Association of the COVID-19 pandemic with bystander cardiopulmonary resuscitation for out-of-hospital cardiac arrest: a population-based analysis in Tokyo, Japan

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ABSTRACT

Background The impact of the COVID-19 pandemic on bystander cardiopulmonary resuscitation (CPR) for out-of-hospital cardiac arrest (OHCA) is unclear. This study aimed to investigate whether rates of bystander CPR and patient outcomes changed during the initial state of emergency declared in Tokyo for the COVID-19 pandemic.

Methods This retrospective study used data from a population-based database of OHCA maintained by the Tokyo Fire Department. By comparing data from the periods before (18 February to 6 April 2020) and during the declaration of a state of emergency (7 April 2020 to 25 May 2020), we estimated the change in bystander CPR rate, prehospital return of spontaneous circulation, and survival and neurological outcomes 1 month after OHCA, accounting for outcome trends in 2019. We performed a multivariate regression analysis to evaluate the potential mechanisms for associations between the state of emergency and these outcomes.

Results The witnessed arrest rates before and after the declaration periods in 2020 were 42.5% and 45.1%, respectively, compared with 44.1% and 44.7% in the respective corresponding periods in 2019. The difference between the two periods in 2020 was not statistically significant when the trend in 2019 was considered. The bystander CPR rates before and after the declaration periods significantly increased from 34.4% to 43.9% in 2020, an 8.3% increase after adjusting for the trend in 2019. This finding was significant even after adjusting for patient and bystander characteristics and the emergency medical service response. There were no significant differences between the two periods in the other study outcomes.

Conclusion The COVID-19 pandemic was associated with an improvement in the bystander CPR rate in Tokyo, while patient outcomes were maintained. Pandemic-related changes in patient and bystander characteristics do not fully explain the underlying mechanism; there may be other mechanisms through which the community response to public emergency increased during the pandemic.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The results of observational studies on the association of the COVID-19 pandemic with bystander cardiopulmonary resuscitation (CPR) rates are inconsistent.

WHAT THIS STUDY ADDS

⇒ The COVID-19 pandemic had a positive association with the bystander CPR rate in Tokyo, while patient outcomes were maintained.
⇒ The increase remained significant even after adjusting for patient and bystander characteristics and emergency medical service response.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The results of this study suggest that there are unidentified factors related to an increased community response to cases of out-of-hospital cardiac arrest (OHCA) during the pandemic.
⇒ Further studies aimed at identifying the underlying factors may strengthen the 'chain of survival' in response to OHCAs.

INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) is a global public health problem, with 175 000 cases in Europe, 350 000 cases in the USA and 120 000 cases in Japan each year.[1–3] Bystander cardiopulmonary resuscitation (CPR) is a key element for improving outcomes after OHCA, and it increases the likelihood of survival after OHCA twofold to fourfold.[4–6]

The COVID-19 pandemic has affected people's lifestyle and interpersonal interactions. CPR requires bystanders to come into close proximity with another individual and perform aerosol-generating procedures with a potential risk of transmission of infection.[7] The perceived threat of viral inoculation may result in decreased willingness of the public to provide CPR.

The results of observational studies on the association of the COVID-19 pandemic with bystander CPR rates are inconsistent; some studies showed a decline in bystander CPR rate[7–13] during the pandemic, whereas others did not.[14–20] These inconsistencies may be partly explained by small sample sizes and unadjusted trends over time, although the disparity among the studies suggests that regional differences also play a role. Moreover, previous studies have focused on merely establishing whether the COVID-19 pandemic affected

