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Clinical paper

Neurological outcomes of out-of-hospital cardiac arrest occurring in Tokyo train and subway stations

J. Miyako[a,*], K. Nakagawa[b], R. Sagisaka[a,c,d], S. Tanaka[a,e], H. Takeuchi[b], H. Takyu[b], H. Tanaka[a,b]

[a] Research Institute of Disaster Management and EMS, Kokushikan University, Tokyo, Japan
[b] Department of Emergency Medical System, Graduate School, Kokushikan University, Tokyo, Japan
[c] Department of Integrated Science and Engineering for Sustainable Societies, Chuo University, Tokyo, Japan
[d] Research and Development Initiative, Chuo University, Tokyo, Japan
[e] Tokai University School of Medicine, Kanagawa, Japan

Abstract

Objectives: The purpose of this study was to identify a relationship between the background environment, bystander and emergency medical services intervention, and favourable neurological outcomes (CPC1-2) one-month after out-of-hospital cardiac arrest (OHCA) occurred at Tokyo train and subway stations.

Methods: This retrospective observational study used OHCA data between 2014 and 2018 that occurred at train stations in Tokyo. The eligible 954 patients were analysed for correlation between background, time frame, and location. Multivariable logistic regression models were used to estimate factors associated with CPC1-2 in patients with cardiogenic OHCA.

Results: A total of 886 OHCA cases, cardiogenic (n=562) and non-cardiogenic (n=324), met the inclusion criteria. Of the cardiogenic cases, 71.9% occurred at the platform and on-a-train. One-month CPC1-2 was achieved in 32.0% of cardiogenic OHCAs, which included 47.3% during morning rush hour, 24.7% during daytime hours, 40.2% during evening rush hour, and 20.5% during night-time/early morning hours. CPC1-2 had significant correlation with morning rush hour (adjusted odds ratio [AOR],4.52; 95% confidence interval [CI], 1.09–18.78), evening rush hour (AOR, 6.85; 95% CI, 1.51–31.15), public access defibrillation (AOR, 5.19; 95% CI, 1.38–19.51), and ventricular fibrillation or pulseless ventricular tachycardia (AOR, 7.56; 95% CI, 1.35–42.43).

Conclusion: A total of 71.9% of cardiogenic OHCAs occurred at platforms and on trains. To improve neurological outcomes of OHCAs at stations, AED installations on train platforms are necessary. Additionally, using artificial intelligence-based platform monitoring for early detection of OHCAs and oering CPR training are required.

Keywords: OHCA, Station, Public access defibrillation, Tokyo

Introduction

Out-of-hospital cardiac arrest (OHCA) is a major public health concern in high-income countries. Tremendous resuscitation research has been conducted to improve resuscitation rates.[1]

Approximately 30% of OHCAs in Japan occur in public places, and many of these are expected to survive with bystander intervention.[2] In Japan, citizen cardiopulmonary resuscitation (CPR) has been promoted since 1993, and the bystander cardiopulmonary resuscitation rate (BCPR) improved 56.6% by 2018.[3] Over 40,000 automated external defibrillators (AEDs) have been installed

* Corresponding author at: Research Institute of Disaster Management and EMS, Kokushikan University, 7-3-1, Nagayama, Tama city, Tokyo 205-8515, Japan.
E-mail address: miyakoj@kokushikan.ac.jp (J. Miyako).
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throughout Tokyo since the Public Access Defibrillation (PAD) program was introduced in 2004,[4] but the PAD implementation rate remains near 13%.[5] This low rate may be due to lacking awareness of AED locations[6].

In Tokyo, 32 million people use the train daily, which is comparable to the world's largest rail networks in New York, London, Paris, and São Paulo.[7] In Japan, train stations are one of the most common places where OHCAs occur.[8] Stations and schools are more likely to receive PADs, thus resulting in more favourable outcomes.[8] However, customers accessing stations vary with time, and the station location affects time required by emergency medical services (EMS) to arrive.

To our knowledge, factors associated with timeframe and location of OHCA occurrence and favourable neurological outcomes have not been evaluated. Thus, this study aimed to identify the OHCA trend incidence at Tokyo train stations and determine the relationship between the timeframe of OHCA occurrence, bystander and EMS intervention, and favourable neurological function at one-month post-arrest.

Methods

Study design and ethical concern

This retrospective observational study analysed data on OHCAs that occurred at train stations in the Tokyo metropolitan area. The Ethics Committee at Kokushikan University approved this study (No. 20021) and the data used were provided by the Tokyo Fire Department (TFD).

Study setting

Tokyo, Japan has a population of approximately 13 million people.[9] Subways and railroads are the main transportation methods in the metropolitan area, and are known to be busiest in mornings and evenings during prime commute hours.[7] Tokyo has 761 stations, including 179 subways owned by the Tokyo Metro Co. Ltd.[10,11] Moreover, there are > 32 million rail passengers during weekdays[7] and > 7.4 million subway passengers daily.[11]

According to the AED installation guidelines in Japan, stations visited by > 10,000 people daily must have AEDs; thus, most train stations have AEDs.[12] Attendants and staff are recommended to undergo AED/CPR training.[13]

TFD is the largest fire department in Japan and has jurisdiction over Tokyo, except Inagi City and the island areas. In Tokyo, when an emergency call is made, the nearest fire station dispatches an EMS team to the scene, and the patient is transported to the nearest critical care centre in the case of an OHCA.[14]

The EMS team consists of three members, including one emergency life support technician (ELST) for advanced procedures. A physician instructs the EMS via telephone or radio, and the ELST performs actions, such as administering adrenaline, and performing advanced airway management with endotracheal intubation (ETI) or supraglottic airway device (SGA).[14] Additionally, discontinuation of resuscitation is not permitted in Japan, and according to protocol, the patient should be transported to the hospital, except in apparent death.

Participants

In this study, we used patients' records of EMS from the TFD. We extracted data on OCHAs that occurred at stations in Tokyo between 1 January 2014 and 31 December 2018. We defined a station as any public or private railroad station running aboveground or underground. We excluded two types of cases: 1) OHCA witnessed by EMS and 2) those presumed not to be OHCA.

