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Original paper

Decline in rescue breathing and its impact on outcomes in pediatric out-of-hospital cardiac arrest due to drowning: a nationwide study, 2012–2023

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Abstract

Background: Rescue breathing is considered essential in pediatric out-of-hospital cardiac arrest (OHCA) due to drowning, a type of asphyxial arrest where hypoxia precedes circulatory collapse. However, the increasing promotion of compression-only CPR (CO-CPR) may have contributed to changes in bystander CPR practices, including a decline in rescue-breathing CPR (RB-CPR). Whether such temporal changes have influenced outcomes in pediatric drowning OHCA remains unclear.

Methods: We analyzed nationwide data from the All-Japan Utstein Registry (2012–2023), including pediatric OHCA patients (≤17 years old) whose arrests were caused by drowning and received bystander CPR from laypersons. Patients were categorized into RB-CPR and CO-CPR groups. The primary outcome was 30-day mortality; secondary outcomes included prehospital absence of return of spontaneous circulation (ROSC) and 30-day unfavorable neurological survival, defined as Cerebral Performance Category score 3–5. We used multivariable Poisson regression to estimate adjusted risk ratio (aRR) and conducted analyses by age and witnessed status.

Results: Among 740 eligible patients, 41.6% received RB-CPR and 58.4% received CO-CPR. The proportion of RB-CPR declined over the study period. CO-CPR was associated with higher 30-day mortality (aRR 1.38, 95% CI 1.14–1.67), higher prehospital absence of ROSC, and worse neurological outcomes compared with RB-CPR. The adverse association of CO-CPR was most pronounced in unwitnessed arrests, where ventilation may be particularly important.

Conclusions: In pediatric drowning OHCA, CO-CPR was associated with worse survival and neurological outcomes than RB-CPR. These findings underscore the necessity for rescue breathing and the importance of ventilation-focused bystander CPR training in pediatric and drowning-related scenarios.

Keywords: Drowning, Out-of-hospital cardiac arrest, Cardiopulmonary resuscitation, Child, Asphyxia

Introduction

Drowning is among the leading causes of unintentional injury-related deaths worldwide, accounting for roughly 7% of all such fatalities. According to the World Health Organization, approximately 300,000 people die from drowning each year across the globe.[1] In Japan as well, drowning ranks as the third most common cause of death from unintentional injury among children and is reported to be the leading cause of accidental death in those aged five years

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and older.[2] Early and effective resuscitation, particularly with ventilation, plays a pivotal role in improving survival and neurological outcomes in out-of-hospital cardiac arrest (OHCA) due to drowning.[3] Previous studies have consistently shown that conventional cardiopulmonary resuscitation (CPR) with rescue breathing (RB-CPR) is associated with better outcomes in pediatric and non-cardiac OHCA compared with compression-only CPR (CO-CPR), which may not provide adequate oxygenation in asphyxia cases.[4–6]

However, in recent years, CO-CPR has become increasingly prevalent in pediatric resuscitation, although it was originally promoted for adult cardiac arrest, owing to its simplicity, ease of instruction, and the greater willingness of laypersons to perform chest compressions.[7,8] Despite this trend, few studies have examined how bystander CPR behaviors have changed over time or how these shifts have affected outcomes in cardiac arrest following drowning, a type of non-cardiac etiology cardiac arrest where rescue breathing plays a particularly critical role.

Therefore, in this study, we comprehensively investigated whether bystander CPR practices have changed over time and how these temporal patterns were associated with mortality and unfavorable neurological outcomes among pediatric OHCA patients due to drowning. Understanding these temporal shifts is essential to clarify the clinical significance of rescue breathing in pediatric resuscitation and to address public health and educational challenges in improving its implementation among bystanders.

