Available online at www.sciencedirect.com

Resuscitation Plus

journal homepage: www.elsevier.com/locate/resuscitation-plus

Clinical paper

Impact of sex of bystanders who perform cardiopulmonary resuscitation on return of spontaneous circulation in out-of-hospital cardiac arrest patients: A retrospective, observational study

Shunsuke Nakamura[a], *Tsuyoshi Nojima*[a,*], *Takafumi Obara*[a], *Takashi Hongo*[a], *Tetsuya Yumoto*[a], *Takashi Yorifuji*[b], *Atsunori Nakao*[a], *Hiromichi Naito*[a]

Abstract

Background: The impact of the sex of bystanders who initiate cardiopulmonary resuscitation (CPR) on out-of-hospital cardiac arrest (OHCA) patients has not been fully elucidated. This study aims to investigate the association between the sex of bystanders who perform CPR and the clinical outcomes of OHCA patients in real-world clinical settings.

Methods: We conducted a retrospective, observational study using data from the Okayama City Fire Department in Japan. Patients were categorized based on bystanders' sex. Our primary outcomes were return of spontaneous circulation (ROSC). Our secondary outcome was 30-day survival and 30-day favorable neurological outcome, defined as Cerebral Performance Category score of 1 or 2. Multivariable logistic regression analysis was used to examine the association between these groups and outcomes.

Results: The study included 3,209 patients with a comparable distribution of male (1,540 patients: 48.0%) and female bystanders (1,669 patients: 52.0%) between the groups. Overall, 221 (6.9%) ROSC at hospital arrival, 226 (7.0%) patients had 30-day survival, and 121 (3.8%) patients had 30-day favorable neurological outcomes. Bystander sex (female as reference) did not contribute to ROSC at hospital arrival (adjusted OR [aOR] 1.11, 95% CI: 0.76–1.61), 30-day survival (aOR 1.23, 95% CI: 0.83–1.82), or 30-day favorable neurological outcomes (aOR 0.66, 95% CI: 0.34–1.27). Basic life support education experience was a bystander factor positively associated with ROSC. Patient factors positively associated with ROSC were initial shockable rhythm and witness of cardiac arrest.

Conclusion: There were no differences in ROSC, 30-day survival, or 30-day neurological outcomes in OHCA patients based on bystander sex.

Keywords: Layperson, Sex difference, Heart arrest, Education

Introduction

Bystander cardiopulmonary resuscitation (CPR) plays a critical role in improving survival of patients following out-of-hospital cardiac arrest (OHCA).[1–4] In witnessed OHCA, patients who received bystander CPR had approximately twice the one-month survival rate compared to those who did not receive bystander CPR.[5] Bystanders who may not recognize cardiac arrest or have no prior CPR experience are encouraged to perform dispatcher-assisted CPR (DA-CPR), thereby increasing the chance of survival.[6–9] DA-CPR assists CPR by allowing the dispatcher to determine whether the patient is in cardiac arrest status and to provide instructions for chest compressions and ventilation or only chest compressions.[9,10] DA-CPR has a lower survival rate compared to public bystander-initiated CPR[9]; this disparity in survival may be associated with the gender of those performing DA-CPR,[10] although this relationship has not been clearly examined.

There have been studies about bystander characteristics including gender difference and CPR performance. However, since most

* Corresponding author.
E-mail address: t.nojima1002@gmail.com (T. Nojima).

https://doi.org/10.1016/j.resplu.2024.100659
Received 12 January 2024; Received in revised form 27 April 2024; Accepted 30 April 2024

studies were conducted using mannequin simulation[11–13] or in unique environment where there are gender differences in BLS education due to factors such as military service,[3] the impact of the sex of bystanders who initiate CPR on OHCA patients has not been fully elucidated.

In this study, we evaluated the impact of bystander sex on outcomes in situations where there are no significant CPR educational background differences. The primary objective of this study was to assess the relationship between bystander sex and clinical outcomes of patients experiencing OHCA in real-world clinical settings in Japan.

Methods

Study design

This retrospective, observational cohort study complied with the principles of the Declaration of Helsinki. Data on OHCA patients managed from January 2012 to December 2020 were obtained from the Okayama City Fire Department database. This study was approved by the Okayama University ethics committee (K2209-13).

