Location of out-of-hospital cardiac arrest and the awareness time interval: a nationwide observational study

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ABSTRACT

Aims A short awareness time interval (ATI, time from witnessing the arrest to calling for help) and bystander cardiopulmonary resuscitation (CPR) are important factors affecting neurological recovery after out-of-hospital cardiac arrest (OHCA). This study investigated the association of the location of OHCA with the length of ATI and bystander CPR.

Methods This population-based observational study used the nationwide Korea OHCA database and included all adults with layperson-witnessed OHCA with presumed cardiac aetiology between 2013 and 2017. The exposure was the location of OHCA (public places, private housing and nursing facilities). The primary outcome was short ATI, defined as <4 min from witnessing to calling for emergency medical service (EMS). The secondary outcome was the frequency of provision of bystander CPR. Multivariable logistic regression analysis was performed to evaluate the association of location of OHCA with study outcomes.

Results Of 30 373 eligible OHCAs, 66.6% occurred in private housing, 24.0% occurred in public places and 9.4% occurred in nursing facilities. In 67.3% of the cases, EMS was activated within 4 min of collapse, most frequently in public places (public places 77.0%, private housing 64.2% and nursing facilities 64.8%; p<0.01). The overall rate of bystander CPR was 65.5% with highest in nursing facilities (77.0%), followed by public places (70.1%) and private housing 62.3%; p<0.01). Compared with public places, the adjusted ORs (AORs) (95% CIs) for a short ATI were 0.58 (0.54 to 0.62) in private housing and 0.62 (0.56 to 0.69) in nursing facilities. The AORs (95% CIs) for bystander CPR were 0.75 (0.71 to 0.80) in private housing and 1.57 (1.41 to 1.75) in nursing facilities.

Conclusion OHCAs in private housing and nursing facilities were less likely to have immediate EMS activation after collapse than in public places. A public education is needed to increase the awareness of necessity of prompt EMS activation.

Key messages

What is already known on this subject

► The longer the awareness time interval (ATI) from witness of collapse to emergency medical service (EMS) activation, the worse the outcome for patients who had out-of-hospital cardiac arrest (OHCA). It is known that the outcome of patients who had OHCA occurring in private housing and nursing facilities is worse than in a public location, but the association of the location of OHCA and ATI was unknown.

What this study adds

► In this retrospective study using a nationwide OHCA database in South Korea, compared with OHCAs occurring in public places, OHCAs that occurred in private housing and nursing facilities showed significantly lower rates of immediate EMS activation after collapse. Potentially, delayed EMS activation of OHCAs in private housing and nursing facilities can worsen the outcome of OHCA.

INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) is a major public health burden throughout the world with the rapid initiation of resuscitation being critical for improving neurological outcomes.[1–3] It is known that the time from collapse to initiation of resuscitation is important, but the interval from awareness of event to calling for help has received less attention than other relevant time intervals.[4 5] The awareness time interval (ATI) is defined as time from the time of witnessed collapse to emergency medical service (EMS) activation.[6] It is the most critical time immediately after the collapse and before bystander cardiopulmonary resuscitation (CPR) is provided. To activate EMS and initiate bystander CPR, a bystander should recognise the event as cardiac arrest. The ATI makes an important contribution to the total no-flow time because an ambulance can be dispatched and dispatcher-assisted CPR (DA-CPR) can be provided only after EMS activation.[7 8] Previous studies reported that the longer the ATI, the lower the likelihood of favourable neurological recovery.[6 9] However, little is known about factors affecting the ATI.

Evidence shows that the location of OHCA is an important prognostic factor for OHCA.[10] Approximately 70% of cases of OHCAs occur in residential areas (private homes and nursing facilities) with worse outcomes than for those occurring in public places.[10–13] Persons with OHCA in private housing are less likely to be found in a shockable rhythm.[12] Bystander CPR rate is lower in residential places and effectiveness of DA-CPR is also lower in

this location than in public places.[10 14] However, it is unknown whether ATI, which reflects the first step of resuscitation efforts, varies according to the location of OHCA.

This study investigated the association between the location of OHCA and time to EMS activation (ATI) and provision rate of bystander CPR. We hypothesised that cases of OHCA occurring in public places would be more likely to have a short ATI and receive more bystander CPR than other places. We also analysed whether the patient's age modified the association between the location of OHCA and the ATI.