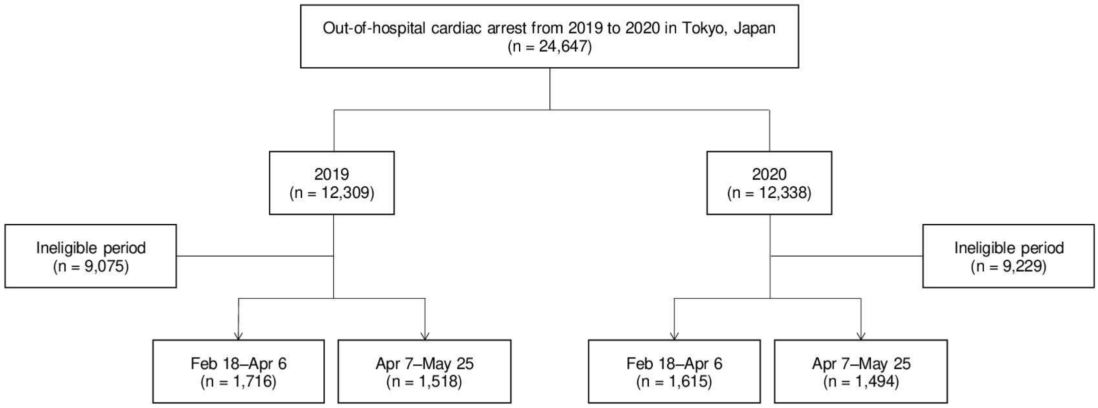

Figure 1 Study flow chart.

public response to OHCA. Although some studies considered the observed differences in bystander CPR rates during the COVID-19 pandemic to be due to pandemic-related changes in patient and bystander characteristics, the potential mechanisms were not statistically analysed.[7 11 14 16] Understanding the association of the COVID-19 pandemic with bystander CPR and its underlying mechanism is important as it aids the revision or strengthening of the so-called 'chain of survival' in response to OHCAs in the current era.

We aimed to investigate the association of the COVID-19 pandemic with the bystander CPR rate and outcomes of OHCA by comparing pandemic and non-pandemic periods and to explore the underlying mechanisms using data from a population-based registry in Tokyo, Japan.

METHODS

This retrospective cohort study was conducted using data from the Utstein-style registry of the Tokyo Fire Department, which included a population-based record of OHCAs in Tokyo, Japan. We included patients who experienced OHCA and were resuscitated and transported to hospitals by Tokyo emergency medical service (EMS) personnel from 18 February to 25 May 2020 and the corresponding period in 2019. The Tokyo Fire Department approved the analysis of the anonymised data. The requirement for informed consent was waived.

EMS in Tokyo

The Tokyo Fire Department serves most parts of Tokyo, except for two municipalities (Inagi City and Tokyo Islands), and covers an area of 1769 km^2. It serves a daytime population of approximately 15.8 million individuals and a night-time population of approximately 13.7 million individuals. All EMS personnel performed CPR in accordance with the International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations.[21] During the study period, EMS personnel instructed laypersons via telephone to perform compression-only CPR unless they knew how to provide rescue breathing and had personal protective equipment. EMS personnel in Japan are legally prohibited from terminating resuscitation; therefore, most patients who experience OHCA undergo resuscitation by EMS personnel and are transported to hospitals, the only exceptions being patients with advance directives such as do-not-resuscitate orders in which a family physician can take over the care of the patient and those where death is certain. For the patients with OHCA, the paramedics continued the CPR at the scene until the Tokyo Fire Department was able to determine a destination hospital.

COVID-19 outbreak in Tokyo

On 11 March 2020, the WHO classified the COVID-19 outbreak as a pandemic. The first COVID-19 case in Tokyo was reported on 24 January 2020, and on 7 April 2020, the Japanese government declared a state of emergency in seven prefectures, including Tokyo. On 7 April 2020, the Tokyo Metropolitan Government requested citizens to practice social distancing and stay at home, and the closure of non-essential businesses was ordered on 11 April 2020. The state of emergency was lifted on 25 May 2020. COVID-19 cases in Tokyo peaked on 17 April 2020, with 206 new cases on that day, and a total of 3941 cases that accounted for 0.028% of the population were confirmed.