Okayama City Fire Department database

This database includes OHCA patients registered by the Okayama City Fire Department. The following data were registered in the database: patient information (Sex, age, initial rhythm, cause of cardiac arrest, return of spontaneous circulation [ROSC], survival at discharge, Cerebral Performance Category [CPC] score after 30 days), prehospital resuscitation information (witnessed cardiac arrest, location of cardiac arrest, bystander CPR, emergency medical service [EMS] response time), and bystander CPR information (bystander's sex, bystander's basic life support [BLS] education experience). Arrest location was classified (home/residence, non-home/public) according to previous literature.[14] EMS response time was defined as time from dispatch to EMS contact. Individual bystander data was first obtained by the dispatcher, then confirmed by EMS personnel on the scene. Information on bystanders who initiated CPR was recorded. Bystander CPR was defined as layperson-initiated CPR on the scene. The cause of cardiac arrest, 30-day survival, and 30-day CPC scores were provided by the physicians at the receiving hospital.

Okayama City emergency medical system

Okayama City, a mix of urban and suburban areas, covers a 789 km^2 area and has the population of approximately 700,000, with 340,000 (48.6%) males and 360,000 (51.4%) females at the time of this study. EMS in Okayama City is operated by 20 fire stations and one command center. EMS personnel are activated by dialing 119. The emergency dispatcher has the role of guiding the caller through the CPR process over the phone. The dispatchers are trained to identify a cardiac arrest within 60 s and, if necessary, provide step-by-step instructions to the caller for performing CPR. These instructions include guidance on chest compressions, rescue breathing, and use of automated external defibrillators (AED) when available. An EMS team (paramedic) with more than three ambulance crew members is dispatched from the nearest fire station to provide immediate care to OHCA patients. At least one EMS personnel capable of emergency life-saving technique must be present on the EMS team.[15] Specially trained emergency life-saving EMS personnel have the authority to perform endotracheal intubation and administer adrenaline. Almost all OHCA patients are transported to the nearest emergency hospital. In Japan, EMS personnel are not allowed to stop resuscitation in the field or during transport once resuscitation has been initiated.

Patient selection, groups, endpoints

Inclusion criteria were all types of OHCA patients who were over 18 years old and received bystander CPR and were transported by the Okayama City Fire Department from January 1, 2012, to December 31, 2020. Exclusion criteria were as follows: patients without information on bystander's sex or cardiac arrest witnessed by medical staff. Eligible patients were divided into two groups based on the sex of the bystander performing CPR, the "male bystander CPR group" or the "female bystander CPR group." Our primary outcome was ROSC at hospital arrival. Secondary outcome was 30-day survival and 30-day favorable neurological outcome. Favorable neurological outcomes were defined as CPC scores of 1 or 2.

Data analysis

Continuous variables are described using medians with interquartile ranges. Categorical variables are summarized using counts and percentages. The Mann-Whitney *U* test or chi-square test was used as an univariable analysis. Our primary aim is to explore the relationship between bystander sex and clinical outcomes of OHCA patients. A multivariable logistic regression analysis was used to adjust for factors associated with primary and secondary outcomes. The following confounding variables were selected: age, patient's sex (male, female), cause of arrest (cardiac, noncardiac), witnessed cardiac arrest (yes, no), location of cardiac arrest (home/residence, non-home/public location), initial shockable rhythm (ventricular fibrillation, tachycardia) at scene, EMS response time (defined as time from patients call to EMS contact), DA-CPR, and bystander's previous BLS education experience (yes, no). These variables were selected based on previous literature suggesting an association of these factors with neurological outcomes.[16,17]

The results of multivariable logistic regression are described with odds ratio (OR) and a 95% confidence interval (CI). Additionally, a subgroup analysis was conducted based on patient sex to determine if there was an impact of bystander sex on outcomes. A multivariable logistic regression analysis was used to adjust for factors associated with outcomes using the same confounding variables for adjustments. A p-value < 0.05 was considered significant. Statistical analysis was performed using STATA/SE 17 (StataCorp, Lakeway, TX, USA).

Results

Patient Characteristics

Fig. 1 is a flow diagram showing the enrollment process for our study population. Of 5,535 patients documented in the data during the study period, 3,209 OHCA patients were included in this analysis, with 1,540 (48.0%) in the male bystander CPR group and 1,669 (52.0%) in the female bystander CPR group.