METHODS

Study design and setting

This was an observational cohort study using the nationwide Korea OHCA database. In Korea, the National Fire Agency (NFA) operates the single EMS system with 17 provincial fire departments.[8] Each fire department has its own dispatch centre and operates a DA-CPR programme. DA-CPR has been used in Korea since 2013. According to the protocol, the dispatcher asks two key questions (unconsciousness and normal breathing) and instructs the bystander in performing CPR when a cardiac arrest is suspected.[7] On arrival at the scene, the EMS provider continues CPR following the EMS CPR protocol during transport.[8 15] Since an EMS provider cannot declare death on-site, the EMS provider continues resuscitation and transfers the patient to a hospital.[8]

Data collection

The nationwide OHCA database was developed in 2006 with the cooperation of NFA and Korea Centers for Disease Control and Prevention (KCDC). This database has collected every EMS-treated OHCA case in South Korea. It consists of data from four sources: the ambulance run sheet, the EMS cardiac arrest registry, the dispatcher CPR registry and hospitals' medical records. The KCDC completes and manages the nationwide OHCA database.[14 16]

Study population

All layperson-witnessed adult (15 years of age or older) patients who had OHCA with presumed cardiac aetiology and treated by EMS from 2013 to 2017 were included in the study. Cases that were EMS-witnessed, found collapsed (unwitnessed), occurred in a hospital or clinic, or had an unknown location of arrest were excluded. Cases with an unknown or an extremely long (≥30 min) ATI were excluded because bystanders may not remember collapse time accurately after 30 min and because it is very unusual to activate EMS more than 30 min after collapse.

Outcome measures

The primary outcome was ATI, defined as the time that elapsed from the bystander witnessing the collapse to calling EMS. To determine the time of collapse, EMS providers arriving on scene asked the bystander about the time of collapse and recorded it in the EMS cardiac arrest registry in minutes. Time of notifying EMS was the EMS call time recorded in the dispatcher CPR registry. A short ATI was defined as within 4 min (<4 min), based on the time criterion previously shown to be associated with a lower likelihood of good neurological outcomes.[6] The secondary outcome was the frequency with which bystander CPR was performed, with or without dispatcher assistance.

Variables and measurements

The primary exposure was the location of arrest. In consideration of the increasing frequency of OHCA in nursing facilities, the location of OHCA was divided into public places, private housing and nursing facilities. Public places were defined as places open to the general public (eg, civic offices, commercial complexes and streets). Private housing was defined as places for living (eg, apartments and housing complexes).[17] Nursing facilities referred to nursing care homes, not hospitals. Both private housing and nursing facilities were considered as residential places.

The following variables were collected from the Korea OHCA database: (1) demographic factors (patients' age, sex and comorbidities); (2) community factors (date of arrest, call time, metropolis, ATI (min), bystander CPR and bystander defibrillation); (3) EMS-related factors (first recorded rhythm by EMS and EMS time intervals (response time, scene time and transport time)); (4) patient outcomes (prehospital return of spontaneous circulation, survival to hospital discharge, good neurological recovery (cerebral performance category score of 1 or 2)).

Statistical analysis

Demographic characteristics were compared according to the exposure groups. The X^2 test was used for categorical variables and the Kruskal-Wallis test for continuous variables. Multivariable logistic regression analysis was conducted for the study outcomes. Adjusted ORs (AORs) with 95% CIs were calculated for the location of OHCA, with public places as the reference. In the adjusted model, age group (young, ≤59; older, 60–79; and oldest, ≥80), sex, metropolitan area, year of event, season, day of the week (weekend vs weekday), time of day and comorbidities were included as confounders. An interaction analysis was conducted to investigate whether patients' age group modified the effect of the location of OHCA on the study outcomes by adding an interaction term (location of OHCA×patient's age group) to the adjusted logistic regression model. To verify the robustness of the study results, a sensitivity analysis was conducted using the same logistic regression analysis method, with a short ATI defined as ≤10 min.

All statistical analyses were conducted using SAS software, V.9.4 (SAS Institute). P values were based on a two-sided significance level of 0.05.

Patient and public involvement

This research was done without patient involvement.

RESULTS

Study population

Of the 145 003 EMS-treated OHCAs, 30 373 cases were included in the study once the exclusion criteria were applied (figure 1).

Characteristics of OHCA cases by location of arrest and patient's age

Among the 30 373 cases, 24.0% occurred in public places, 66.6% occurred in private housing and 9.4% occurred in nursing facilities. A short ATI (≤4 min) was found in 77.0% of the cases in public places, 64.2% of the cases in private housing and 64.8% of the cases in nursing facilities (p<0.01). Bystander CPR was performed in 70.1% of cases in public places, 62.3% of cases in private housing and 77.0% of cases in nursing facilities (p<0.01) (table 1).

