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Clinical paper

# Bystander-initiated conventional vs compression-only cardiopulmonary resuscitation and outcomes after out-of-hospital cardiac arrest due to drowning

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## Abstract

**Background:** Great emphasis has been placed on rescue breathing in out-of-hospital cardiac arrest (OHCA) due to drowning. However, there is no evidence about the effect of rescue breathing on neurologically favorable survival after OHCA due to drowning. The aim of this study is to examine the effect of bystander-initiated conventional (with rescue breathing) versus compression-only (without rescue breathing) cardiopulmonary resuscitation (CPR) in OHCA due to drowning.

**Methods:** This nationwide population-based observational study using prospectively collected government-led registry data included patients with OHCA due to drowning who were transported to an emergency hospital in Japan between 2013 and 2016. The primary outcome was one-month neurologically favorable survival.

**Results:** The full cohort (n = 5121) comprised 2486 (48.5%) male patients, and the mean age was 72.4 years (standard deviation, 21.6). Of these, 968 (18.9%) received conventional CPR, and 4153 (81.1%) received compression-only CPR. 928 patients receiving conventional CPR were propensity-matched with 928 patients receiving compression-only CPR. In the propensity score-matched cohort, one-month neurologically favorable survival was not significantly different between the two groups (7.5% in the conventional CPR group vs. 6.6% in the compression-only CPR group; risk ratio, 1.15; 95% confidence interval, 0.82–1.60; $P = 0.4147$). This association was consistent across a variety of subgroup analyses.

**Conclusions:** Among patients with OHCA due to drowning, there were no differences in one-month neurologically favorable survival between bystander-initiated conventional and compression-only CPR groups, although several important data (e.g., water temperature, submersion duration, or body of water) could not be addressed. Further study is warranted to confirm our findings.

**Keywords:** Out-of-hospital cardiac arrest, Cardiopulmonary resuscitation, Drowning, Basic life support, Epidemiology

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https://doi.org/10.1016/j.resuscitation.2019.08.026
Received 19 June 2019; Received in revised form 30 July 2019; Accepted 17 August 2019

## Introduction

Drowning is an important public health issue in the world as about 400,000 deaths due to drowning occur each year, which account for 0.7% of all deaths worldwide.[1–3] Globally, approximately 1.5 people die from drowning every minute of every day. In Japan, there are about 5,000–6,000 drowning deaths annually.

Cardiac arrest from drowning is due primarily to anoxia.[4–6] Therefore, as with pediatric out-of-hospital cardiac arrest (OHCA), where asphyxial nature is predominant,[7–10] great emphasis has been placed on rescue breathing in OHCA due to drowning.[5,6,11–13] On the other hand, chest compression-only cardiopulmonary resuscitation (CPR) without rescue breathing has become more and more familiar with citizens thanks to the simplicity to teach, learn, remember, and perform.[14–17]

Thus far, no randomized clinical trial (RCT) has examined the effect of conventional (i.e., chest compression and rescue breathing) versus compression-only CPR in OHCA due to drowning, to the best of our knowledge, neither has observational study.

We sought to assess which bystander CPR (conventional versus compression-only CPR) would be associated with an increased chance of neurologically favorable survival after OHCA due to drowning.

## Materials and methods

### *Data source, study setting, and participants*

The All-Japan Utstein Registry is a nationwide population-based registry of OHCA patients sponsored by the Fire and Disaster Management Agency (FDMA). This registry prospectively collected data in accordance with the Utstein-style uniform reporting for cardiac arrest,[18,19] and not the dedicated Utstein-style reporting template for drowning.[20] As has been described in detail previously,[16,17,21–27] data on OHCA patients transported to an emergency hospital are prospectively collected by trained emergency medical services (EMS) personnel. This registry included almost all OHCA patients, including those who have do-not-resuscitate (DNR) orders as EMS personnel in Japan are not allowed to terminate out-of-hospital resuscitation except in specific situations (e.g., decapitation, rigor mortis, livor mortis, and decomposition). Data collected from three sources (1-1-9 dispatch centers, fire stations, and receiving hospitals) are integrated into the All-Japan Utstein Registry system on the FDMA database server. Data integrity, accuracy, and completeness are secured through the certification by the FDMA and the logical internal checks using standardized software.