Baseline clinical information of both patients and bystanders are presented in Table 1. Among the OHCA patients, 1,678 (52.2%) were male, the median age was 82 years, median EMS response time was 7 min, 174 (5.4%) had shockable rhythm, 1,635 (50.9%) had estimated cardiac origin, 1,283 (39.9%) experienced a witnessed cardiac arrest, 2,920 (90.9%) had DA-CPR, and 1,162

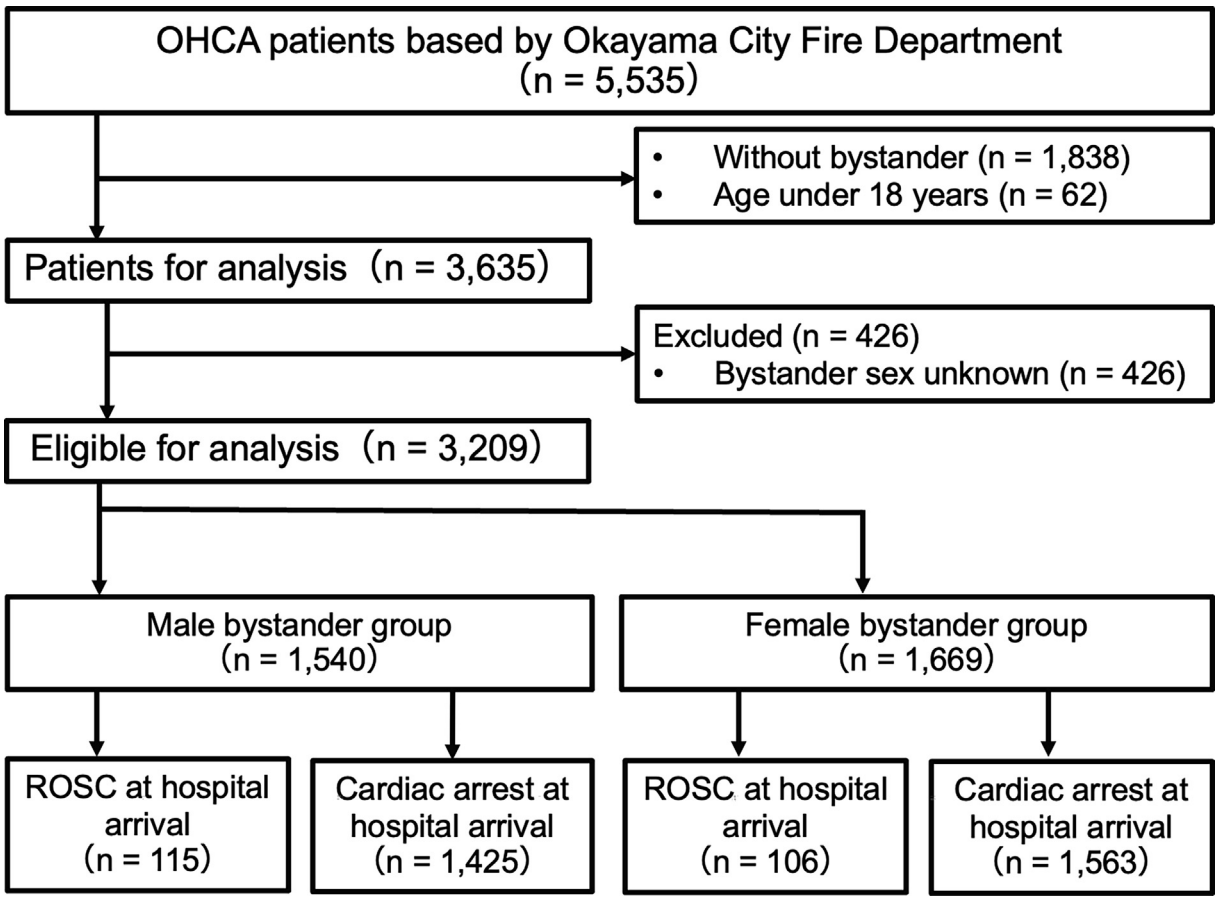

Fig. 1 – Flow chart showing the enrollment process for our study population. CPR; cardiopulmonary resuscitation, OHCA; out-of-hospital cardiac arrest.

(36.2%) had a public location of cardiac arrest. Eight hundred twenty-six (25.7%) bystanders had past BLS education experience.