Methods

Study design and setting

We analyzed data from the All-Japan Utstein Registry, a nationwide OHCA registry based on Utstein style guidelines.[9] Our study focused on pediatric patients (17 years old or younger) with OHCA due to drowning who received bystander resuscitation from laypersons before they were transported to medical facilities between January 1, 2012, and December 31, 2023. We excluded cases where bystander CPR was not performed or where data on bystander CPR type was missing or unknown. Cardiac arrest was defined as the cessation of cardiac mechanical activity, indicated by the absence of signs of circulation.[10] Initial rhythm and return of spontaneous circulation (ROSC) were assessed by Emergency Medical Services (EMS) personnel upon arrival. ROSC was defined as the presence of a palpable pulse. However, pediatric patients with a palpable pulse who remained hemodynamically unstable due to bradycardia or other conditions and required ongoing chest compressions were not classified as ROSC. This study was approved by the Okayama University Institutional Review Board (K2404-008) and adhered to Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

CPR by bystanders

In Japan, all citizens have been legally permitted to use automated external defibrillators (AEDs) since 2004, and nationwide community CPR programs have provided widespread training in chest compressions, rescue breathing, and AED use. In 2006, dispatcher-assisted CPR was introduced, and dispatchers have since encouraged bystanders to perform CO-CPR if rescue breathing is not feasible, particularly for adult patients with cardiac arrest.[11] All resuscitation efforts in Japan follow the Japanese resuscitation guidelines. The impact of the COVID-19 pandemic on bystander CPR practices in Japan has been described in detail elsewhere.[12] In this study, RB-CPR was defined as CPR involving chest compressions and rescue breathing, while CO-CPR was defined as CPR involving chest compressions only. Because rescue-breathing–only CPR is not captured in the registry, the present findings are limited to cases in which chest compressions were performed by bystanders.

EMS system in Japan

The EMS system in Japan has been previously described.[13,14] In brief, the EMS system is operated by local fire stations offering 24/7 services. Each dispatched ambulance is typically staffed by three personnel, including at least one emergency life-saving technician (ELST). ELSTs receive advanced training and are authorized to use supraglottic airway devices and administer intravenous adrenaline under remote physician supervision, although intraosseous access remains prohibited. Adrenaline administration is allowed for patients aged eight and older and tracheal intubation is allowed for those aged 15 and above. Pediatric OHCA patients are transported to the nearest emergency or critical care center, and all prehospital treatments follow Japanese resuscitation guidelines.

Data collection and quality control

The data for this study included age, sex, bystander-witnessed cardiac arrest, dispatcher-assisted CPR, bystander involvement (family or non-family layperson or unknown/missing), initial rhythm at EMS contact (shockable, non-shockable), AED use by bystanders, prehospital treatment by EMS (defibrillation, airway intubation, intravenous cannulation, epinephrine), and transport time (call to EMS contact, call to arrival at the hospital). Age groups were categorized as infants (<one year old), young children (one to seven years old), and older children/adolescents (eight to 17 years old). RB-CPR was defined as CPR involving chest compressions and rescue breathing, while CO-CPR was defined as CPR involving chest compressions only. All prehospital and bystander-related variables were obtained from EMS documentation recorded immediately after the prehospital care.

Study outcomes

The primary outcome of interest was 30-day mortality. Secondary outcomes included prehospital absence of ROSC, hereafter referred to as "no ROSC," defined as failure to achieve any ROSC prior to hospital arrival as assessed by EMS personnel, and 30-day neurologically unfavorable survival, defined as a Cerebral Performance Category score of 3 (severe disability), 4 (coma or vegetative state), or 5 (death) at the time of discharge.[15]