Data collection

The Tokyo Fire Department collects the date of emergency call, patient demographics, presence of the witness, relationship of the witness to the patient (family member, EMS personnel, healthcare provider, friend or other), presumed aetiology of cardiac arrest, details regarding the bystander CPR, dispatcher instructions regarding CPR, initial recorded cardiac rhythm, intravenous epinephrine administration, call-to-response time (time from the emergency call to arrival of the EMS vehicle at the scene), on-scene time (time from EMS vehicle arrival on scene to departure for the hospital), transport time (time from scene to hospital arrival), call-to-hospital time (time from the emergency call to arrival of the EMS vehicle at the hospital), prehospital return of spontaneous circulation (ROSC), and survival and neurological status 1 month after the cardiac arrest. The aetiology (cardiac vs non-cardiac) was determined clinically by the physician in charge at the hospitals in collaboration with the EMS personnel. The information regarding bystander CPR and dispatcher CPR instruction were reported on the EMS record. Neurological outcomes were determined by the physician responsible for the care of the patient using the cerebral performance category (CPC), with categories 1, 2, 3, 4 and 5 representing good cerebral performance, moderate cerebral disability, severe cerebral disability, coma or a vegetative state, and death, respectively.[22] The EMS personnel collected data in collaboration with physician in charge of the patient's care and then uploaded the data to the registry on the Tokyo Fire Department's database server. The data were then checked for consistency, and incomplete forms were returned to the respective fire

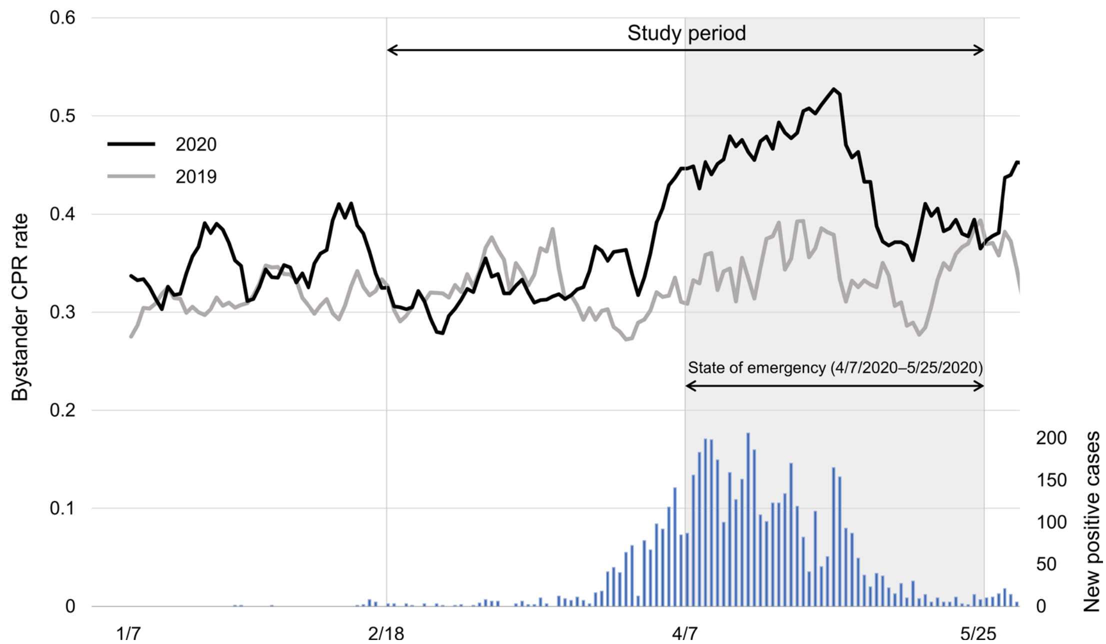

Figure 2 Trends in bystander CPR rate and daily new confirmed COVID-19 cases in Tokyo. CPR, cardiopulmonary resuscitation.

stations for completion. In this study, numerical variables were categorised into quartiles.