Among all OHCA patients, 221 (6.9%) had ROSC at hospital arrival, 226 (7.0%) had 30-day survival, and 121 (3.8%) had 30-day favorable neurological outcomes. The male bystander CPR group performed resuscitation for younger OHCA patients than the female bystander CPR group (79 vs. 84 years, $p < .01$), while patient sex did not differ between the two groups (809 [52.5%] vs. 869 [52.1%], $p = 0.79$). The female bystander group had a higher proportion of BLS education experience compared with the male bystander group (267 [17.3%] vs. 559 [33.5%], $p < .01$).

Impact of bystander sex on outcomes

The impact of bystander sex on ROSC, 30-day survival, and 30-day favorable neurological outcome with univariable and multivariable logistic regression analysis are shown in Table 2. Bystander sex (female as reference) did not contribute to ROSC (crude OR 1.19, 95% CI: 0.91–1.56; adjusted OR [aOR] 1.11, 95% CI: 0.76–1.61), 30-day survival (crude OR 1.43, 95% CI: 1.09–1.37; aOR 1.23, 95% CI: 0.83–1.81), 30-day favorable neurological outcomes (crude OR 1.36, 95% CI: 0.94–1.96; aOR 0.66, 95% CI: 0.34–1.27). The results showed that the presence of initial shockable rhythm (aOR 4.92, 95% CI: 2.89–8.38), witnessed cardiac arrest (aOR 2.45, 95% CI: 1.67–3.61), and bystander BLS education experience (aOR 1.42, 95% CI: 1.13–1.86) were associated with ROSC.

Subgroup analysis

Subgroup analyses were performed according to patient sex (Table 3). Male patients had a higher proportion of ROSC when the bystander was male compared to female (male 71/809 [8.8%] vs. female 55/869 [6.3%]). On the other hand, when patients were female, the proportion of ROCS with a female bystander was higher (male 44/731 [6.0%] vs. female 51/800 [6.4%]). However, bystander sex had no significant effect on ROSC, regardless of patient sex after adjustment (male patients: aOR 1.29, 95% CI: 0.78–2.11, female patients: aOR 0.88, 95% CI: 0.45–1.62).

Discussion

In this study, we found that bystander sex was not associated with ROSC, 30-day survival, and 30-day neurological outcomes in OHCA patients, as indicated by both the univariate and multivariate logistic models. BLS education experience was a bystander factor associated with ROSC in these patients. Patient factors positively associated with ROSC was initial shockable rhythm, witness of cardiac arrest.

Previous studies have established various performance metrics for CPR quality such as chest compression depth, rate, and recoil.[18–20] Recent studies have shown a correlation between CPR performance and bystander sex. One study reported a difference

Table 1 – Characteristics of OHCA patients and bystanders.

	All (n = 3,209)	Male Bystander group (n = 1,540)	Female Bystander group (n = 1,669)	p-value
Patient Characteristics				
Sex (male), n (%)	1,678 (52.2)	809 (52.5)	869 (52.1)	0.79
Age, median [IQR]	82 [70–88]	79 [67–87]	84 [73–89]	<.01
EMS response time (min), median [IQR]	7 [5–9]	7 [5–9]	7 [5–9]	0.036
Call to hospital arrival (min), median [IQR]	26 [20–32]	26 [20–32]	25 [20–32]	<.01
Initial shockable rhythm, n (%)	174 (5.4)	96 (6.2)	78 (4.7)	0.052
Estimated cardiac origin, n (%)	1,635 (50.9)	772 (50.1)	863 (51.7)	0.37
Witnessed CA, n (%)	1,283 (39.9)	587 (38.1)	696 (41.7)	0.038
Dispatcher assisted CPR, n (%)	2,920 (90.9)	1,392 (90.4)	1,528 (91.6)	0.25
Location of CA				<.01
Home/Residence, n (%)	2,047 (63.8)	1,070 (69.5)	977 (58.5)	
Non-home/Public, n (%)	1,162 (36.2)	470 (30.5)	692 (41.5)	
Patient outcomes				
ROSC at hospital arrival, n (%)	221 (6.9)	115 (7.5)	106 (6.4)	0.21
30-day Survival, n (%)	226 (7.0)	127 (8.2)	99 (5.9)	0.01
CPC at 30 days				
CPC 1, n (%)	108 (3.4)	62 (4.0)	46 (2.8)	–
CPC 2, n (%)	13 (0.4)	5 (0.3)	8 (0.5)	–
CPC 3, n (%)	24 (0.7)	17 (1.1)	7 (0.4)	–
CPC 4, n (%)	81 (2.5)	43 (2.8)	38 (2.3)	–
CPC 5, n (%)	2,983 (92.9)	1,413 (91.8)	1,570 (94.1)	–
30-day favorable neurological outcome, n (%)	121 (3.8)	67 (4.4)	54 (3.2)	0.098
Bystander Characteristics				
BLS education experience, n (%)	826 (25.7)	267 (17.3)	559 (33.5)	<.01

Favorable neurological outcome was defined as CPC 1 or 2.