Data variables

OCHAs occurring at stations were categorised into five locations: platforms, on the track/railroad crossings, on a train, indoor facilities, and outdoor facilities. Indoor facilities included restrooms, offices, storerooms, first-aid rooms, monorails, and inside the ropeway. Outdoor facilities included corridors, stairs, entrances, lobbies, guest seating areas, escalators, elevators, parking lots, plazas, and driveways.

Subgroups were defined to analyse the effects of patient age and season. We defined the elderly group as patients $\geq$ 65-years-old and the non-elderly group as < 65-years-old. The months of occurrence were categorised into spring (March–May), summer (June–August), autumn (September–November), and winter (December–February). Data used in this study did not differentiate between weekdays and weekends.

We also defined rush hours as the timeframe in which $\geq$ 900,000 people use stations in the Tokyo metropolitan area on weekdays.[7] The timeframe of occurrence was classified into four categories: 1) morning rush hour (7:00–9:59); 2) daytime (10:00–16:59); 3) evening rush hour (17:00–20:59); and 4) night-time/early morning (21:00–6:59).

BCPR was categorised into conventional CPR, hands-only CPR, ventilation only or none. The initial documented rhythm by EMS was classified into four categories: sinus, ventricular fibrillation (VF) or pulseless ventricular tachycardia (PVT), pulseless electrical activity (PEA), and asystole (Asys). Herein, PAD refers to defibrillation by a layperson using a public AED. In PAD cases, the initial documented electrocardiographic rhythm was VF or PVT as AEDs deliver shocks only with these rhythms.

For airway clearance by EMS, endotracheal intubation (ETI) and supraglottic airway device (SGA) using a laryngeal tube or laryngeal mask, were classified as the ETI/SGA subgroup. The other group was classified as 'no advanced airway device' or 'not applicable (i.e., return of spontaneous circulation ([ROSC])'.

Activity time subgroups were defined and analysed as specific activity time and EMS intervention may influence outcomes. Activity time was divided into three groups using the third quartile value. The time from the EMS call to patient contact ('call to contact') was early (1–8 min), intermediate (9–11 min), or late ($\geq$12 min). The time from patient contact to scene departure ('contact to departure') was early (1–15 min), intermediate (16–21 min), or late ($\geq$22 min). The time from EMS departure to hospital arrival ('departure to hospital') was early (1–5 min), intermediate (6–9 min), or late ($\geq$10 min).

Study endpoint

The primary endpoint was survival with favourable neurological outcomes at 1-month post-arrest. The secondary endpoint was ROSC before hospital arrival. Cerebral function for all patients was assessed by the treating physician in the hospital after 1-month post arrest. Outcome at discharge was assessed when patients were discharged within a month. Cerebral function was defined using the Glasgow–Pittsburgh cerebral performance category (CPC) scale: 1, good cerebral performance; 2, moderate cerebral disability; 3, severe cerebral disability; 4, coma/vegetative state; and 5, death. In Japan, data on whether patients are discharged alive and total hospitalization days are not registered. ROSC was assessed by EMS. All OHCA data were entered by EMS personnel.

Statistical analysis

Continuous variables in patient analysis were presented as medians (interquartile ranges) and categorical variables as numbers (percentages). We analyzed the distribution of all OHCAs locations. Characteristics of patients with cardiogenic OHCA and outcomes were analysed in the timeframe and occurrence location using one-way analysis of variance for continuous variables and chi-square or Fisher's exact test for categorical variables. We also performed multivariable logistic regression analysis to assess factors associated with CPC1-2 and ROSC in cardiogenic OHCA. Logistic regression analysis was limited to cardiogenic OHCA due to possible bystander intervention. The adjusted odds ratio (AOR) and 95% confidence interval (CI) were estimated. For multivariable logistic regression analysis, the variables 'sinus' in the first documentation by EMS and 'not applicable' in the type of airway clearance were excluded from the data presented in Tables 1 and 2 and entered directly into the model

Table 1 – Background of patients with cardiogenic OHCA in the time frame of occurrence.