Statistical analysis

First, we assessed temporal trends in bystander CPR type over the study period. Then, we evaluated the associations between CPR type and clinical outcomes. Unadjusted temporal trends in bystander CPR with rescue breathing were assessed using a Cochran–Armitage–type trend test. Categorical variables are presented as numbers with percentages and were compared using the chi-square test to identify intergroup differences. Continuous variables are presented as median with interquartile range, and intergroup comparisons were performed using the Wilcoxon Mann–Whitney test. Poisson regression with robust variance was employed to estimate adjusted risk ratios (aRR) with 95% confidence intervals (CIs) for outcomes. In the multivariable analysis, clinically relevant factors associated with outcomes were included as potential confounders. These variables included year, age, sex, witness status, dispatcher-assisted CPR (yes or no), bystander involvement (family), AED use by bystanders (yes or no), and EMS response time (from call to patient contact). Subgroup analyses were also conducted based on age categories (infants, young children, and older children/adolescents) and witness status (witnessed arrest, unwitnessed arrest). We also performed epoch-specific analyses by dividing the study period into 2012–2017 and 2018–2023, using the same analytical approach as in the main analysis. All statistical analyses were performed using Stata Version 18 (Stata-Corp LP, College Station, TX, USA).

Results

A total of 740 pediatric patients with cardiac arrest due to drowning who received bystander CPR in Japan between 2012 and 2023 were identified (Fig. 1). We first examined temporal trends in bystander CPR type over the study period. Among the identified patients, 41.6% (308/740) received RB-CPR and 58.4% (432/740) received CO-CPR from bystanders. As shown in Fig. 2, the annual proportion of pediatric drowning OHCA patients who received bystander RB-CPR gradually declined during the study period. RB-CPR accounted for approximately 45% of bystander CPR in 2012 and fell to approximately 30% after 2020, whereas CO-CPR became increasingly predominant. This decreasing trend was statistically significant over the study period ($p < 0.001$).

Table 1 summarizes patient demographics and clinical characteristics. Patients who received RB-CPR were generally younger and more likely to have witnessed arrests or family bystanders than those who received CO-CPR. Dispatcher-assisted CPR was less frequent in the RB-CPR group. Non-shockable rhythms and advanced prehospital interventions such as intubation or epinephrine administration were less common in the RB-CPR group,

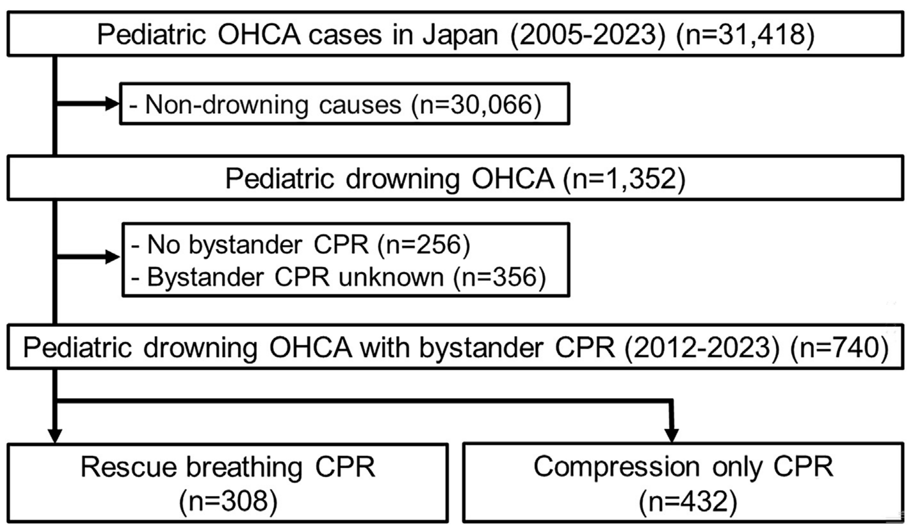

Fig. 1 – Study flow.