OHCA: out-of-hospital cardiac arrest, IQR: interquartile range, EMS: emergency medical services, BLS: basic life support, CA: cardiac arrest, CPR: cardiopulmonary resuscitation, ROSC: return of spontaneous circulation, CPC: Cerebral Performance Category.

in CPR performance in mannequin simulation based on bystander sex,[13] indicating that females exhibited significantly lower compression depth and adequate compression rates compared to males. Another study found that male bystanders performed deeper chest compressions than females.[12] Additionally, another report on gender differences in CPR effort indicated that females showed higher exertion during CPR; however, these differences were due to BMI and varying physical fitness conditions.[21] These studies suggested that females tend to deliver lower-quality CPR compared to males. Nevertheless, it is important to note that these studies were not conducted in real-life situations.

In contrast, analysis of real clinical data from several studies suggests that there is no significant difference in CPR performance based on bystander sex. Takei et al. conducted a study related to bystander CPR, focusing on emergency medical technician (EMT) assessments of chest compression quality. They found no difference in CPR quality based on bystander sex.[22] Their study also highlighted that effective CPR was linked to the presence of multiple rescuers, bystander initiative, and non-elderly bystanders. Similarly, Park et al. evaluated chest compression quality through subjective observations by EMTs to investigate factors linked to high-quality bystander CPR.[23] This study also revealed no variation in CPR quality based on bystander sex and highlighted bystander age as the primary factor influencing CPR quality. One study from Korea highlighted the effectiveness of CPR performed by bystanders of different sexes on OHCA patient outcomes in the clinical setting; however, this study was biased due to the differences in previous CPR education between males and females, with the majority of males receiving CPR training in the military.[24] In this study, bystanders' BLS education experience was also associated with favorable outcomes. Another study in Korea investigated the relationship between bystander sex and CPR rates, as well as interactions with patient sex.[22] As far as we know, our present study is the first to explore the relationship between bystander sex and prognosis in Japan, where there are no apparent distinctions in BLS education experience between males and females in society.

Although data is conflicting, the prognosis for OHCA in females is indicated to be worse compared to males.[25,26] Previous studies have reported that female OHCA patients in public settings were less likely to receive bystander CPR and AED compared with male OHCA patients.[27] Indeed, resuscitation attempts for OHCA patients might vary depending on the sex of the bystander or public vs. clinical setting.[28,29] Bystanders may hesitate to perform resuscitation, especially for female OHCA patients, considering undressing for resuscitation.[27] Our study did not have large sample size compared to previous study, however, a subgroup analysis by patient revealed no correlation in bystanders between bystanders' sex and ROSC.

This study had several limitations. First, identifying the primary bystander is challenging when there are multiple bystanders at the scene. In this study, we designated the bystander who performed CPR as the primary bystander when the EMS arrived at the scene. Second, this study is constrained by its focus on prehospital treatment, while neuro critical care management in post-cardiac arrest syndrome was not explored. Differences in intensive care may have

Table 2 – Multivariable logistic regression analysis examining the impact of bystander sex on ROSC, 30-day survival, and 30-day favorable neurological outcomes.