CPR training programs in Japan are provided by such as local fire departments based on the Japanese CPR guidelines, which basically conform to the American Heart Association (AHA) guidelines. Almost four million Japanese citizens are estimated to be trained in the CPR program every year. Dispatcher's instruction for bystander CPR started around 1999, and has been changed from conventional CPR to compression-only CPR since 2006, with compression-only CPR being specifically recommended if it might be difficult for the bystander to perform rescue breathing.[16,17,28,29]

This study included patients with OHCA due to drowning submitted to the All-Japan Utstein Registry between January 1, 2013, and December 31, 2016. Patients whose etiology of cardiac arrest was documented as drowning were selected. We excluded patients with missing or unknown data on bystander CPR and dispatcher-assisted CPR. Although we included both witnessed and unwitnessed OHCA patients, we excluded EMS personnel-witnessed OHCA patients. We also excluded patients with an unrealistic or contradictory (i.e., negative or considerably long) time interval and patients with missing or unknown data on EMS activity times. Additionally, patients not receiving any bystander CPR or patients receiving only rescue breathing were excluded (Fig. 1).

This study was conducted according to the amended Declaration of Helsinki, with a waiver of informed consent due to the anonymous nature of the data, with approval from the institutional review board of University of the Ryukyus.

### *Data collection*

This registry collected data on patient characteristics (i.e., sex and age), bystander characteristics (i.e., witness, bystander CPR, and dispatcher-assisted CPR), cardiac arrest characteristics (i.e., etiology of cardiac arrest and initial rhythm), and event characteristics (i.e., time and place of cardiac arrest). Witnessed arrest is typically defined as a cardiac arrest that is seen or heard by another person or is monitored. However, some witness of arrest may be based on the moment of submersion, as it is sometimes difficult to notice the moment of actual cardiac arrest in OHCA due to drowning. Initial rhythm is defined as the rhythm recorded at the time of first analysis of the monitor or defibrillator after cardiac arrest. To enable appropriate reporting, bradycardia is retained as an option when CPR is provided for severe bradycardia with pulse and poor perfusion (most commonly in pediatric cardiac arrest).[30] In this registry, bradycardia is assumed to be recorded as the other rhythms. The registry also collected data on prehospital care by healthcare professionals (i.e., intravenous line insertion, epinephrine administration, advanced airway management, and physician involvement in prehospital advanced life support [ALS]). In addition, each EMS squad recorded a series of EMS activity times (i.e., emergency call receipt, contact with patient, and hospital arrival). Response time represents the time interval between emergency call and contact with patient. Transport time represents the time interval between contact with patient and hospital arrival. The time intervals were calculated based on the EMS activity times recorded in whole minutes. The calculated time interval of 0 min means that two events occurred within the same whole minute. The etiology of cardiac arrest was provisionally determined by attending physicians in emergency department in collaboration with EMS personnel on the day of the emergency transportation. To reconfirm the etiology of the cardiac arrest and collect the outcome data on survival and neurological status, one-month follow-up survey was conducted by each fire department, based on an inquiry for the receiving hospital. If the patient information was not acquired from the hospital because of hospital transfer or discharge within one month, further investigations were conducted by the fire department in cooperation with the hospital personnel.