A short ATI was found in 72.6% of the OHCA cases in the young group (≤59 years), 66.5% in the older group (60–79 years) and 63.6% in the oldest group (≥80 years) (p<0.01) (online supplemental table 1).

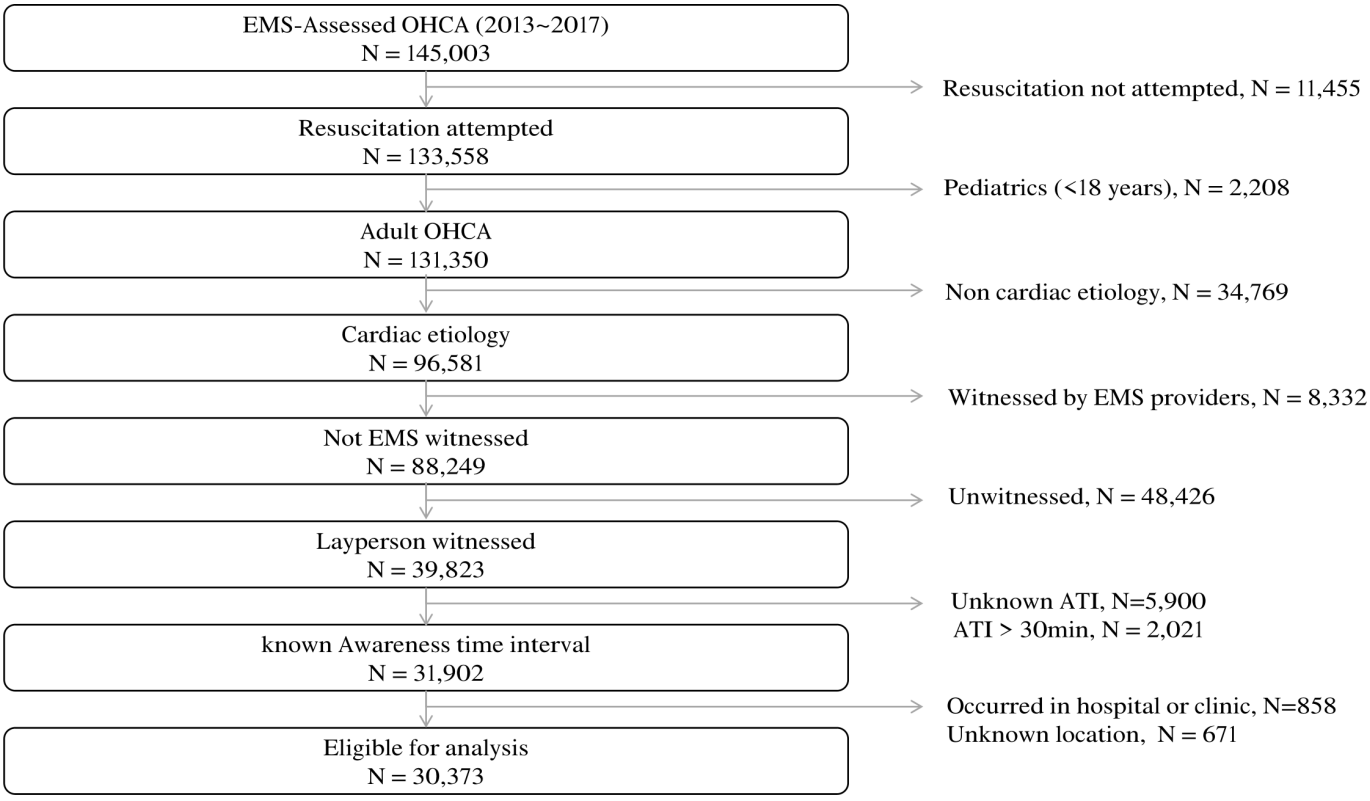

Figure 1 Patient flow. ATI, awareness time interval; EMS, emergency medical service; OHCA, out-of-hospital cardiac arrest.

Main analysis

In the adjusted model, compared with public places, the AORs (95% CI) for a short ATI were 0.58 (0.54 to 0.62) for private housing and 0.62 (0.56 to 0.69) for nursing facilities. The AORs (95% CI) for bystander CPR were 0.75 (0.71 to 0.80) for private housing and 1.57 (1.41 to 1.75) for nursing facilities (table 2).