	n / N (%)	Crude OR (95% CI)	Adjusted OR (95% CI)
ROSC at hospital arrival			
Patient factor			
Sex (male)	126/1,678 (8)	1.23 (0.93–1.62)	0.99 (0.67–1.45)
Age	–	0.98 (0.97–0.99)	0.99 (0.98–1.00)
EMS response time	–	1.00 (0.97–1.04)	1.00 (0.95–1.06)
Initial shockable rhythm	37/174 (21)	7.93 (5.23 – 12.0)	4.92 (2.89–8.38)
Estimated cardiac origin	121/1,635 (7)	1.18 (0.90 – 1.55)	1.02 (0.68–1.53)
Witnessed CA	155/1,283 (12)	3.87 (2.88 – 5.21)	2.45 (1.67–3.61)
Dispatcher assisted CPR	191/2,920 (7)	0.60 (0.40 – 0.91)	1.39 (0.68–2.86)
Non-home/Public location of CA	110/1,162 (9)	1.82 (1.39–2.40)	1.45 (0.96–2.18)
Bystander factor			
Sex (male)	115/1,540 (7.5)	1.19 (0.91–1.56)	1.11(0.76–1.61)
BLS education experience	83/826 (10)	1.88 (1.41–2.50)	1.42 (1.13–1.86)
30-day survival			
Patient factor			
Sex (male)	129/1,678 (8)	1.23 (0.94–1.62)	0.61 (0.40–0.92)
Age	–	0.97 (0.96–0.98)	0.98 (0.97–0.99)
EMS response time	–	0.94 (0.89–0.98)	0.89 (0.83–0.96)
Initial shockable rhythm	61/174 (35)	17.8 (12.2–25.9)	9.24 (5.63–15.2)
Estimated cardiac origin	142/1,635 (9)	1.69 (1.28–2.23)	1.53 (0.99–2.36)
Witnessed CA	172/1,283 (13)	5.37 (3.92–7.35)	3.13 (2.08–4.71)
Dispatcher assisted CPR	189/2,920 (6)	0.47 (0.32–0.69)	0.84 (0.45–1.59)
Non-home/Public location of CA	102/1,162 (9)	1.49 (1.14–1.96)	1.18 (0.77–1.81)
Bystander factor			
Sex (male)	127/1,540 (8)	1.43 (1.09–1.37)	1.23 (0.83–1.82)
BLS education experience	72/826 (9)	1.49 (1.11 – 2.01)	0.97 (0.59–1.60)
30-day favorable neurological outcomes			
Patient factor			
Sex (male)	79/1,628 (5)	1.75 (1.20–2.56)	0.76 (0.38–1.53)
Age	–	0.96 (0.95–0.97)	0.97 (0.95–0.99)
EMS response time	–	0.96 (0.91–1.02)	0.92 (0.82–1.03)
Initial shockable rhythm	42/174 (24)	47.9 (27.2–84.8)	17.9 (8.30–38.8)
Estimated cardiac origin	92/1,635 (6)	3.18 (2.08–4.85)	6.89 (2.30–20.7)
Witnessed CA	101/1,283 (8)	8.14 (5.01–13.2)	3.67 (1.76–7.64)
Dispatcher assisted CPR	98/2,920 (3)	0.40 (0.25–0.64)	0.74 (0.27–2.05)
Non-home/Public location of CA	65/1,162 (6)	2.11 (1.46–3.03)	2.66 (1.33–5.29)
Bystander factor			
Sex (male)	67/1,540 (4)	1.36 (0.94–1.96)	0.66 (0.34–1.27)
BLS education experience	46/826 (6)	2.01 (1.37–2.95)	1.25 (0.57–2.77)

Multivariable logistic regression analysis was adjusted for patient age, patient sex, EMS response time, witnessed cardiac arrest, initial shockable rhythm, cardiac origin, dispatcher assisted CPR, non-home/public location of cardiac arrest, bystander sex, and bystander BLS education experience.

ROSC: return of spontaneous circulation, CI: confidence interval, OR: odds ratio, EMS: emergency medical services, CA: cardiac arrest, CPR: cardiopulmonary resuscitation, BLS: basic life support.

had an impact on neurological outcomes. Third, important factors for investigation regarding quality of CPR such as chest compression rate, depth, fraction, interruption time, first responder intervention time, and/or early defibrillation were not documented in this study. Fourth, due to retrospective design of the study, we must acknowledge that uncaptured data on other characteristics of bystander personnel such as age, duration of CPR, use of AED, and time interval between onset and BLS training, may impact outcomes. Fifth, our patients were all from a single geographic region with a relatively small sample size. In addition, it should be noted that racial difference could not be considered in this study. Sixth, the etiology of cardiac arrest is described by a binary variable (cardiac/non-cardiac); however, instructions to bystanders (DA-CPR) and clinical outcomes may vary according to different etiologies. Finally, pre-arrest CPC scores of OHCA patients could not be obtained; therefore, it cannot be ruled out that any low CPC scores were present pre-arrest.

