statistically insignificant.

Most cardiac arrests (1,295 patients) occurred at home, with some in public places (153), streets (88) and workplaces (45). Survival rate was higher for the events in the streets (8.0%) and public places (5.9%), but lower for those at home (2.1%) and at the workplace (2.2%) (p=0.003).

The numbers of patients and survival rates according to call–response interval and response–hospital interval are shown in Figs 6 and 7. The call–response interval ranged from 0 to 38 min (mode, 5 min by 1-min intervals), the duration of staying from 1 to 96 min (mode, 10–14 min by 5-min intervals), and interval from scene to hospital from 1 to 69 min (mode, 5–9 min by 5-min intervals; excluding 29 non-transferred patients).

The survival rate was 9.9% for the call–response inter-
val of 0–4 min, but steeply dropped to 2.5% for 4–7 min, 2.0% for 7–10 min, and 0.8% for 10 min or more (trend p<0.001). By response–hospital interval, the survival rate was 4.9%, 3.0%, 2.4%, and 2.9%, for the time of less than 10, 10–19, 20–29, and 30 min or more, respectively, being not significantly different.

Clinical Factors

Tentative clinical diagnoses given at emergency rooms included cardiovascular diseases for 1,255 (78.4%) patients, stroke for 129 (8.1%), and respiratory diseases for 60 (3.8%). The survival rate was 2.5% for cardiovascular diseases, 2.3% for stroke, and 5.0% for respiratory diseases with no significant difference.

One hundred and ninety-two arrested patients (12.0%) received cardiopulmonary resuscitation from bystanders before the arrival of the ambulance. Of these, 109 were the patient’s family member, 46 were medical professionals, and 12 were patient’s colleagues. Chest compression alone was performed for 87 patients, chest compression plus ventilation for 53, and ventilation alone for 29. The survival rate of the patients with bystander resuscitation was 3.6% not overwhelming 2.3% of those without such first aid (p=0.28). Survival rates by kind of bystander or intervention could not be examined because of too few survivors in each category.

Paramedics were on board the ambulances in 990 events (61.9%) and not in 610 (38.1%). The survival rate was 3.5% when paramedics were on board, which was significantly higher than the 1.8% when not on board (p=0.03).

Electrocardiogram was monitored at the scene for 546 patients, 98% of which were recorded when a paramedic was on board. The survival rate of those with electrocardiographic monitoring was 3.0%, which was similar to that of unmonitored patients (2.8%). Nine of 95 patients (9.5%) with ventricular fibrillation survived compared with only 4 of 367 (1.1%) with cardiac arrest (p=0.001).

Multivariate Analysis

The results by multivariate analysis are summarized in Table 1. Age (<60 years old, OR=2.25), day of the week (Saturday to Tuesday, OR=3.17), location (home and workplace, OR=0.39), call–response interval (<4 min, OR=3.94), and personnel (paramedics on board, OR=2.46) independently affected the probability of 1-month survival.

Electrocardiographic findings were not included in this analysis because they were not exhaustive.

Discussion

This is a retrospective cohort study based on routine ambulance reports. Our methodological advantages are the large number enrolled and the completeness of enumeration, which may reinforce generalization of the findings. Because the paramedic system was just being implemented during the study period, a new paradigm was also verified in this study.

One-month survival significantly differed by age, time, and location. Younger victims were much more likely to recover, as expected because of their greater vitality. Events that occurred during the night or early morning and in relatively segregated places, such as the home or workplace, yielded poor survival possibly because of delayed discovery and therefore a reduced likelihood of successful resuscitation. The morning peak of defibrillation energy requirement might be another possible explanation.

To our surprise, the survival rate followed a sine curve by day of the week with a peak on Sunday and a nadir on Thursday, showing a 10-fold difference in magnitude. The mean call–response interval was 6.0 min on Sunday and 6.4 min on Thursday; that is, the proportion of the call–response interval of less than 4 min was 8.4% and 7.8%, correspondingly. Even after controlling for this factor in the multivariate analysis, the daily variation still persisted. The mean age of the patients on Sundays was rather higher than on Thursdays (69.2 vs 67.1 years old). There were no significant differences in either diagnosis or location of the events by day of the week. The work shift of the emergency personnel was a uniform 6-day cycle, which could not explain such a 7-day variation. No other study has reported a daily variation of survival, although that of sudden death is well documented.

Thus, this enigma is still unresolved. The shorter the call–response interval, the higher was the survival rate. The critical time appears to be 4 min, which is comparable with previous reports.

The interval from scene to hospital was, however, not significantly associated with survival. These findings indicate the importance of quick arrival of an ambulance at the scene and early life support interventions, irrespective of the interval to hospital.

Patients cared for by paramedics on board were more likely to be alive 1 month later, which was also comparable with the findings of previous studies and this finding further confirmed that additional life support procedures contribute to a better prognosis. At present in Japan, paramedics on board have to obtain a doctor’s permission to perform such interventions as electric defibrillation and airway insertion, which implies that full resuscitation will be somewhat delayed. Thus, intervention based on the paramedic’s own decision is under consideration by the Japanese Government.

We found that only 12% of patients with cardiac arrest received resuscitation from a bystander before the arrival of emergency personnel, and that the 1-month survival rate was not significantly different between the recipients and non-recipients of bystanders’ resuscitation. In most previous studies appropriate bystander cardiopulmonary resuscitation has substantially improved patient outcome and therefore it is a crucial challenge for us to educate the general population in the correct cardiopulmonary resuscitation techniques.

In total, 2.8% of the patients were alive at 1 month after the event, which is much lower than in Western countries. This low rescue rate might be partly explained by the long interval (approximately 5 min) from emergency call to the ambulance’s arrival at the scene. Another plausible explanation is that the proportion of aged people with inherently poor recovery has greatly increased in Japan in recent years. The lack of adequate to bystanders’ resuscitation might also suppress survival.

Study Limitations

Because the data set analyzed in this study was solely provided by the daily reports of emergency medical services, the situation both before the emergency call and after hospital admission were not fully recorded. Also, information about any witnesses and the cardiac rhythm at resuscitation was limited. Thus, these factors could confound our findings.
Conclusion
Quick arrival of an ambulance will improve the survival of out-of-hospital cardiac arrest. Prompt revision of the national regulations for paramedics’ activities is now warranted and general education of lifesaving techniques would be another key factor. Survival, however, is still poor even in the paramedic era. We also emphasize that prevention and early detection of critical diseases is essential.

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