Outcomes

The primary outcome measure was the bystander CPR rate. The secondary outcome measures were the rates of prehospital ROSC, survival at 1 month after cardiac arrest and survival with favourable neurologic outcomes. A favourable neurological outcome was defined as a CPC of 1 or 2.[23]

Statistical analysis

Bystander CPR rates for the period before the declaration of a state of emergency in 2020 ('before declaration period', 18 February to 6 April 2020) were compared with those during the state of emergency ('after declaration period', 7 April to 25 May 2020) in Tokyo. We then determined if there were differences in patient and EMS characteristics during these periods. To mitigate the effects of extraneous factors (eg, trend towards increasing bystander CPR rates[6] and potential seasonal changes), we considered outcome trends in the same periods in 2019, using a linear regression model that included the year (2019 or 2020), the period and year–period interaction as fixed effects. We then tested whether changes in the bystander CPR rate could be sufficiently explained by changes in the patient and bystander characteristics and the EMS response to OHCA between before and after declaration periods using multivariate linear regression analysis adjusted for these potential mediators. We constructed two regression models. Model I included patient and bystander-related covariates: patient age and sex, site of cardiac arrest (private residence or not), witness (family member, EMS personnel, healthcare provider, friend, other or none), presumed aetiology (cardiogenic or non-cardiogenic), year (2019 or 2020), period and year–period interaction term. Model II included the patient and bystander covariates included in Model I as well as EMS-related covariates: call-to-response time and dispatcher instructions regarding CPR (yes or no). For prehospital ROSC, survival at 1 month post OHCA, and favourable neurological outcome at 1 month post OHCA, call-to-hospital time was also included as a covariate of Model II. The covariates were selected before the analysis based on previous research and clinical plausibility.[5 6 8 10 12 21 24] All statistical analyses were performed using the R V.3.6.1 (R Foundation for Statistical Computing, Vienna, Austria). All statistical tests were two-sided, and statistical significance was assessed using 95% CIs.

Patient and public involvement

Patients or the public were not involved in the design, conduct, reporting or dissemination plans of our research.

RESULTS

A total of 24 647 patients experienced OHCA in 2019 (n=12 309) and 2020 (n=12 338). Of these, 6343 patients who experienced OHCA during the study period (from 18 February 2019 to 25 May 2019, or from 18 February 2020 to 25 May 2020) were included in the analysis (figure 1). There were no missing values for the variables of interest in the dataset. The median age was 79 years (IQR, 67–86 years), and 3646 (57.5%) of the patients were men. The number of daily new cases of COVID-19 are shown at the bottom of figure 2. The median daily new cases per 100 000 population was 0.04 (IQR, 0.01–0.12; maximum, 1.00) and 0.58 (IQR, 0.11–0.96; maximum, 1.47) before and after the declaration of the state of emergency (arising from COVID-19), respectively.

Table 1 summarises the patients' baseline characteristics before and after the declaration of a state of emergency. After adjusting for the trends in 2019, the rate of dispatcher instructions regarding CPR (8.5% (95% CI, 3.4% to 13.7%)), call-to-response time (0.4 min (95% CI, 0.1 to 0.7)), on-scene time (1.0 min (95% CI, 0.4 to 1.7)) and call-to-hospital time (1.6 min (95% CI, 0.6 to 2.6)) showed a significant increase in 2022. The proportions of patients with short (<4 min) call-to-response time, short (<14 min) on-scene time and short (3–27 min) call-to-hospital time significantly decreased, whereas the proportion of patients with long (8–69 min) call-to-response time, long (21–129 min) on-scene time and long (40–208 min) call-to-hospital time significantly increased. The witnessed arrest rates before and after the declaration periods in 2020 were 42.5% and 45.1%, respectively, compared with rates of 44.1% and 44.7%

Table 1 Changes in baseline characteristics of patients who experienced out-of-hospital cardiac arrest in Tokyo from before to after declaration of a state of emergency