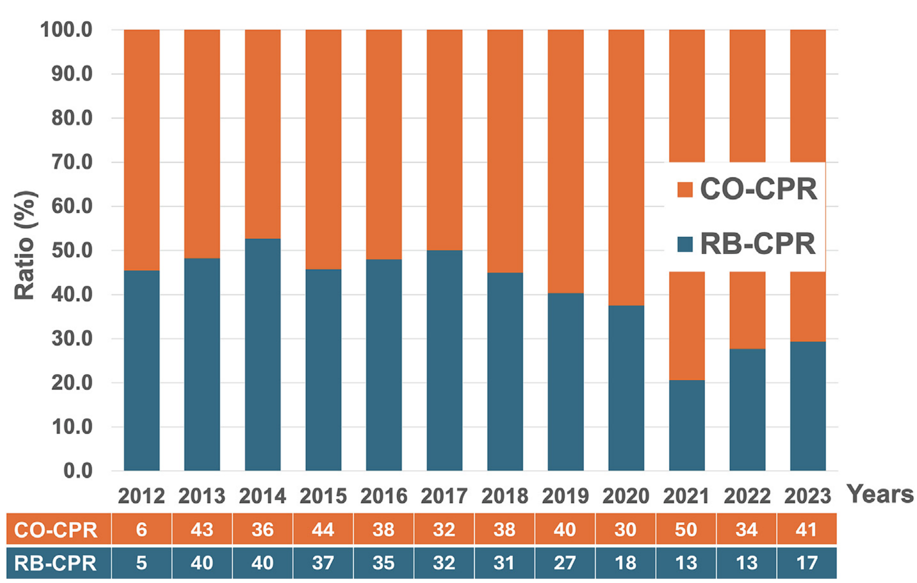

Fig. 2 – **Yearly trends in bystander CPR type among pediatric out-of-hospital cardiac arrest patients due to drowning. A statistically significant decreasing temporal trend was observed over the study period (*p* < 0.001).**

Table 1 – Characteristics of pediatric drowning OHCA patients receiving CO-CPR or RB-CPR during 2012–2023.

	RB-CPR (n = 308)		CO-CPR (n = 432)		P-value*
Age, median [IQR]	4.0	[1–8]	6.0	[2–13]	<0.001
Age group, n (%)					<0.001
Infants (<1yr)	29	(9.4)	41	(9.5)	
Young children (1–7 yr)	184	(59.7)	194	(44.9)	
Older children/adolescents (8–17 yr)	95	(30.8)	197	(45.6)	
Sex, male, n (%)	205	(66.6)	286	(66.2)	0.920
Witness, n (%)	84	(27.3)	61	(14.1)	<0.001
Dispatcher CPR instruction, n (%)[a]	184	(64.6)	304	(71.0)	0.069
Bystander involvement, n (%)					0.002
Family	42	(13.6)	29	(6.7)	
Non-family layperson	31	(10.1)	26	(6.0)	
Unknown/Missing	235	(76.3)	377	(87.3)	
AED by bystander, n (%)[b]	6	(3.2)	4	(1.2)	0.120
Initial rhythm at EMS contact, n (%)					<0.001
Shockable (VF/pulseless VT)	3	(1.0)	7	(1.6)	
Non-shockable (asystole/PEA)	154	(50.0)	337	(78.0)	
Presence of pulse	150	(48.7)	88	(20.4)	
Missing	1	(0.3)	0	(0.0)	
Prehospital treatment by EMS, n (%)					
Defibrillation[c]	10	(4.0)	18	(4.6)	0.746
Airway intubation[d]	37	(18.1)	71	(19.5)	0.671
Intravenous cannulation[e]	20	(8.1)	51	(12.8)	0.063
Epinephrine[f]	18	(7.2)	47	(11.7)	0.063
Transport time, median [IQR]					
Call to EMS contact[g]	8.0	[6–11]	7.5	[6–10]	0.223
Call to arrival at the hospital[h]	34.0	[25–29]	31.0	[25–29]	0.036

Abbreviations: OHCA: out-of-hospital cardiac arrest; CPR: cardiopulmonary resuscitation, RB-CPR: cardiopulmonary resuscitation with rescue breathing, CO-CPR: compression-only cardiopulmonary resuscitation, IQR: interquartile range, AED: automated external defibrillator, VF: ventricular fibrillation, VT: ventricular tachycardia, PEA: pulseless electrical activity, EMS: emergency medical service.