### *Outcomes*

The primary outcome was favorable neurologic outcome one month after the event. Neurologic outcome was assessed by inpatient attending physicians using the Glasgow-Pittsburgh cerebral performance category (CPC) scores. A CPC score of 1 (good performance) or 2 (moderate disability) was regarded as a favorable neurologic

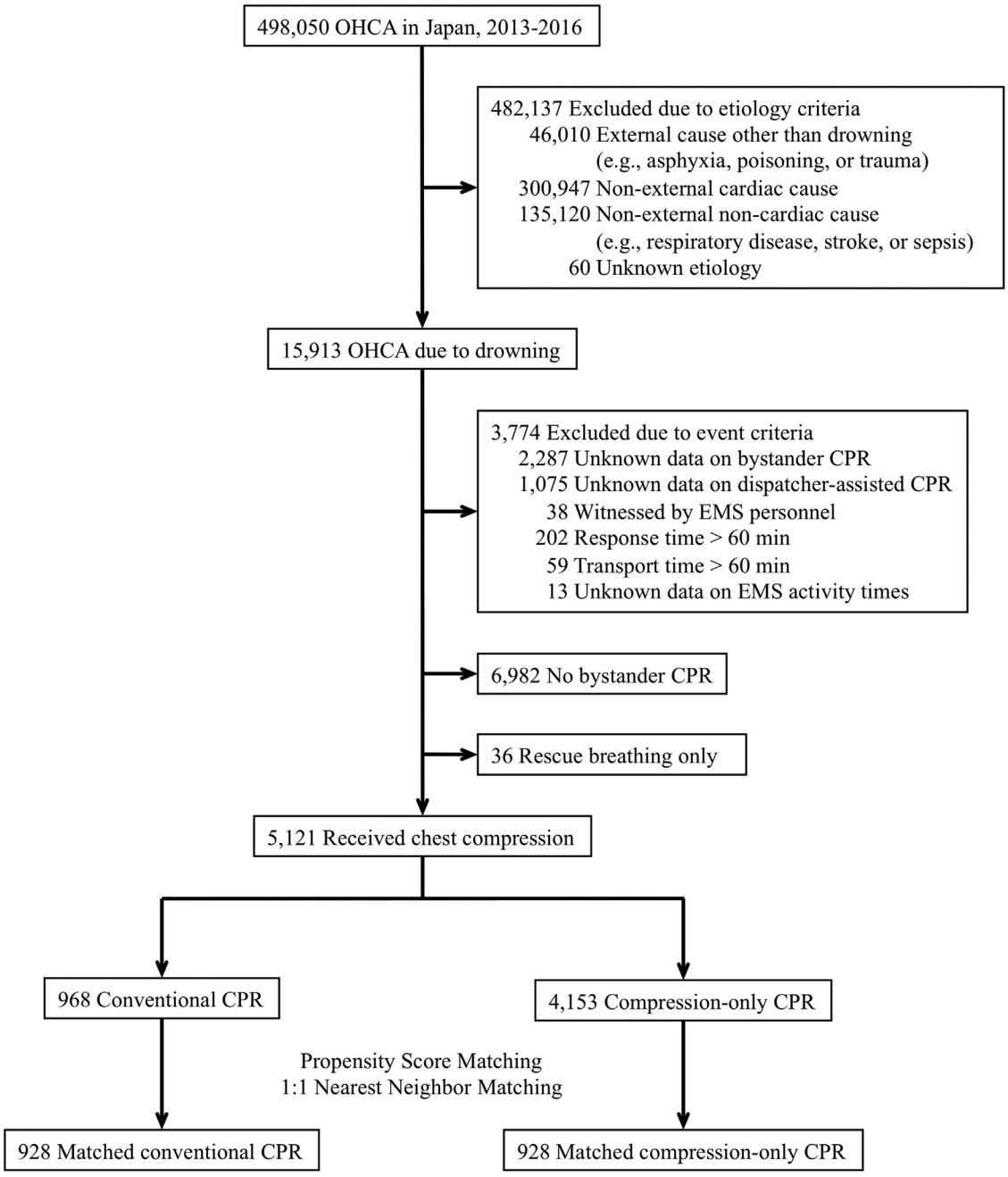


**Fig. 1 – Study flow diagram.**
***Abbreviations*: CPR, Cardiopulmonary resuscitation; EMS, Emergency medical service; OHCA, Out-of-hospital cardiac arrest**

outcome, whereas a CPC score of 3 (severe disability), 4 (vegetative state), or 5 (death) was regarded as a poor neurologic outcome.[19,31] The secondary outcomes were one-month survival and prehospital return of spontaneous circulation (ROSC).