Table 3 – Subgroup analysis according to patient sex. Multivariable logistic regression analysis was used to examine ROSC.

	n/N (%)	Adjusted OR (95% CI)
Male patients		
Bystander sex		
Male	71/809 (8.8)	1.29 (0.78–2.11)
Female	55/869 (6.3)	Ref
Female patients		
Bystander sex		
Male	44/731 (6.0)	0.88 (0.45–1.62)
Female	51/800 (6.4)	Ref

Subgroup analysis was conducted according to patients' sex. This analysis was focused "bystander sex". Multivariable logistic regression analysis adjusted for patient age, EMS response time, witnessed cardiac arrest, initial shockable rhythm, cardiac origin, dispatcher assisted CPR, non-home/public location of cardiac arrest and bystander BLS education experience.

ROSC: return of spontaneous circulation, CI: confidence interval, OR: odds ratio, EMS: emergency medical services, CPR: cardiopulmonary resuscitation, BLS: basic life support.

Conclusion

There was no difference in ROSC, 30-day survival, and 30-day neurological outcomes in OHCA patients based on sex of the bystander who initiated CPR.

Ethics approval and consent to participate

This study conforms to the principles outlined in the Declaration of Helsinki and was approved by the ethics committee of the Okayama University Hospital, ID: K2209-13. Patient consent was waived for all participants enrolled in this study because of its retrospective study design.

Consent for publication

Not applicable.

Availability of data and materials

The datasets from this study are available from the corresponding author upon request.

Credit authorship contribution statement

Shunsuke Nakamura: Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization. **Tsuyoshi Nojima:** Writing – review & editing, Visualization, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Takafumi Obara:** Writing – review & editing, Visualization, Formal analysis, Conceptualization. **Takashi Hongo:** Writing – review & editing, Visualization, Formal analysis. **Tetsuya Yumoto:** Writing – review & editing, Visualization. **Takashi Yorifuji:** Writing – review & editing, Visualization, Formal analysis. **Atsunori Nakao:** Writing – review & editing, Supervision, Investigation. **Hiromichi Naito:** Writing – review & editing, Visualization, Supervision, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank the members Okayama City Fire Department. We thank Christine Burr for editing the manuscript.

Author details

[a]*Department of Emergency, Critical Care, and Disaster Medicine, Faculty of Medicine, Dentistry, and Pharmaceutical Sciences, Okayama University, 2-5-1 Shikata-cho, Kita-ku, Okayama 700-8558, Japan* [b]*Department of Epidemiology, Faculty of Medicine, Dentistry, and Pharmaceutical Sciences, Okayama University, 2-5-1 Shikata-cho, Kita-ku, Okayama 700-8558, Japan*

REFERENCES

1. Hasselqvist-Ax I, Riva G, Herlitz J, et al. Early cardiopulmonary resuscitation in out-of-hospital cardiac arrest. N Engl J Med 2015;372:2307–15.
2. Kragholm K, Wissenberg M, Mortensen RN, et al. Bystander efforts and 1-year outcomes in out-of-hospital cardiac arrest. N Engl J Med 2017;376:1737–47.
3. Park HJ, Jeong WJ, Moon HJ, et al. Factors associated with high-quality cardiopulmonary resuscitation performed by bystander. Emerg Med Int 2020;2020:8356201.
4. Yan S, Gan Y, Jiang N, et al. The global survival rate among adult out-of-hospital cardiac arrest patients who received cardiopulmonary resuscitation: a systematic review and meta-analysis. Crit Care 2020;24:61.