[a] Evaluated in 713 patients.
[b] 509 patients.
[c] 642 patients.
[d] 569 patients.
[e] 648 patients.
[f] 650 patients.
[g] 541 patients.
[h] 635 patients.
* P-value: χ^2 test for categorical variables and Wilcoxon Mann–Whitney test for continuous variables.

while EMS response and transport times were similar between groups.

Table 2 shows the associations between bystander CPR type and outcomes based on multivariable Poisson regression analyses. CO-CPR was associated with an increased likelihood of pre-hospital no ROSC compared with RB-CPR (aRR 1.22 [95% CI 1.06–1.39]). Thirty-day mortality (aRR 1.38 [95% CI 1.14–1.67]) and 30-day unfavorable neurological survival (aRR 1.33 [95% CI 1.14–1.54]) were also significantly higher among patients who received CO-CPR. In epoch-specific analyses comparing 2012–2017 and 2018–2023, the associations of RB-CPR and CO-CPR with all outcomes were largely consistent across periods (Supplemental Table 1).

Subgroup analyses were conducted based on age categories (Table 3). In infants (<one year old), point estimates suggested higher mortality with CO-CPR compared with RB-CPR (aRR 1.25 [95% CI 0.59–2.65]); however, this association did not reach statistical significance. For young children (1–7 years old), CO-CPR was associated with substantially higher 30-day mortality (aRR 1.86 [95% CI 1.30–2.65]). In older children/adolescents (8–17 years old), the association was weaker and not statistically significant (aRR 1.10 [95% CI 0.92–1.32]). Similar non-significant trends were observed for prehospital no ROSC and 30-day unfavorable neurological survival. Similarly, when stratified by witnessed status, CO-CPR was associated with significantly higher mortality in unwitnessed arrests (aRR 1.32 [95% CI 1.09–1.59]). In witnessed arrests, no sta-

Table 2 – Poisson regression with robust variance of the association between type of bystander CPR and outcomes during 2012–2023.

	All (2012–2023) (*N* = 740)		
	RB-CPR	CO-CPR	
	Case/*N* (%)	Case/*N* (%)	aRR* [95% CI]
Pre-hospital No ROSC	161/308 (52.3)	347/432 (80.3)	1.22 [1.06–1.39]
30-day Mortality	127/308 (41.2)	292/432 (67.6)	1.38 [1.14–1.67]
30-day unfavorable Neurological survival	158/308 (51.3)	345/432 (79.9)	1.33 [1.14–1.54]

aRR: adjusted risk ratio, CI: confidence interval, CPR: cardiopulmonary resuscitation, CO-CPR: compression-only cardiopulmonary resuscitation, RB-CPR: cardiopulmonary resuscitation with rescue breathing, ROSC: return of spontaneous circulation; EMS: emergency medical service.

* RB-CPR was used as the reference category in Poisson regression models with robust variance; models were adjusted for year, age, sex, witness, dispatcher CPR instruction, bystander involvement, automated external defibrillator by bystander, call to EMS contact time.

Table 3 – Subgroup analysis by age group: Poisson regression with robust variance for the association between type of bystander CPR and outcomes, 2012–2023.