	2019		2020		
Variables*	**18 Feb–6 Apr (n=1716)**	**7 Apr–25 May (n=1518)**	**18 Feb–6 Apr (n=1615)**	**7 Apr–25 May (n=1494)**	**Percentage change in 2020 with respect to 2019 (95% CI)**
Age group, years†					
0–65	408 (23.8)	415 (27.3)	364 (22.5)	313 (21.0)	−5.1 (−9.3 to −1.0)
66–77	423 (24.7)	346 (22.8)	362 (22.4)	371 (24.8)	4.3 (0.1 to 8.5)
78–85	418 (24.4)	352 (23.2)	399 (24.7)	377 (25.2)	1.7 (−2.5 to 5.9)
86–109	467 (27.2)	405 (26.7)	490 (30.3)	433 (29.0)	−0.8 (−5.3 to 3.6)
Men	989 (57.6)	879 (57.9)	918 (56.8)	860 (57.6)	0.5 (−4.4 to 5.3)
Arrest at private residence	1181 (68.8)	1009 (66.5)	1142 (70.7)	1063 (71.2)	2.8 (−1.8 to 7.3)
Witnessed arrest	756 (44.1)	679 (44.7)	687 (42.5)	674 (45.1)	1.9 (-3.0 to 6.8)
Witness					
Family	359 (20.9)	311 (20.5)	348 (21.5)	353 (23.6)	3.4 (−4.0 to 10.8)
EMS personnel	96 (5.6)	100 (6.6)	91 (5.6)	116 (7.8)	1.9 (−3.3 to 7.1)
Healthcare provider	46 (2.7)	42 (2.8)	40 (2.5)	45 (3.0)	0.8 (−2.8 to 4.3)
Friend	10 (0.6)	20 (1.3)	7 (0.4)	10 (0.7)	−1.2 (−3.1 to 0.7)
Other	245 (14.3)	206 (13.6)	201 (12.4)	150 (10.0)	−4.9 (−11.6 to 1.8)
Presumed cardiac aetiology	1006 (58.6)	956 (63.0)	962 (59.6)	941 (63.0)	−0.9 (−5.7 to 3.9)
AED use by a bystander	40 (2.3)	58 (3.8)	21 (1.3)	23 (1.5)	−1.3 (−2.7 to 0.2)
Dispatcher CPR instructions	789 (46.0)	696 (45.8)	735 (45.5)	783 (52.4)	8.5 (3.4 to 13.7)
Initial VF/VT cardiac rhythm	93 (5.4)	100 (6.6)	89 (5.5)	108 (7.2)	0.6 (−1.8 to 2.9)
Epinephrine administration	190 (11.1)	173 (11.4)	180 (11.1)	157 (10.5)	−1.0 (−4.1 to 2.1)
Call-to-response time, min†					
<4	327 (19.1)	322 (21.2)	335 (20.7)	272 (18.2)	−4.7 (−8.6 to −0.8)
4–5	485 (28.3)	478 (31.5)	529 (32.8)	525 (35.1)	−0.8 (−5.4 to 3.7)
6–8	389 (22.7)	345 (22.7)	402 (24.9)	373 (25.0)	0.0 (−4.2 to 4.2)
8–69	515 (30.0)	373 (24.6)	349 (21.6)	324 (21.7)	5.5 (1.3 to 9.8)
On-scene time, min†					
<14	351 (20.5)	342 (22.5)	296 (18.3)	210 (14.1)	−6.3 (−10.2 to −2.5)
14–17	546 (31.8)	422 (27.8)	459 (28.4)	346 (23.2)	−1.2 (−5.7 to 3.2)
18–21	423 (24.7)	364 (24.0)	427 (26.4)	394 (26.4)	0.6 (−3.7 to 4.9)
21–129	396 (23.1)	390 (25.7)	433 (26.8)	544 (36.4)	7.0 (2.6 to 11.4)
Transport time, min†					
<6	365 (21.3)	308 (20.3)	327 (20.2)	294 (19.7)	0.4 (−3.6 to 4.4)
6–8	416 (24.2)	387 (25.5)	377 (23.3)	429 (28.7)	−2.5 (−6.8 to 1.9)
9–12	462 (26.9)	402 (26.5)	448 (27.7)	371 (24.8)	−2.1 (−6.5 to 2.3)
13–170	473 (27.6)	421 (27.7)	463 (28.7)	400 (26.8)	4.1 (−0.2 to 8.4)
Call-to-hospital time, min†					
3–27	437 (25.5)	392 (25.8)	377 (23.3)	248 (16.6)	−7.1 (−11.2 to −3.0)
28–33	477 (27.8)	400 (26.4)	452 (28.0)	398 (26.6)	0.0 (−4.3 to 4.5)
34–39	394 (23.0)	345 (22.7)	388 (24.0)	365 (24.4)	0.6 (−3.5 to 4.8)
40–208	408 (23.8)	381 (25.1)	398 (24.6)	483 (32.3)	6.4 (2.0 to 10.7)