Interaction analysis

While individuals in all groups had lower AOR of a short ATI in private homes, the likelihood of a short ATI decreased with age in private homes: 0.59 (0.54 to 0.66) for the young group, 0.46 (0.41 to 0.50) for the old group and 0.42 (0.3 to 0.46) for the oldest group. The AOR for bystander CPR in private homes also decreased with age: 0.74 (0.67 to 0.81) for the young group, 0.55 (0.50 to 0.60) for the old group and 0.52 (0.47 to 0.57) for the oldest group (reference: public places).

However, in, nursing facilities, the young group had the lowest likelihood of a short ATI: 0.34 (0.22 to 0.52) for the young group, compared with 0.48 (0.40 to 0.56) for the old group and 0.47 (0.41 to 0.54) for the oldest group, with public places as the reference. Nevertheless, the AOR for bystander CPR was significantly higher in public places for the young age group: 2.18 (1.20 to 3.97) for the young group, but not significantly different from public places for the old group: 1.09 (0.90 to 1.31) for the old group, or the oldest group: 1.08 (0.95 to 1.24) (table 3).

Sensitivity analysis

When the criterion for a short ATI was changed from 4 to 10 min, private housing and nursing facilities still showed statistically significant AORs of less than 1 compared with public places: 0.44 (0.39 to 0.49) for private housing and 0.52 (0.44 to 0.62) for nursing facilities. In an interaction analysis with age group, similar results were found to that of the original interaction analysis (table 4).

DISCUSSION

This study demonstrated that compared with OHCA cases occurring in public places, rapid activation of EMS after collapse was less for OHCA occurring in private housing and nursing facilities. We observed that compared with the OHCA cases occurring in public places, in private housing, the older the patient, the greater the likelihood of delayed EMS activation and the lower the likelihood of bystander CPR. At nursing facilities, more patients received bystander CPR than for those occurring in public places, but rapid EMS activation after collapse was less likely to happen.

The time from collapse to the start of resuscitation significantly affects the outcome of patients who had OHCA.[2 3] Various efforts have been made by community and EMS to shorten the time to the initiation of resuscitation.[18] EMS activation is the first step of OHCA treatment. ATI, time interval from collapse to calling for EMS, is known to be linearly associated with good neurological outcome.[6] However, not much attention has been paid to the ATI and little is known regarding the factors that delay the ATI. One possible reason for this might be the common perception that laypeople will naturally activate EMS immediately upon witnessing a collapse. However, people do not always activate EMS immediately and the ATI of OHCA varies.[6 19] A previous study reported that 25% of bystanders activated EMS more than 6 min after witnessing a collapse and the survival rate was low for that population.[6] In a study conducted in Amsterdam, 21% of bystanders who witnessed OHCA called other people first without activating EMS, which delayed the initiation of bystander CPR and worsened survival outcomes.[20]

Table 1 Demographics of all out-of-hospital cardiac arrests by location of cardiac arrest

	Total		Public places		Private housing		Nursing facilities		
	N	%	N	%	N	%	N	%	P value
Total	30 373	100.0	7293	100.0	20 236	100.0	2844	100.0	
Female	19 612	64.6	5777	79.2	12 824	63.4	1011	35.5	<0.01
Age (years)									<0.01
≤59	8485	27.9	3478	47.7	4917	24.3	90	3.2	
60~79	13 035	42.9	3013	41.3	9233	45.6	789	27.7	
≤80	8853	29.1	802	11.0	6086	30.1	1965	69.1	
Median (IQR)	72 (58–81)		61 (52–73)		73 (60–81)		84 (78–89)		<0.01
ATI (min)									<0.01
0~1	15 939	52.5	4410	60.5	10 083	49.8	1446	50.8	
2~3	4517	14.9	1207	16.6	2912	14.4	398	14.0	
4~5	3148	10.4	692	9.5	2133	10.5	323	11.4	
6~	6769	22.3	984	13.5	5108	25.2	677	23.8	
Median (IQR)	1 (0–5)		1 (0–3)		2 (0–6)		1 (0–5)		<0.01
Early ATI (<4)	20 456	67.3	5617	77.0	12 995	64.2	1844	64.8	<0.01
Bystander effort									
CPR	19 900	65.5	5112	70.1	12 599	62.3	2189	77.0	<0.01
Defibrillation	266	0.9	172	2.4	83	0.4	11	0.4	<0.01
Primary ECG									<0.01
VF/VT	5323	17.5	2676	36.7	2573	12.7	74	2.6	
PEA	3340	11.0	853	11.7	2185	10.8	302	10.6	
Asystole	21 710	71.5	3764	51.6	15 478	76.5	2468	86.8	
EMS time interval (min), median (IQR)									
Response time	7 (5–9)		7 (5–9)		7 (5–9)		7 (5–10)		<0.01
Scene time	11 (8–15)		9 (7–13)		11 (8–16)		10 (7–15)		<0.01
Transport time	6 (4–10)		6 (4–11)		6 (4–10)		7 (4–12)		<0.01
Patients' outcome									
Prehospital ROSC	4779	15.7	2302	31.6	2349	11.6	128	4.5	<0.01
Survival to discharge	3890	12.8	2015	27.6	1800	8.9	75	2.6	<0.01
Good CPC	2651	8.7	1507	20.7	1134	5.6	10	0.4	<0.01