5. Agency FaDM. Current Status of Emergency Medical Service, 2020 (in Japanese).
6. Rea TD, Eisenberg MS, Culley LL, Becker L. Dispatcher-assisted cardiopulmonary resuscitation and survival in cardiac arrest. Circulation 2001;104:2513–6.
7. Tanaka Y, Nishi T, Takase K, et al. Survey of a protocol to increase appropriate implementation of dispatcher-assisted cardiopulmonary resuscitation for out-of-hospital cardiac arrest. Circulation 2014;129:1751–60.
8. Wander PL, Fahrenbruch CE, Rea TD. The dispatcher assisted resuscitation trial: indirect benefits of emergency research. Resuscitation 2014;85:1594–8.
9. Riva G, Jonsson M, Ringh M, et al. Survival after dispatcher-assisted cardiopulmonary resuscitation in out-of-hospital cardiac arrest. Resuscitation 2020;157:195–201.
10. Goto Y, Funada A, Maeda T, Goto Y. Association of dispatcher-assisted cardiopulmonary resuscitation with initial shockable rhythm and survival after out-of-hospital cardiac arrest. Eur J Emerg Med 2022;29:42–8.
11. Verplancke T, De Paepe P, Calle PA, De Regge M, Van Maele G, Monsieurs KG. Determinants of the quality of basic life support by hospital nurses. Resuscitation 2008;77:75–80.
12. Leary M, Buckler DG, Ikeda DJ, et al. The association of layperson characteristics with the quality of simulated cardiopulmonary resuscitation performance. World J Emerg Med 2017;8:12–8.
13. Wang J, Zhuo CN, Zhang L, Gong YS, Yin CL, Li YQ. Performance of cardiopulmonary resuscitation during prolonged basic life support in military medical university students: a manikin study. World J Emerg Med 2015;6:179–85.
14. Naim MY, Griffis HM, Berg RA, et al. Compression-only versus rescue-breathing cardiopulmonary resuscitation after pediatric out-of-hospital cardiac arrest. J Am Coll Cardiol 2021;78:1042–52.
15. Naito H, Yumoto T, Yorifuji T, et al. Improved outcomes for out-of-hospital cardiac arrest patients treated by emergency life-saving technicians compared with basic emergency medical technicians: a JCS-ReSS study report. Resuscitation 2020;153:251–7.
16. Grunau B, Kime N, Leroux B, et al. Association of intra-arrest transport vs continued on-scene resuscitation with survival to hospital discharge among patients with out-of-hospital cardiac arrest. JAMA 2020;324:1058–67.
17. Jensen TW, Ersboll AK, Folke F, et al. Training in basic life support and bystander-performed cardiopulmonary resuscitation and survival in out-of-hospital cardiac arrests in Denmark, 2005 to 2019. JAMA Netw Open 2023;6:e233338.
18. Abella BS. High-quality cardiopulmonary resuscitation: current and future directions. Curr Opin Crit Care 2016;22:218–24.
19. Cheskes S, Byers A, Zhan C, et al. CPR quality during out-of-hospital cardiac arrest transport. Resuscitation 2017;114:34–9.
20. Lin Y, Cheng A, Grant VJ, Currie GR, Hecker KG. Improving CPR quality with distributed practice and real-time feedback in pediatric healthcare providers - A randomized controlled trial. Resuscitation 2018;130:6–12.
21. Lopez-Gonzalez A, Sanchez-Lopez M, Rovira-Gil E, Gonzalez-Garcia A, Ferrer-Lopez V, Martinez-Vizcaino V. Sex differences in the effort indicators during cardiopulmonary resuscitation manoeuvres on manikins. Eur J Emerg Med 2015;22:62–5.
22. Lee G, Ro YS, Park JH, Hong KJ, Song KJ, Shin SD. Interaction between bystander sex and patient sex in bystander cardiopulmonary resuscitation for out-of-hospital cardiac arrests. Resuscitation 2023;187 109797.
23. Takei Y, Nishi T, Matsubara H, Hashimoto M, Inaba H. Factors associated with quality of bystander CPR: the presence of multiple rescuers and bystander-initiated CPR without instruction. Resuscitation 2014;85:492–8.
24. Kim HB, Cho GC, Lee YH. Can bystanders' gender affect the clinical outcome of out-of-hospital cardiac arrest: a prospective, multicentre observational study. Am J Emerg Med 2021;48:87–91.
25. Parikh PB, Hassan L, Qadeer A, Patel JK. Association between sex and mortality in adults with in-hospital and out-of-hospital cardiac arrest: a systematic review and meta-analysis. Resuscitation 2020;155:119–24.
26. Malik A, Gewarges M, Pezzutti O, et al. Association between sex and survival after non-traumatic out of hospital cardiac arrest: a systematic review and meta-analysis. Resuscitation 2022;179:172–82.
27. Matsui S, Kitamura T, Kiyohara K, et al. Sex Disparities in receipt of bystander interventions for students who experienced cardiac arrest in Japan. JAMA Netw Open 2019;2:e195111.
28. Lei H, Hu J, Liu L, Xu D. Sex differences in survival after out-of-hospital cardiac arrest: a meta-analysis. Crit Care 2020;24:613.
29. Perman SM, Vogelsong MA, Del Rios M. Is all bystander CPR created equal? Further considerations in sex differences in cardiac arrest outcomes. Resuscitation 2023;182 109649.