Characteristics	Overall	Rush hours in the morning	Daytime	Rush hours in the evening	Night time/early morning	P value
N(%)	562—	129(23.0)	194(34.5)	112(19.9)	127(22.6)	
Demographic						
Age						*<0.001*
Non elderly patient < 65	343(61.0)	91(70.5)	93(47.9)	72(64.3)	87(68.5)	
Elderly patient ≧65	219(39.0)	38(29.5)	101(52.1)	40(35.7)	40(31.5)	
Sex male	478(85.1)	117(90.7)	149(76.8)	95(84.8)	117(92.1)	*<0.001*
Witnessed arrest	444(79.0)	102(79.1)	156(80.4)	95(84.8)	91(71.7)	*0.09*
Season						*0.69*
Spring	142(25.3)	34(26.4)	51(26.3)	26(23.2)	31(24.4)	
Summer	115(20.5)	25(19.4)	44(22.7)	19(17.0)	27(21.3)	
Autumn	122(21.7)	30(23.3)	37(19.1)	22(19.6)	33(26.0)	
Winter	183(32.6)	40(31.0)	62(32.0)	45(40.2)	36(28.4)	
Bystander care						
Conventional CPR	113(20.1)	24(18.6)	43(22.2)	25(22.3)	21(16.5)	*0.002*
Hands-only CPR	347(61.7)	88(68.2)	113(58.3)	77(68.8)	69(54.3)	
None/Ventilation only	102(18.2)	17(13.2)	38(19.6)	10(8.9)	37(29.1)	
PAD	275(48.9)	77(59.7)	81(41.8)	68(60.7)	49(38.6)	*<0.001*
First documentation rhythm by EMS						*<0.001*
Sinus	178(31.7)	51(39.5)	50(25.8)	50(44.6)	27(21.3)	
VF / PVT	113(20.1)	33(25.6)	32(16.5)	20(17.9)	28(22.1)	
PEA / Asys	262(46.6)	43(33.3)	109(56.2)	41(36.6)	69(54.3)	
Others	9(1.6)	2(1.6)	3(1.6)	1(0.9)	3(2.4)	
EMS treatment						
Defibrillation	186(33.1)	50(38.8)	51(26.3)	32(28.6)	53(41.7)	*0.01*
Adrenaline administration	118(21.0)	23(17.8)	48(24.7)	19(17.0)	28(22.1)	*0.31*
Airway management						*0.01*
Not inserted advanced devices	371(66.0)	87(67.4)	122(62.9)	74(66.1)	88(69.3)	
ETI or SGA	112(19.9)	20(15.5)	48(24.7)	14(12.5)	30(23.6)	
Not applicable (i.e. ROSC)	79(14.1)	22(17.1)	24(12.4)	24(21.4)	9(7.1)	
Call-to-contact interval, median(IQR), min	10(8–12)	9(8–12)	10(8–13)	11(8–13)	10(8–12)	*0.28*
Early phase (1–8 min)	177(31.5)	53(41.1)	61(31.4)	28(25.0)	35(27.6)	*0.09*
Intermediate phase (9–11 min)	193(34.3)	40(31.0)	61(31.4)	41(36.6)	51(40.2)	
Late phase (≧12 min)	192(34.2)	36(27.9)	72(37.1)	43(38.4)	41(32.3)	
Contact-to-departure interval, median (IQR), min	15(12–18)	15(12–17)	15(12–18)	14(11–18)	16(13–19)	*0.51*
Early phase (1–15 min)	170(30.2)	39(30.2)	65(33.5)	35(31.3)	31(24.4)	*0.56*
Intermediate phase (16–21 min)	151(26.9)	40(31.0)	41(21.1)	34(30.4)	36(28.3)	
Late phase (≧21 min)	241(42.9)	50(38.8)	88(45.4)	43(38.4)	60(47.2)	
Departure-to-hospital interval, median (IQR), min	8(6–11)	8(6–11)	8(6–12)	7(6–11)	8(6–11)	*0.52*
Early phase (1–5 min)	121(21.5)	28(21.7)	39(20.1)	25(22.3)	29(23.4)	*0.53*
Intermediate phase (6–9 min)	239(42.5)	63(48.8)	76(39.2)	49(43.8)	51(41.1)	
Late phase (≧10 min)	199(35.4)	38(29.5)	79(40.7)	38(33.9)	44(35.5)	
Outcomes						
ROSC	272(48.4)	75(58.1)	80(41.2)	76(67.9)	41(32.3)	*<0.001*
CPC1-2	180(32.0)	61(47.3)	48(24.7)	45(40.2)	26(20.5)	*<0.001*

PAD means defibrillation by a layperson using a public AED.

Abbreviations: CPR, cardiopulmonary resuscitation; PAD, public access defibrillation; EMS, emergency medical services; VF, ventricular fibrillation; PVT, pulseless ventricular tachycardia; PEA, pulseless electrical activity; Asys, asystole; ETI, endotracheal intubation; SGA, supraglottic airways; ROSC, return of spontaneous circulation; IQR, interquartile range; CPC, cerebral performance category.

Table 2 – Background of patients with cardiogenic OHCA at the location of occurrence.

Characteristics	Overall		Platform		In the track Railroad crossing		On the train		Stations indoor facilities		Stations outdoor facilities		*P-value*
n(%)	562	—	286	(50.9)	2	(0.4)	118	(21.0)	45	(8.0)	111	(19.8)	
Demographic													
Age													*0.11*
Non elderly patient <65	343	(61.0)	177	(61.9)	2	(100.0)	79	(66.9)	28	(62.2)	57	(51.4)	
Elderly patient ≧65	219	(39.0)	109	(38.1)	0	(0.0)	39	(33.1)	17	(37.8)	54	(48.6)	
Sex male	478	(85.1)	240	(83.9)	1	(50.0)	105	(89.0)	36	(80.0)	96	(86.5)	*0.31*
Witnessed arrest	444	(79.0)	240	(83.9)	1	(50.0)	98	(83.1)	18	(40.0)	87	(78.4)	*<0.001*
Season													*0.55*
Spring	142	(25.3)	69	(24.1)	1	(50.0)	28	(23.7)	11	(24.4)	33	(29.7)	
Summer	115	(20.5)	52	(18.2)	0	(0.0)	26	(22.0)	8	(17.8)	29	(26.1)	
Autumn	122	(21.7)	69	(24.1)	1	(50.0)	21	(17.8)	11	(24.4)	20	(18.0)	
Winter	183	(32.6)	96	(33.6)	0	(0.0)	43	(36.4)	15	(33.3)	29	(26.1)	
Bystander care													
Conventional CPR	113	(20.1)	55	(19.2)	0	(0.0)	37	(31.4)	6	(13.3)	15	(13.5)	*<0.001*
Hands-only CPR	347	(61.7)	192	(67.1)	1	(50.0)	71	(60.2)	14	(31.1)	69	(62.2)	
None/Ventilation only	102	(18.1)	39	(13.6)	1	(50.0)	10	(8.5)	25	(55.6)	27	(24.3)	
PAD	275	(48.9)	150	(52.4)	1	(50.0)	73	(61.9)	7	(15.6)	44	(39.6)	*<0.001*
First documentation rhythm by EMS													*<0.001*
Sinus	178	(31.7)	95	(33.2)	0	(0.0)	45	(38.1)	2	(4.4)	36	(32.4)	
VF/PVT	113	(20.1)	61	(21.3)	1	(50.0)	19	(16.1)	6	(13.3)	26	(23.4)	
PEA/Asys	262	(46.6)	128	(44.8)	1	(50.0)	50	(42.4)	35	(77.8)	48	(43.2)	
Other	9	(1.6)	2	(0.7)	0	(0.0)	4	(3.4)	2	(4.4)	1	(0.9)	
EMS treatment													
Defbrillation	186	(33.1)	89	(31.1)	1	(50.0)	45	(38.1)	13	(28.9)	38	(34.2)	*0.64*
Adrenaline administration	118	(21.0)	64	(22.4)	0	(0.0)	21	(17.8)	11	(24.4)	22	(19.8)	*0.74*
Airway management													*0.11*
Not inserted advanced devices	371	(66.0)	192	(67.1)	2	(100.0)	79	(66.9)	29	(64.4)	69	(62.2)	
ETI or SGA	112	(19.9)	55	(19.2)	0	(0.0)	18	(15.3)	15	(33.3)	24	(21.6)	
Not applicable (i.e.. ROSC)	79	(14.1)	39	(13.6)	0	(0.0)	21	(17.8)	1	(2.2)	18	(16.2)	
Call-to-contact interval, median (IQR), min	10	(8-12)	10	(8-13)	7	(5-9)	10	(8-13)	10	(8-12)	9	(8-12)	*0.20*
Early phase(1-8min)	177	(31.5)	90	(31.5)	1	(50.0)	35	(29.7)	13	(28.9)	38	(34.2)	*0.74*
Intermediate phase(9-11min)	193	(34.3)	95	(33.2)	1	(50.0)	37	(31.4)	19	(42.2)	41	(36.9)	
Late phase(≧12min)	192	(34.2)	101	(35.3)	0	(0.0)	46	(39.0)	13	(28.9)	32	(28.8)	
Contact-to-departure interval, median(IQR),min	15	(12-18)	15	(12-18)	18	(8-27)	15	(13-19)	16	(13-21)	13	(11-18)	*0.11*
Early phase(1-15min)	170	(30.2)	88	(30.8)	1	(50.0)	26	(22.0)	10	(22.2)	45	(40.5)	*0.31*
Intermediate phase(16-21min)	151	(26.9)	82	(28.7)	0	(0.0)	36	(30.5)	12	(26.7)	21	(18.9)	
Late phase(≧21min)	241	(42.9)	116	(40.6)	1	(50.0)	56	(47.5)	23	(51.1)	45	(40.5)	
Departure-to-hospital interval, median (IQR), min	8	(6-11)	10	(7-12)	8	(6-11)	8	(6-11)	9	(5-13)	7	(5-11)	*0.43*
Early phase(1-5min)	121	(21.5)	57	(19.9)	0	(0.0)	21	(17.8)	11	(24.4)	32	(28.8)	*0.4*
Intermediate phase(6-9min)	239	(42.5)	128	(44.8)	1	(50.0)	54	(45.8)	14	(31.1)	42	(37.8)	
Late phase(≧10min)	199	(35.4)	101	(35.3)	1	(50.0)	43	(36.4)	19	(42.2)	35	(31.5)	
Outcome													
ROSC	272	(48.4)	146	(51.0)	1	(50.0)	60	(50.8)	9	(20.0)	56	(50.5)	*0.003*
CPC1-2	180	(32.0)	95	(33.2)	1	(50.0)	41	(34.7)	3	(6.7)	40	(36.0)	*0.004*