ATI, awareness time interval; CPC, Cerebral Performance Scale ; CPR, cardiopulmonary resuscitation; EMS, emergency medical service; IQR, interquartile range; PEA, pulseless electrical activity; ROSC, return of spontaneous circulation; VF, ventricular fibrillation; VT, ventricular tachycardia.

While a majority of OHCA cases occur in residential areas, the survival outcomes of those cases are poorer than those occur in public places.[10] A previous study reported that OHCA cases occurring in residential places not only have lower bystander CPR rate but the effect of DA-CPR programme was also lower than the cases occurring in public places.[14] This study adds to the existing knowledge by demonstrating that EMS activation was more delayed in residential places, both private housing and nursing facilities, than public places. This aligns with previous studies, which pointed out that OHCA occurring in residential places was a risk factor for inappropriate calls made by bystanders, such as calling somewhere other than EMS.[6 19] In this study, EMS was activated immediately only in half of the cases in private housing and nursing facilities. Since EMS activation is the first step for DA-CPR, if EMS activation is delayed, DA-CPR may also be delayed. It is known that the effects of DA-CPR programmes vary according to the location of OHCA.[14 21] Delays in the ATI in private places can explain why a DA-CPR programme did not improve the neurological outcomes in private housing and nursing facilities. A delayed ATI itself may adversely affect neurological recovery and contribute to worse outcomes by decreasing effectiveness of DA-CPR.[6]

Table 2 Multivariable logistic regression analysis of outcome by location of cardiac arrest

	Total	Outcome		Adjusted*	
	N	N	%	OR	95% CI
Early ATI (<4 min)					
Total	30 373	20 456	67.3		
Public places	7293	5617	77.0	1.00	
Private housing	20 236	12 995	64.2	0.58	0.54 to 0.62
Nursing facilities	2844	1844	64.8	0.62	0.56 to 0.69
Bystander CPR					
Total	30 373	19 900	65.5		
Public places	7293	5112	70.1	1.00	
Private housing	20 236	12 599	62.3	0.75	0.71 to 0.80
Nursing facilities	2844	2189	77.0	1.57	1.41 to 1.75

*Adjusted for age group, gender, metropolis, year, season, weekend, night times and comorbidities (diabetes, hypertension, heart disease, stroke).
ATI, awareness time interval; CPR, cardiopulmonary resuscitation; OR, odds ratio.

This study analysed nursing facilities separately from private housing. They are similar to private housing in terms of being a place where people live, but similar to public places in that there are many people nearby. In this study, bystander CPR was more likely to be provided to patients in nursing facilities compared with other places, but the likelihood of a short ATI was lower than in public places. A study from Japan reported that in nursing facilities, bystander CPR was not associated with good

Table 3 Multivariable logistic regression analysis with interaction between patient's age group and location of cardiac arrest

	≤59			60–79			≥80		
	AOR	95% CI	P value	AOR	95% CI	P value	AOR	95% CI	P value
Early ATI (<4 min)									
Public place	1.00			1.00			1.00		
Private housing	0.59	0.54 to 0.66	<0.01	0.46	0.41 to 0.50	<0.01	0.42	0.38 to 0.46	<0.01
Nursing facilities	0.34	0.22 to 0.52	<0.01	0.48	0.40 to 0.56	<0.01	0.47	0.41 to 0.54	<0.01
Bystander CPR									
Public place	1.00			1.00			1.00		
Private housing	0.74	0.67 to 0.81	<0.01	0.55	0.50 to 0.60	<0.01	0.52	0.47 to 0.57	<0.01
Nursing facilities	2.18	1.20 to 3.97	0.01	1.09	0.90 to 1.31	0.38	1.08	0.95 to 1.24	0.25

Adjusted for gender, metropolis, year, season, weekend, night times and comorbidities (diabetes, hypertension, heart disease, stroke).
AOR, adjusted OR; ATI, awareness time interval; CPR, cardiopulmonary resuscitation.