	Infants (<1 yr) (*n* = 70)			Younger children (1–7 yr) (*n* = 378)			Older children/adolescents (8–17 yr) (*n* = 292)		
	RB-CPR	CO-CPR		RB-CPR	CO-CPR		RB-CPR	CO-CPR	
	Case/*N* (%)	Case/*N* (%)	aRR* [95% CI]	Case/*N* (%)	Case/*N* (%)	aRR* [95% CI]	Case/*N* (%)	Case/*N* (%)	aRR* [95% CI]
Pre-hospital No ROSC	16/29 (55.2)	34/41 (82.9)	1.39 [0.93–2.09]	88/184 (47.8)	141/194 (72.7)	1.17 [0.96–1.44]	57/95 (60.0)	172/197 (87.3)	1.16 [0.97–1.38]
30-day Mortality	7/29 (24.1)	24/41 (58.5)	1.25 [0.59–2.65]	64/184 (34.8)	110/194 (56.7)	1.86 [1.30–2.65]	56/95 (58.9)	158/197 (80.2)	1.10 [0.92–1.32]
30-day unfavorable Neurological survival	12/29 (41.4)	33/41 (80.5)	1.49 [0.92–2.42]	86/184 (46.7)	137/194 (70.6)	1.37 [1.07–1.74]	60/95 (63.2)	175/197 (88.8)	1.22 [1.03–1.44]

aRR: adjusted risk ration, CI: confidence interval, CPR: cardiopulmonary resuscitation, CO-CPR: compression-only cardiopulmonary resuscitation, RB-CPR: cardiopulmonary resuscitation with rescue breathing, ROSC: return of spontaneous circulation, EMS: emergency medical service.

* RB-CPR was used as the reference category in Poisson regression models with robust variance; models were adjusted for year, age, sex, witness, dispatcher CPR instruction, bystander involvement, automated external defibrillator by bystander, call to EMS contact time.

Table 4 – Subgroup analysis by witness status: Poisson regression with robust variance for the association between type of bystander CPR and outcomes, 2012–2023.

	Witnessed arrest (*n* = 145)			Unwitnessed arrest (*n* = 595)		
	RB-CPR	CO-CPR		RB-CPR	CO-CPR	
	Case/*N* (%)	Case/*N* (%)	aRR* [95% CI]	Case/*N* (%)	Case/*N* (%)	aRR* [95% CI]
Pre-hospital No ROSC	16/84 (19.1)	32/61 (52.5)	1.99 [0.99–3.98]	145/224 (64.7)	315/371 (84.9)	1.16 [1.02–1.33]
30-day Mortality	14/84 (16.7)	21/61 (34.4)	2.49 [0.88–7.05]	113/224 (50.5)	271/371 (73.1)	1.32 [1.09–1.59]
30-day unfavorable Neurological survival	18/84 (21.4)	29/61 (47.5)	2.93 [1.28–6.72]	140/224 (62.5)	316/371 (85.2)	1.23 [1.07–1.42]

aRR: adjusted risk ration, CI: confidence interval, CPR: cardiopulmonary resuscitation, CO-CPR: compression-only cardiopulmonary resuscitation, RB-CPR: cardiopulmonary resuscitation with rescue breathing, ROSC: return of spontaneous circulation, EMS: emergency medical service.

* RB-CPR was used as the reference category in Poisson regression models with robust variance; models were adjusted for years, age, sex, dispatcher CPR instruction, bystander involvement, automated external defibrillator by bystander, call to EMS contact time.

tistically significant difference in mortality was observed; however, differences were noted for 30-day unfavorable neurological outcomes (Table 4).

Discussion

In this nationwide registry-based analysis of pediatric OHCA due to drowning, we observed a steady decline in bystander CPR with rescue breathing from 2012 to 2023, accompanied by an increasing prevalence of CO-CPR. However, among patients who received bystander CPR, CO-CPR was associated with higher mortality and unfavorable neurological outcomes compared with RB-CPR, particularly among younger children (1–7 years old). In older children and adolescents (8–17 years old), CO-CPR showed a similar tendency, with significantly worse neurological outcomes. These age-related differences may reflect variations in drowning circumstances and timing of resuscitation between younger children and adolescents. Overall, our findings highlight the essential role of ventilation in pediatric resuscitation for asphyxial cardiac arrest, in which oxygen deprivation precedes circulatory collapse. The relatively favorable outcomes observed in this study may be partly explained by the restriction to pediatric drowning cases with bystander CPR and by the inclusion of patients who achieved ROSC after hospital arrival in longer-term outcome analyses; therefore, these findings should be interpreted with caution given the limited sample size and the selected nature of the cohort.