PAD means defibrillation by a layperson using a public AED.

Abbreviations: CPR, cardiopulmonary resuscitation; PAD, public access defibrillation; EMS, emergency medical services; VF, ventricular fibrillation; PVT, pulseless ventricular tachycardia; PEA, pulseless electrical activity; Asys, asystole; ETI, endotracheal intubation; SGA, supraglottic airways; ROSC, return of spontaneous circulation; IQR, interquartile range; CPC, cerebral performance category.

because they are intermediate factors in the outcomes. Occurrences on tracks and at railroad crossings were excluded due to the low number of cases. A total of 376 cases were included in the logistic regression analysis.

When conducting logistic regression analysis, the variance inflation factor for each variable must be < 10 and multicollinearity problems must not exist. Conformity to a linear gradient was graphically checked, and age, call-to-contact interval, contact-to-departure interval, and departure-to-hospital interval, for which linearity could not be confirmed, were categorised and modelled. The model of multivariable logistic regression analysis was evaluated using the goodness-of-fit test, R^2 value, and area under the receiver operating characteristic curve (AUROC). The overdispersion parameter (Pearson's chi-square/degree of freedom of the model fit statistic) was < 1.5, confirming that the model was not over dispersed. The α-level was set at $p < 0.05$ (two-tailed test). SAS JMP Pro ver.15 (SAS Institute Inc. Cary, NC, USA) was used for statistical analyses.

Results

Study population

The inclusion criteria and group categorization are presented in Fig. 1. There were 954 of 63,089 OHCA cases during the study period that occurred at a train station. We excluded cases that were 1) witnessed by EMS (n=63) and 2) presumed not to be OHCA (n=5). A total of 886 OHCA cases were included, consisting of cardiogenic (n=562) and non-cardiogenic OHCAs (n=324). Non-cardiogenic OHCA cases included traffic injury (n=184), other exogenous (n=66), stroke (n=26), suffocation (n=6), cancer (n=4), poison (n=1), and others (n=37).

OHCA occurrence location distribution

The distribution of OHCA occurrence location is shown in Fig. 2. Cardiogenic OHCA cases (71.9%) occurred on the platform (n=286) or on a train (n=118), while non-cardiogenic OHCA cases (86.4%) occurred on the platform (n=130) and in track/railroad crossing (n=150).

Background of cardiogenic OHCA outcome by witnessed status, bystander intervention, and defibrillation

Outcomes by witnessed status, bystander intervention, and defibrillation are shown in Fig. 3. Of the 274 patients with cardiogenic OHCA who received BCPR and PAD, 70.4% achieved ROSC before hospital arrival, and 49.3% achieved CPC1-2. A total of 444 OHCAs were witnessed, 383 (86.3%) received BCPR, and 244 (55.2%) received PAD. In patients with witnessed arrest, 239 (53.8%) achieved ROSC and 160 (36.3%) achieved CPC1-2. The initial rhythm of 331 patients was VF or PVT, 204 (61.6%) were ROSC, and 141 (42.6%) were CPC1-2.

Occurrence timeframe and location

We analysed the cardiogenic OHCA occurrence timeframe and background (Table 1). There were 562 cardiogenic OHCA cases, wherein 129 (23.0%) occurred during the morning rush hour, 194 (34.5%) during daytime, 112 (19.9%) during evening rush hour, and 127 (22.6%) at night-time/early morning.