*Data are presented as number (%).
†Numerical variables were categorised into quartiles.
AED, automated external defibrillator; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; VF, ventricular fibrillation; VT, ventricular tachycardia.

in the respective corresponding periods in 2019. The difference between the two periods in 2020 was not statistically significant when the trend in 2019 was considered (adjusted difference, 1.9%; 95% CI, −3.0 to 6.8).

The bystander CPR rate increased from 34.4% in the before declaration period to 43.9% in the after declaration period in 2020 (figure 2). The difference was statistically significant after adjusting for the trend in 2019, with an adjusted difference of 8.3% (95% CI, 3.6 to 13.0) (table 2). This increase in the bystander CPR rate remained significant after the patient and bystander characteristics were further adjusted (adjusted difference, 9.3%; 95% CI, 4.8 to 13.7). In Model II (the fully adjusted model that was further adjusted for EMS-related covariates), the increase in bystander CPR remained significant (adjusted difference, 6.9%; 95% CI, 2.8 to 11.1). Furthermore, in Model II, the dispatcher CPR instruction had a significant and the strongest association with bystander CPR (adjusted difference, 34.6%; 95% CI, 32.5 to 36.8). After adjusting for the trend in 2019, there was no significant difference in the proportion of patients for whom bystander CPR was initiated after the dispatcher instruction between the before and after declaration periods in 2020. There was no significant difference between the two periods in the other study outcomes.

Table 2 Changes in study outcomes from before to after declaration of a state of emergency

Variables*	2019		2020		Percentage change in 2020 with respect to 2019 (95% CI)		
	18 Feb–6 Apr (n=1716)	7 Apr–25 May (n=1518)	18 Feb–6 Apr (n=1615)	7 Apr–25 May (n=1494)	Crude	Model I†	Model II‡
Bystander CPR	557 (32.5)	511 (33.7)	556 (34.4)	656 (43.9)	8.3 (3.6 to 13.0)	9.3 (4.8 to 13.7)	6.9 (2.8 to 11.1)
Prehospital ROSC	177 (10.3)	168 (11.1)	118 (7.3)	128 (8.6)	0.5 (–2.4 to 3.3)	0.4 (–2.3 to 3.2)	0.5 (–2.3 to 3.2)
1 month survival	104 (6.1)	114 (7.5)	73 (4.5)	66 (4.4)	–1.6 (–3.8 to 0.7)	–1.4 (–3.5 to 0.8)	–1.4 (–3.5 to 0.8)
1 month CPC I or 2	58 (3.4)	78 (5.1)	43 (2.7)	40 (2.7)	–1.7 (–3.5 to 0.1)	–1.5 (–3.2 to 0.1)	–1.5 (–3.3 to 0.2)

*Data are presented as number (%).
†Model I was adjusted for age (categorised into quartiles), sex, site of cardiac arrest (private residence or not), witness (family member, EMS personnel, healthcare provider, friend, other or none), presumed aetiology (cardiogenic or non-cardiogenic), year (2019 or 2020), period (18 February to 6 April or 7 April to 25 May) and year–period interaction term.
‡In addition to covariates in Model I, Model II was adjusted for call-to-response time (categorised into quartiles) and dispatcher instructions regarding CPR (yes or no).
CPC, cerebral performance category; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; ROSC, return of spontaneous circulation.

DISCUSSION

Our analysis revealed that the bystander CPR rate in Tokyo was significantly higher in the period after a state of emergency was declared due to the COVID-19 pandemic than before it. EMS responses to OHCA also significantly changed after the pandemic; the rate of dispatcher instructions regarding CPR significantly increased and prehospital times significantly lengthened. However, the increase in bystander CPR rate remained significant even after adjusting for patient and bystander characteristics and EMS response.