The observed decline in RB-CPR remained evident across epochs (2012–2017 and 2018–2023), and the associations between CPR type and outcomes were largely consistent over time. In epoch-specific analyses comparing 2012–2017 and 2018–2023, the associations between CPR type and major clinical outcomes remained largely consistent. This finding suggests that the declining use of RB-CPR itself, rather than temporal changes in CPR quality, may represent a key concern. In this context, prior studies from Japan have reported low willingness to perform mouth-to-mouth ventilation, primarily driven by lack of confidence in rescue breathing rather than fear of infection, with notable variations by sex and occupational background.[16,17] Such psychosocial barriers may partly explain the persistently low prevalence of ventilation during bystander CPR in Japan. In addition, dispatcher-assisted CPR in Japan has generally emphasized a chest-compression–first approach. However, because the Utstein registry does not capture the specific content of dispatcher instructions, we were unable to assess how dispatcher guidance may have influenced the selection of CPR type. Cardiac arrest in drowning typically occurs secondary to progressive hypoxemia. In this study, as in previous reports, the low incidence of shockable rhythms further supports the importance of high-quality CPR that includes rescue breathing.[18,19] Therefore, early restoration of both oxygenation and circulation through CPR that includes rescue breathing is essential to achieve better outcomes. However, our findings suggest that the widespread promotion of CO-CPR may have unintentionally contributed to a decline in the implementation of rescue breathing, even for pediatric and non-cardiac arrests, which were not its original targets. In addition, the COVID-19 pandemic further discouraged the use of rescue breathing during CPR due to concerns about infection transmission, likely contributing to an even greater decline in its practice, even among pediatric cases where ventilation is essential.[12,20,21] This concern has also been highlighted in an international consensus statement on drowning resuscitation during this pandemic.[22]

Furthermore, witnessed status is generally recognized as a strong predictor of outcomes in pediatric OHCA.[23,24] In our study as well, RB-CPR was more frequently performed in witnessed arrests. However, when subgroup analyses were stratified by witnessed status, the beneficial effect of RB-CPR was evident in unwitnessed arrests, where CO-CPR was significantly associated with higher mortality and unfavorable neurological outcomes compared with RB-CPR; similar trends were observed in witnessed arrests but did not reach statistical significance. This finding likely reflects the longer interval between submersion and CPR initiation in unwitnessed arrests, during which progressive hypoxemia develops. As a result, in these asphyxial cardiac arrests, ventilation becomes particularly critical for successful resuscitation; chest compressions alone are insufficient to reverse severe hypoxemia, notably when CPR is initiated later than in witnessed arrests.

Our findings are strongly consistent with and supported by the 2024 joint guidelines issued by the American Heart Association (AHA) and the American Academy of Pediatrics (AAP).[25] These guidelines recommend performing CPR that includes both chest compressions and rescue breaths for all drowning victims after removal from the water. They also define drowning primarily as a hypoxic event and emphasize that oxygen supplementation during and after CPR, when available, contributes to improved outcomes. These findings are also consistent with the most recent European Resuscitation

Council guidelines, which similarly recognize drowning as a hypoxic event and recommend initiating resuscitation with rescue breathing after removal from the water, followed by standard basic life support.[26] These international consensus reinforces our conclusion that omission of rescue breathing may worsen survival and neurological outcomes in pediatric OHCA due to drowning.