Regarding patient age, 343 cardiogenic OHCA cases (61.0%) occurred among non-elderly individuals, although the elderly had a higher percentage during daytime hours.

In terms of BCPR, 347 cases (61.7%) had hands-only CPR, 113 (20.1%) had conventional CPR, and 102 (18.2%) had ventilation only or none.

PAD was received in 275 cases (48.9%) with cardiogenic OHCAs, wherein 77 cases (59.7%) occurred during morning rush hour, 81 (41.8%) during daytime, 68 (60.7%) during evening rush hour, and 49 (38.6%) at night-time/early morning.

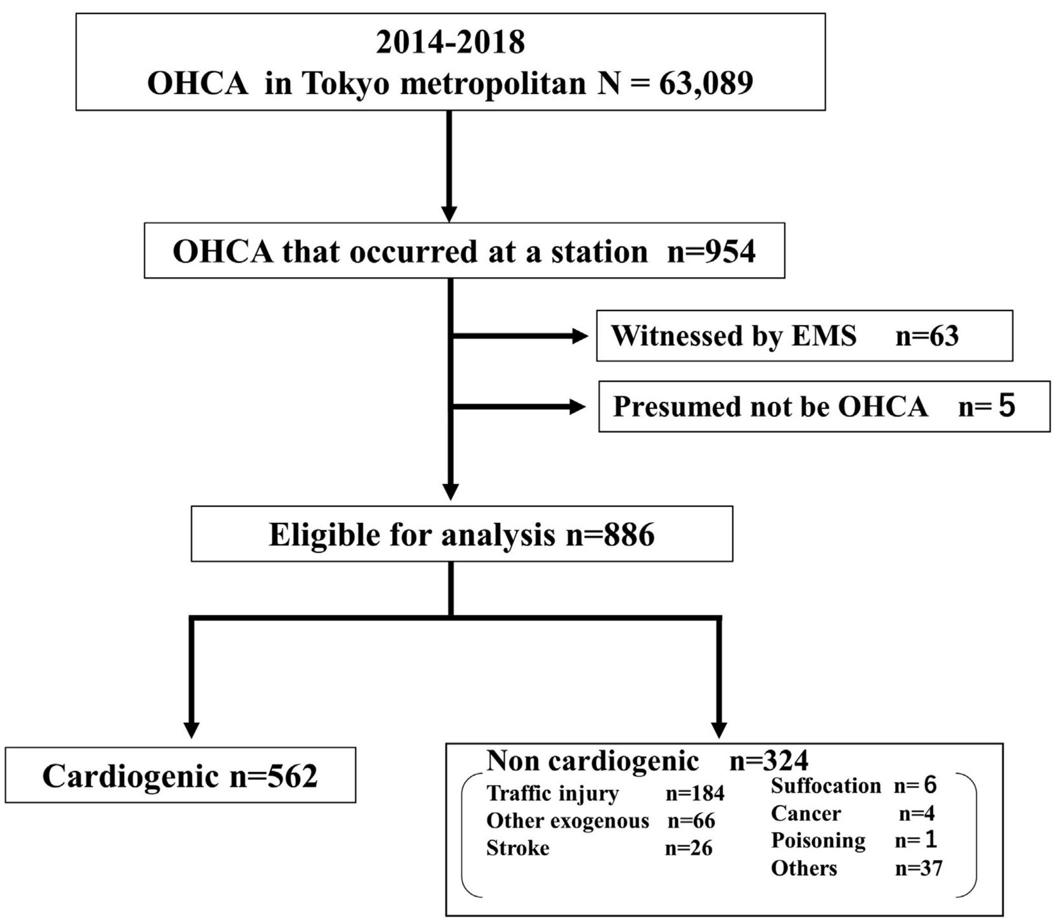

Fig. 1 – Study population and subjects. Abbreviations: OHCA, out-of-hospital cardiac arrest; EMS, emergency medical services.

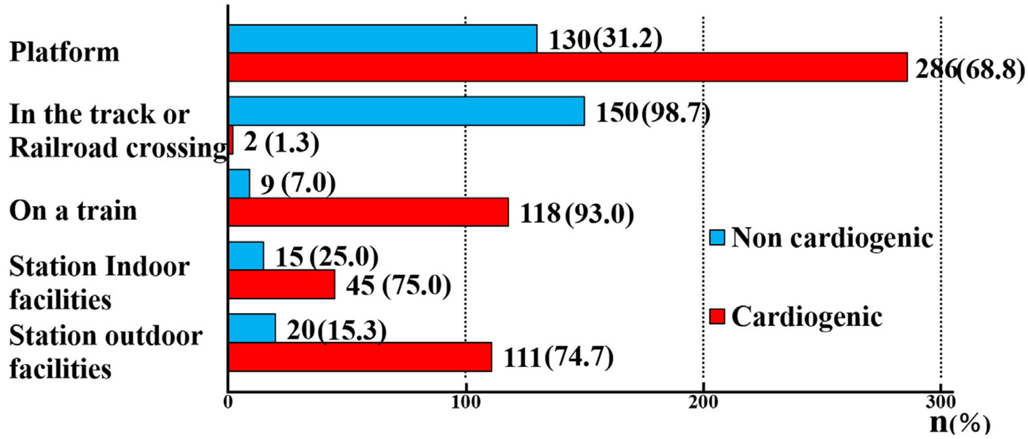

Fig. 2 – OHCA occurrence location distribution.