Table 4 Sensitivity analysis for multivariable logistic regression analysis and interaction analysis

	Multivariable model					Interaction model					
	Total	Outcome		Model		≤59		60–79		≥80	
	N	N	%	AOR	95% CI	AOR	95% CI	AOR	95% CI	AOR	95% CI
Early ATI2 (<10 min)											
Total	30 373	27 146	89.4								
Public places	7293	6896	94.6	1.00		1.00		1.00		1.00	
Private housing	20 236	17 725	87.6	0.44	0.39 to 0.49	0.59	0.50 to 0.70	0.39	0.33 to 0.46	0.39	0.33 to 0.46
Nursing facilities	2844	2525	88.8	0.52	0.44 to 0.62	0.32	0.18 to 0.57	0.46	0.35 to 0.60	0.49	0.40 to 0.60

Adjusted for age group, gender, metropolis, year, season, weekend, night times and comorbidities (diabetes, hypertension, heart disease, stroke).
AOR, adjusted OR; ATI, awareness time interval.

neurological outcomes.[21] The poor prognosis of patients who had OHCA in nursing facilities despite the higher likelihood of bystander CPR may be due to the delayed recognition of OHCA and EMS activation. It is unknown why people in nursing facilities delayed EMS activation, which is a gap that has not been revealed by the studies to date. Further research is needed to improve OHCA outcome in nursing facilities.

Both older age and residential place are risk factors for a poor outcome of patients who had OHCA.[10 22] Based on this, we hypothesised that response to collapse would vary depending on the patient's age. In the interaction analysis, the older patients in private housing were less likely to have early EMS activation and to receive bystander CPR than those in public places. The elderly in the private home are likely to be isolated or with a partner who is unable to recognise collapse or act on it.[23] The elderly in the private housing are a vulnerable population with a high probability of delaying EMS activation and not receiving a bystander CPR despite the high risk of cardiac arrest. In nursing facilities, different from private housing, younger patients (≤59 years old) were least likely to have early EMS activation compared with those in public places. It is possible that a collapse will be discovered late since nursing home staff think that collapse is unlikely to occur in young patients and pay relatively little attention to them. However, it is difficult to know exactly why in this study. Not much is known about younger patients in nursing homes. Further studies are needed in the future.

A short ATI is important both in itself and for enhancing the effectiveness of DA-CPR.[15] Private housing, nursing facilities and elderly patients, who experience OHCA more frequently, appear to have delayed EMS activation. Identifying vulnerable populations and providing targeted education for early recognition and EMS activation should be emphasised to improve the survival outcomes of OHCA.

Limitations

This study had several limitations. First, the EMS call time was automatically recorded, but the collapse time was recorded based on laypeople's statements. Accurate measurement of time is a major methodological challenge in any OHCA research as many time variables, including collapse time, depend on recollections of bystanders in highly stressful situations. Therefore, the accuracy of the ATI measurement in this study may be subject to measurement bias. However, we believe that the misclassification of the collapse time is non-differential, meaning that bystanders' inaccurate recollection of collapse time is random regardless of the location of the OHCAs (public or private places). As non-differential random errors may lead to an underestimate of the true association, a careful interpretation of the study results is needed. Second, we could not separate the ATI into the time from collapse to the recognition of the event as OHCA and the time from recognition to EMS activation. To develop an intervention programme to shorten the ATI, further research is needed to identify which component of the ATI was delayed. Third, as an observational study, there may have been covariates that were not adjusted in the logistic model.

CONCLUSION

OHCA cases that occurred in private housing and nursing facilities were significantly less likely to have rapid, immediate activation of EMS than cases of OHCA occurring in public places. A public campaign is needed to increase the awareness of the necessity of a prompt EMS activation and response to OHCA, targeting vulnerable places, including private homes and nursing facilities.

Contributors SYK—writing (original draft) and formal analysis. SYL—conceptualisation, data curation, formal analysis, data interpretation, writing (review

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