The incidence of OHCA during the state of emergency was similar to that in the control period in 2019, which was consistent with the results of previous studies.[8 18 25] Although it is possible that some of the OHCAs observed during the pandemic were due to respiratory failure or indirect complications of COVID-19, the effect of the pandemic on the incidence of OHCA might have been marginal because of the very low incidence of COVID-19 during the study period. We found that the call-to-response, on-scene and call-to-hospital times were significantly longer during the pandemic than those prior to the pandemic, which is also consistent with previous reports.[11 12 16 25] The time spent gathering information regarding COVID-19, precautionary measures to minimise COVID-19 exposure and transmission from patients with OHCA, and restricted resources of hospitals to accept patients with OHCA during the COVID-19 pandemic might have contributed to the increased prehospital time. In this study, dispatcher CPR instruction had significant and the strongest impact on bystander CPR. Previous studies have shown that dispatcher CPR instruction increases bystander CPR provision,[26] and these results suggest this is true even during a pandemic.

Although the increased rate of bystander CPR observed in this study was counterintuitive and contradicted the results of previous studies,[7–13] we found three other studies that have reported an increase in bystander CPR rate during the pandemic.[15 16 25] The authors of those studies speculated that the increase in bystander CPR rate can be explained by the fact that people stayed at home during the pandemic; therefore, the OHCA was likely to be witnessed by family members. However, none of these studies observed a significant increase in the proportion of witnessed cardiac arrest during the pandemic, and previous studies showed that patients with OHCA witnessed by family members were less likely to receive bystander CPR than those witnessed by a non-family member.[27 28] Similarly, we did not find a significant change in the proportion of witnessed OHCA. Moreover, although it was attenuated, the increase in bystander CPR rate during the pandemic remained significant, even after adjusting for the patient and bystander characteristics and the EMS response.

Our results suggest that there are unidentified factors related to an increased community response to OHCA during the pandemic. One potential factor is strengthened solidarity in the community that promotes altruistic behaviour in response to a looming threat. A survey reported that the number of individuals joining an open online course on basic life support increased during the COVID-19 pandemic.[29] Furthermore, the level of willingness of trainees and the proportion of trainees with high willingness increased during the pandemic. Considering that the top identified barriers for laypersons to perform CPR included fear and a lack of confidence,[30] it is theoretically possible that the altruistic social environment helped them overcome these barriers. Further studies aimed at identifying the underlying factors may strengthen the ‘chain of survival’ in response to OHCAs.

Limitations

This study has several limitations. First, it is an observational study. Although we found a significant association between the declaration of a state of emergency due to the COVID-19 pandemic and the rate of bystander CPR, we cannot infer causality. Second, we could not identify the mechanism underlying the increase in the bystander CPR rate during the pandemic. Third, the dataset did not include detailed information regarding bystander CPR (eg, quality of CPR, bystander CPR duration and number of bystanders who participated in CPR). Last, the study period was relatively short. The long-term association of the COVID-19 pandemic with the community response to and outcomes of OHCA could be different from those observed here.

CONCLUSION

The declaration of a state of emergency during the COVID-19 pandemic was associated with an increase in the bystander CPR rate in Tokyo, even when accounting for changes in patient and bystander characteristics. The identification of other mechanisms through which the community response to public emergency increased during the pandemic could help future efforts to strengthen the chain of survival.

Contributors KeS conceptualised and designed the study, drafted the initial manuscript and reviewed and revised the manuscript. KH, KaS and YH contributed to analysis and interpretation of data, revised the manuscript critically for important intellectual content. All authors approved the final manuscript as submitted and

agree to be accountable for all aspects of the work. KeS is the guarantor who accepts full responsibility for the finished work and/or the conduct of the study, had access to the data, and controlled the decision to publish.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval The study protocol was approved by the ethics committee of Tokyo Bokutoh Hospital (approval number: 03-049).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. Registry data may be available with permission of the Tokyo Fire Department.

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