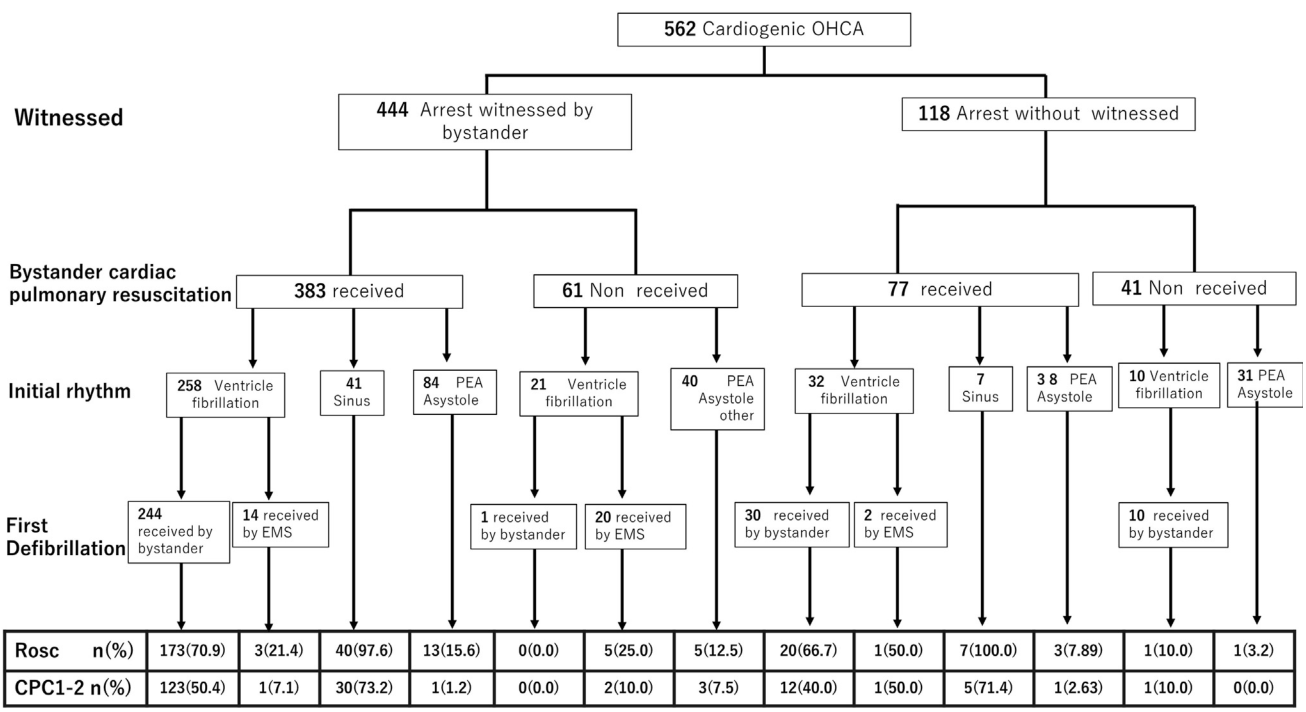

Fig. 3 – Outcome by witnessed status, bystander intervention and defibrillation. Abbreviations: OHCA, out-of-hospital cardiac arrest; PEA, pulseless electrical activity; EMS, emergency medical services; ROSC, return of spontaneous circulation; CPC, cerebral performance category.

As for the first documented rhythm by EMS, 178 cases (31.7%) were in sinus, 113 (20.1%) in VF/PVT, 262 (46.6%) in PEA/Asys, and 9 (1.6%) were in the ‘other’ category. ROSC before hospital arrival was achieved in 272 patients (48.4%) with cardiogenic OHCAs. CPC1-2 was achieved in 180 cases (32.0%) of cardiogenic OHCAs, wherein 61 cases (47.3%) during the morning rush hour, 48 (24.7%) during daytime, 45 (40.2%) during the evening rush hour, and 26 (20.5%) at night-time/early morning.

We analysed the location and background of cardiogenic OHCA occurrence (Table 2). There were 562 cases of cardiogenic OHCA, of which 286 (50.9%) were on platforms, 2 (0.4%) on tracks and railroad crossings, 118 (21.0%) on trains, 45 (8.0%) in station indoor facilities, and 111 (19.8%) at station outdoor facilities. BCPR was 247 (86.3%) in the platform, 1 (50.0%) in the track and railroad crossing, 108 (91.6%) on a train, 20 (44.4%) in station indoor facilities, and 84 (75.7%) in station outdoor facilities. The highest number of PADs was 73 (61.9%) for OHCAs that occurred “on the train”.

Analysis of ROSC and CPC1-2 factors

The results pertaining to factors related to ROSC before hospital arrival based on multivariable logistic regression analysis are shown in Table 3. ROSC was significantly correlated with the following variables: evening rush hour (AOR, 3.79; 95% CI: 1.52–9.48), PAD (AOR, 2.57; 95% CI: 1.23–5.35), VF/PVT (AOR, 2.88; 95% CI: 1.15–7.26), and adrenaline administration (AOR, 2.30; 95% CI: 1.15–4.60).

Table 3 – Association between patient background and outcome after cardiogenic out-of-hospital cardiac arrest at the station.[a]