### *Statistical analysis*

The full cohort and propensity score-matched cohort were characterized using descriptive statistics. Categorical variables were presented as counts with frequencies (%), and were compared with the $\chi^2$ test. Continuous variables were presented as means with standard deviations (SDs), and were compared with the *t* test.

Propensity score-matched analyses were performed in an effort to control for selection bias and confounding due to the lack of randomization in selecting conventional or compression-only CPR. The propensity score for each patient receiving bystander-initiated conventional or compression-only CPR was estimated with a multivariable logistic regression model. The model included the following variables having the pre-treatment characteristics: age, sex (male or female), witness (no witness, witness by family member, or

witness by non-family member), dispatcher's instruction for CPR (yes or no), initial rhythm (ventricular fibrillation [VF], ventricular tachycardia [VT], pulseless electrical activity [PEA], asystole, or others), year of arrest, season of arrest (spring, summer, autumn, or winter), time of arrest (daytime or nighttime), and region of arrest (north, east, west, or south). A 1:1 nearest-neighbor matching on the propensity score was performed using a caliper of 0.2 without replacement between patients receiving conventional and compression-only CPR.[32] The success of the matching procedure was confirmed by comparing the distribution of baseline characteristics in the matched cohort with standardized differences within ± 0.1.[33] Risk ratios (RRs) of favorable neurologic outcomes for patients receiving conventional vs compression-only CPR were reported with 95% confidence intervals (CIs).

Subgroup analyses were performed to further characterize the association between the type of bystander CPR (conventional vs compression-only CPR) and favorable neurologic outcomes after OHCA due to drowning according to several predefined subgroups: age group (< 1, 1–17, 18–64, or ≥65 years), witness (no witness, witness by family member, or witness by non-family member), and initial rhythm (shockable [VF or VT], non-shockable rhythm [PEA or asystole], or others). Differences among subgroups were assessed by including an interaction term between the type of bystander CPR variable (conventional vs compression-only CPR) and the subgroup variable of interest in the propensity score-matched cohort. As several previous studies indicated that there might be differences in the effectiveness of bystander-initiated conventional vs compression-only CPR depending on response time,[34,35] post-hoc sensitivity analysis was also performed based on response time interval (<10 min or ≥10 min).

JMP Pro 14.0.0 software (SAS Institute Inc., Cary, NC, USA) was used to conduct statistical analyses. A two-sided *P* value of 0.05 was regarded as significance level for all hypothesis tests.

## Results

During the study period, we identified 5121 patients with OHCA due to drowning who received bystander-initiated chest compression (Fig. 1). Of these, 968 (18.9%) received both chest compression and rescue breathing (i.e., conventional CPR), and 4153 (81.1%) received only chest compression (i.e., compression-only CPR). 928 patients receiving conventional CPR were propensity-matched with 928 patients receiving compression-only CPR.

Table 1 summarizes the baseline characteristics of the full cohort and the propensity score-matched cohort according to the type of bystander CPR. In the full cohort, 2486 patients (48.5%) were male, and the median age was 79 years (interquartile ranges, 70–85 years). Approximately 90% of patients were unwitnessed and had asystole as the initial rhythm. After propensity score matching, the baseline characteristics were well balanced on pre-treatment characteristics between the conventional and compression-only CPR groups. As for post-treatment characteristics, although there were some missing data on prehospital care by healthcare professionals, the frequency of prehospital ALS tended to be high in the conventional CPR group. Particularly, advanced airway management was more frequently performed in the conventional CPR group than in the compression-only CPR group. Transport time was significantly longer in the conventional CPR group compared with the compression-only CPR group.

Table 2 shows the primary and secondary outcomes of patients with OHCA due to drowning in the propensity score-matched cohort. After propensity matching, there were no differences in favorable neurologic outcomes (RR, 1.15; 95%CI, 0.82–1.60), one-month survival (RR, 1.21; 95%CI, 0.91–1.61), and prehospital ROSC (RR, 1.18; 95%CI, 0.89–1.56) between the bystander-initiated conventional and compression-only CPR groups, although the point estimates for the treatment effect favor conventional CPR.