Although the widespread promotion of CO-CPR has increased the overall rate of bystander CPR, particularly among adults, our findings highlight the need, from an educational and public health perspective, to restore public confidence and skills in rescue breathing, especially in homes and communities where pediatric drowning frequently occurs. CPR training for parents, caregivers, and school staff should prioritize ventilation techniques, and dispatcher-assisted protocols should offer clear age- and cause-specific guidance. National and global programs have shown that large-scale CPR education can markedly improve bystander response and outcomes. For example, the World Restart a Heart campaign trained over 675,000 people worldwide in CPR in 2018, and Japan's national certification program increased the number of CPR-certified citizens from 9.9 million to 34.9 million between 2005 and 2020, raising bystander CPR implementation from 40.6% to 56.8%.[27,28] Building upon these achievements, incorporating rescue breathing into public CPR education, especially in pediatric and drowning-related scenarios, may be a key strategy to further enhance both CPR performance and neurological outcomes. Strengthening such drowning-focused educational and dispatcher systems, alongside improved access to defibrillation and oxygen at aquatic facilities, may help rebuild the "drowning chain of survival," as outlined in the 2024 AHA/AAP drowning resuscitation guidelines,[25] and ultimately improve outcomes in pediatric drowning-related cardiac arrest.

This study has several limitations. First, as in previous studies, our registry followed the Utstein reporting template for cardiac arrest rather than that for drowning.[29] Consequently, several key variables recommended in the Utstein drowning template, such as water temperature, submersion duration, and type of water body, were unavailable, although these factors may influence outcomes after OHCA due to drowning. Information on the specific location of cardiac arrest (e.g., residential, bath, pool, ocean, or river) was also not recorded. Second, although background characteristics were adjusted using multivariable Poisson regression, the absence of data on unmeasured confounders, such as CPR quality, location of arrest, and time interval from collapse to initiation of bystander CPR, could have influenced the results. In addition, CPR performed by family members may be correlated with witnessed status, age, and potentially, drowning location; therefore, residual confounding cannot be excluded despite multivariable adjustment. Third, our analysis was limited to pediatric patients who received bystander CPR from laypersons; therefore, we could not evaluate how CO-CPR might affect outcomes among those who did not receive any bystander intervention. Finally, as with all epidemiological studies, potential limitations included data validity, integrity, and ascertainment bias. However, the large sample size, population-based design covering all OHCA cases in Japan, and uniform data collection based on Utstein-style reporting guidelines were intended to minimize these potential biases.

Conclusion

This nationwide analysis of pediatric OHCA due to drowning in Japan revealed a marked decline in bystander CPR with rescue breathing over the past decade, accompanied by an increase in CO-CPR. Among patients who received bystander CPR, CO-CPR was significantly associated with higher mortality and worse neurological outcomes, consistent with previous studies. These findings highlight the indispensable role of ventilation in asphyxial cardiac arrests such as drowning. To improve survival and neurological recovery among pediatric drowning victims, it is crucial to re-emphasize and reinforce the importance of rescue breathing in public CPR education and dispatcher-assisted CPR instructions.

Consent for publication

Not applicable.

Availability of data and materials

The data that support the findings of this study are available from the All-Japan Utstein Registry; however, restrictions apply to the availability of these data, which were used under license for the present study and are therefore not publicly available. However, the data are available from the authors on reasonable request and with permission from the All-Japan Utstein Registry.

CRediT authorship contribution statement

Takafumi Obara: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Tsuyoshi Nojima:** Writing – review & editing, Methodology, Formal analysis. **Naomi Matsumoto:** Writing – review & editing, Methodology, Formal analysis, Conceptualization. **Kohei Tsukahara:** Writing – review & editing, Methodology, Conceptualization. **Takashi Hongo:** Writing – review & editing, Methodology, Formal analysis. **Tetsuya Yumoto:** Writing – review & editing, Methodology, Conceptualization. **Takashi Yorifuji:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Atsunori Nakao:** Writing – review & editing, Supervision, Project administration, Investigation. **Hiromichi Naito:** Writing – review

& editing, Methodology, Formal analysis, Data curation, Conceptualization.

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: K2404-008. Patient consent was waived.

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Declaration of competing interest

The authors declared no other potential conflicts of interest with respect to the research, authorship, and/or publication for this article.

Appendix A. Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.resuscitation.2026.111049.

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