		ROSC[b]				CPC1-2[c]			
		COR	(95%CI)	AOR[d]	(95%CI)	COR	(95%CI)	AOR[d]	(95%CI)
Age Non elderly patient < 65		2.21	(1.56–3.13)	1.36	(0.73–2.52)	2.51	(1.69–3.72)	1.09	(0.42–2.82)
Sex male		1.23	(0.77–1.96)	0.99	(0.41–2.38)	1.13	(0.68–1.88)	0.79	(0.18–3.48)
Year									
	2014	Reference		Reference		Reference		Reference	
	2015	1.25	(0.74–2.13)	1.05	(0.44–2.47)	1.58	(0.86–2.89)	1.49	(0.37–6.10)
	2016	1.62	(0.96–2.72)	0.87	(0.35–2.16)	2.17	(1.22–3.87)	2.01	(0.51–7.96)
	2017	1.07	(0.64–1.78)	1.17	(0.51–2.67)	1.46	(0.81–2.64)	1.28	(0.34–4.83)
	2018	1.57	(0.93–2.64)	0.70	(0.26–1.87)	2.70	(1.52–4.80)	1.14	(0.26–4.90)
Season									
	Spring	0.72	(0.46–1.12)	0.69	(0.33–1.44)	1.00	(0.62–1.62)	0.66	(0.22–1.97)
	Summer	1.14	(0.72–1.82)	1.22	(0.57–2.63)	1.23	(0.74–2.02)	0.63	(0.17–2.29)
	Autumn	1.01	(0.64–1.60)	0.68	(0.30–1.54)	1.40	(0.86–2.27)	0.60	(0.17–2.06)
	Winter	Reference		Reference		Reference		Reference	
Time frame									
	Morning rush hour	2.91	(1.75–4.85)	2.01	(0.84–4.79)	3.48	(2.01–6.05)	4.52	(1.09–18.78)
	Daytime	1.47	(0.92–2.35)	1.63	(0.70–3.77)	1.28	(0.74–2.19)	2.90	(0.69–12.22)
	Evening rush hour	4.43	(2.57–7.63)	3.79	(1.52–9.48)	2.61	(1.47–4.63)	6.85	(1.51–31.15)
	Nighttime or Early morning	Reference		Reference		Reference		Reference	
Location									
	Platform	4.17	(1.94–8.98)	0.86	(0.28–2.66)	6.96	(2.10–23.05)	1.25	(0.10–14.83)
	on a train	4.14	(1.83–9.35)	0.51	(0.14–1.78)	7.45	(2.18–25.53)	1.81	(0.14–22.84)
	Stations outdoor facilities	4.07	(1.79–9.24)	1.40	(0.42–4.69)	7.89	(2.30–27.09)	5.69	(0.48–67.32)
	Stations indoor facilities	Reference		Reference		Reference		Reference	
Type of BCPR									
	Conventional CPR	10.92	(5.37–22.21)	2.10	(0.72–6.12)	8.43	(3.39–20.98)	0.22	(0.03–1.57)
	Hands-only CPR	9.40	(4.96–17.80)	1.98	(0.80–4.92)	10.19	(4.34–23.90)	0.86	(0.19–3.91)
	None or Ventilation only	Reference		Reference		Reference		Reference	
Bystander care									
	Witnessed arrest	3.00	(1.93–4.68)	1.50	(0.71–3.16)	2.76	(1.64–4.64)	2.24	(0.61–8.30)
	Dispatcher-assisted BCPR	0.86	(0.59–1.25)	1.20	(0.62–2.31)	0.89	(0.59–1.34)	1.47	(0.57–3.81)
	PAD	6.20	(4.30–8.93)	2.57	(1.23–5.35)	5.19	(3.49–7.71)	5.19	(1.38–19.51)
First documentation rhythm by EMS									
	VF or PVT	3.90	(2.38–6.40)	2.88	(1.15–7.26)	11.31	(5.36–23.87)	7.56	(1.35–42.43)
	Others	2.55	(0.61–10.58)	2.11	(0.37–12.18)	3.15	(0.36–27.67)	1.36	(0.05–34.03)
	PEA or Asystole	Reference		Reference		Reference		Reference	
EMS treatment									
	Defibrillation	0.75	(0.52–1.06)	1.16	(0.46–2.88)	0.84	(0.58–1.23)	0.78	(0.13–4.82)
	Airway management ETI or SGA	0.23	(0.14–0.39)	0.61	(0.31–1.22)	0.09	(0.03–0.24)	0.38	(0.11–1.39)
	Adrenaline administration	0.33	(0.21–0.52)	2.30	(1.15–4.60)	0.04	(0.01–0.13)	0.25	(0.06–1.06)
Call-to-contact interval									
	Early phase (1–8 min)	0.90	(0.60–1.36)	1.34	(0.67–2.67)	0.89	(0.57–1.39)	1.38	(0.47–4.04)
	Intermediate phase (9–11 min)	0.86	(0.57–1.28)	0.91	(0.44–1.87)	1.22	(0.80–1.87)	1.11	(0.35–3.51)
	Late phase (≧12 min)	Reference		Reference		Reference		Reference	
Contact-to-departure interval									
	Early phase (1–15 min)	1.85	(1.22–2.80)	0.73	(0.30–1.76)	2.25	(1.43–3.55)	1.08	(0.20–5.89)
	Intermediate phase (16–21 min)	1.66	(1.12–2.49)	0.62	(0.27–1.44)	2.03	(1.30–3.18)	1.47	(0.26–8.19)
	Late phase (≧21 min)	Reference		Reference		Reference		Reference	
Departure-to-hospital interval									
	Early phase (1–5 min)	1.00	(0.64–1.57)	1.10	(0.49–2.46)	1.19	(0.73–1.92)	1.46	(0.41–5.20)
	Intermediate phase (6–9 min)	0.99	(0.68–1.44)	0.98	(0.50–1.92)	1.14	(0.76–1.72)	1.62	(0.54–4.90)
	Late phase (≧10 min)	Reference		Reference		Reference		Reference	

Abbreviations: ROSC, return of spontaneous circulation; CPC, cerebral performance category; COR, crude odds ratio; CI, confidence interval; AOR, adjusted odds ratio; BCPR, bystander cardiopulmonary resuscitation; PAD, public access defibrillation; VF, ventricular fibrillation; PVT, pulseless ventricular tachycardia; PEA, pulseless electrical activity; EMS, emergency medical services; ETI, endotracheal intubation; SGA, supraglottic airways.

[a]We excluded cases that were in sinus rhythm at the time of EMS arrival and cases that occurred at in the tracks/railroad crossings, and 376 cases were included in the multivariable analysis.

[b]For analysis, good-of-fit tests was P = 0.69. All variables had no multicollinearity (VIF < 10). Area under receiver operating characteristics curve was 0.80. R^2 was 0.21. Over dispersion parameter = 1.07.

[c]For analysis, good-of-fit tests was P ≒1.0. All variables had no multicollinearity (VIF < 10). Area under receiver operating characteristics curve was 0.90. R^2 was 0.39. Over dispersion parameter = 1.25.

[d]Adjusted, age, sex, year, season, time frame, location, type of BCPR, witnessed arrest, dispatcher-assisted BCPR, PAD, rhythm at the EMS arrives, defibrillation by EMS, airway management, adrenalin administration, call-to-contact interval, contact-to-departure interval, departure-to-hospital interval.

The results related to CPC1-2 factors based on multivariable logistic analysis are shown in Table 3. CPC1-2 was significantly correlated with morning rush hour (AOR, 4.52; 95% CI: 1.09–18.78) and in the evening rush hour (AOR, 6.85; 95% CI: 1.51–31.15), PAD (AOR, 5.19; 95% CI: 1.38–19.51), and VF/PVT (AOR, 7.56; 95% CI: 1.35–42.43).

Discussion

In this study, we analysed OHCA occurrence location distribution at stations in Tokyo and factors associated with ROSC and favourable neurological outcomes in cardiogenic OHCAs. We found that 71.9% of cardiogenic OHCAs occurred on platforms and on trains. Furthermore, CPC1-2 was correlated with shockable rhythm at the scene, PAD, and occurrence during morning and evening rush hours.

The CPC1-2 of cardiogenic OHCAs witnessed at subway stations was 26.7% in São Paulo, 28.7% in London, [15,16] and 36.3% in Tokyo stations. At Osaka station, the CPC1-2 of patients with shockable rhythm was 28.0%, while that in Tokyo was 42.6%, which was higher than in other areas. Tokyo train stations recorded the highest resuscitation rates worldwide.

Every station had at least one AED, and the PAD implementation rate was approximately 50%. In this study, we found that PAD implementation rate and favourable neurological outcomes differed depending on timeframe, which recorded a higher rate during rush hours. Cardiogenic OHCA cases (72%) occurred on platforms and in trains. This was similar to the 2007 study reported by Fukuike et al.[17] where 86.4% of non-cardiogenic OHCAs occurred on tracks, railroad crossings, and platforms. This may be due to common accidents, such as individuals jumping in front of moving trains, visually impaired people, unsupervised children, and drunk individuals falling onto the tracks.[18]

Shibahashi et al. reported that the cost effectiveness of installing AEDs at stations was high but they must be installed strategically because: 1) stations are places where OHCAs are likely to occur; 2) the VF ratio is high; and 3) it is public.[19] Fukuike et al. stated that AEDs should be installed on platforms and in trains.[17] However, in Tokyo and many other cities, AEDs are not usually installed in the trains, except in long-distance trains.[12] According to the AED installation guidelines, AEDs are generally installed near ticket gates in train and subway stations in Japan.[12] This may be due to prioritization for safety management. However, in this study, we found that OHCAs are often witnessed on platforms and trains. OHCA patients on trains are usually lowered to the platform by bystanders. Therefore, we recommend placing at least one AED on each platform as 71.9% of patients receive CPR on the platform.

Smith et al. reported a lower rate of PAD implementation when bystanders did not know AED locations.[6] Station in Tokyo is large, complex, and intersected by multiple railroad tracks.[20] As a result, bystanders may not know AED locations and it will take a long time to get one. To get AEDs to patients as soon as possible, it is also important to increase the number of signboards indicating AED locations.

In a previous study, the ROSC of OHCA and the percentage of PAD performed at stations in Tokyo 2007–2008 were 28.3% and 26.5%, respectively.[17] In this study, ROSC was 48.4%, PAD was 48.9%, and CPC1-2 was 32.0%, which is a doubled improvement over the past decade. This improvement may be due to: 1) increased number of AEDs; 2) popularisation of CPR among citizens; and 3) dispatch-assisted CPR. Additionally, CPR training is provided to approximately 300,000 or more people every year, especially by TFD and the Japanese Red Cross Society.[21]

CPC1-2 at one month post-OHCA occurring morning and evening rush hours were as high as 47.3% and 40.2%, respectively, which was almost double the results for other timeframes of the day. Depending on the timeframe, there was a notable difference in age of customers at stations, with more elderly customers during daytime hours. Therefore, poor outcomes are possible. Additionally, there are more non-elderly people during early morning/night-time; however, poor outcomes still occur. During rush hours, there is a temporary increase in the number of customers because it is the common time for commuting to work, school, and home. Therefore, we believe that there are multiple bystanders and many PADs performed as a result. However, there are some issues that need to be addressed. Patients with OHCA during non-rush hours had lower rates of PAD (38.6%) and CPC1-2 at 1 month (20.5%). It is important to have a plan to deal with OHCA when people are less attentive. In addition to continued CPR and AED training, in the São Paulo metro, real-time video inside a station provided early recognition of OHCA and improved resuscitation rates.[15] In Japan, camera placement in stations is designed to prevent traffic accidents and ensure safety. It is reported that cameras equipped with artificial intelligence can detect cardiac arrest. [22,23] Railroad companies in Japan should install cameras with artificial intelligence on platforms to be alert to cardiac arrests so that station staff can quickly perform PADs even during non-rush hours.

Limitations

We were unable to identify the relationship between the accurate number of train users and area density; therefore, establishing a specific relationship between the stop position of the ambulance and the location of OHCA occurrence was not possible. If OHCA occurred on a train between stations, defibrillation took longer. However, these data do not distinguish whether the train is running or stopped. There may be a significant difference in the number of train users between weekdays and weekends. The initiation time of BCPR, PAD, and the density of the AED locations were unknown. Furthermore, the number and type of bystanders and their experience with CPR training were unknown due to data exclusions. The advanced life support procedure order performed by EMS was not considered, and outcomes may differ as a result.

Conclusions

We identified trends in locations of OHCAs occurring at Tokyo stations and factors associated with favourable neurological outcomes. AEDs should be placed on platforms as 71.9% of cardiogenic OHCAs occur on platforms and trains. Furthermore, we found significant correlations between CPC1-2 and OHCA occurrence during rush hour, as well as VF/PVT on the first documented rhythm by EMS and PAD. To improve future neurological outcomes of OHCAs at stations, installation of AEDs on platforms in addition to the use of artificial intelligence monitoring and offering CPR training are necessary.

CRediT authorship contribution statement

J. Miyako: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Visualization, Writing – original draft. **K. Nakagawa:** Validation. **R. Sagisaka:** Methodology, Validation, Writing – review & editing. **S. Tanaka:** Writing – review & editing. **H. Takeuchi:** Conceptualization. **H. Takyu:** Conceptualization. **H. Tanaka:** Writing – review & editing, Project administration, Supervision.

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