In the subgroup analyses (Fig. 2), no significant differences were observed in one-month favorable neurologic outcomes between the two groups in all subgroups. Additionally, there was no significant interaction for age (*P for Interaction* = 0.7946), witness (*P for Interaction* = 0.9960), initial rhythm (*P for Interaction* = 0.1507), or response time (*P for Interaction* = 0.2304), indicating that the association between the type of bystander CPR (conventional vs. compression-only CPR) and one-month favorable neurologic outcomes did not change regardless of such subgroup characteristics.

## Discussion

In this nationwide population-based observational study of OHCA due to drowning, no association of improvement in one-month neurologic favorable outcomes with the type of bystander CPR (conventional vs compression-only CPR) was demonstrated in the propensity score-matched analysis. This association was consistently demonstrable with several subgroup analyses. Similar associations were also demonstrated for one-month survival and prehospital ROSC.

Studies on bystander CPR during OHCA due to drowning are scarce.[21,36,37] To the best of our knowledge, no RCT has examined the effect of conventional versus compression-only CPR in OHCA due to drowning, neither has observational study. Thus, this study is the first study to compare bystander-initiated conventional versus compression-only CPR in OHCA due to drowning.

If the study population is not limited to the patients with OHCA due to drowning, there are three RCTs examining the effect of conventional versus compression-only CPR in OHCA.[38–40] Each of these RCTs failed to find the survival benefit between conventional and compression-only CPR, but meta-analyses of these RCTs revealed that compression-only CPR was significantly associated with increased survival compared with conventional CPR.[41,42] A number of observational studies also indicated that compression-only CPR might be more effective than conventional CPR,[16,22,43] although these studies mainly targeted adult patients with OHCA due to primary cardiac cause. On the other hand, controversy remains as to which bystander CPR, either conventional or compression-only CPR, is superior for OHCA due to non-cardiac cause and/or pediatric OHCA.[17,23–25,44–46] Among such study population, conventional CPR (with rescue breathing) could be beneficial, or had no effect on survival after OHCA. Similar to those studies, our findings showed no significant difference between bystander-initiated conventional and compression-only CPR, although there was a tendency favoring conventional CPR. Considering that the simplicity of compression-only CPR to teach, learn, remember, and perform can improve the implementation rate of bystander CPR,[14–17,47] our findings suggest that compression-only CPR may be an attractive option for bystanders even in OHCA due to drowning, although an adequately powered RCT would be needed to determine which is superior, conventional or compression-only CPR.

**Table 1 – Baseline characteristics of the full cohort and the propensity score-matched cohort according to the type of bystander CPR.**

| Characteristic | Full cohort | Propensity score-matched cohort | | |
|---|---|---|---|---|
| | n = 5121 | Conventional CPR n = 928 | Compression-only CPR n = 928 | Standardized difference (%) |
| Baseline characteristics | | | | |
| Age, y | | | | |
| -Mean (SD) | 72.4 (21.6) | 65.0 (26.9) | 65.9 (26.7) | −3.2113 |
| -Median (IQR) | 79 (70-85) | 76 (55-84) | 76 (59-84) | NA |
| 1) < 1 y - No. (%) | 30 (0.6) | 8 (0.9) | 15 (1.6) | −6.8718 |
| 2) ≥ 1, < 18 y - No. (%) | 265 (5.2) | 99 (10.7) | 86 (9.3) | 4.6742 |
| 3) ≥ 18, < 65 y - No. (%) | 665 (13.0) | 188 (20.3) | 169 (18.2) | 5.2029 |
| 4) ≥ 65 y - No. (%) | 4161 (81.2) | 633 (68.2) | 658 (70.9) | −5.8701 |
| Sex | | | | |
| 1) Male - No. (%) | 2486 (48.5) | 490 (52.8) | 486 (52.4) | 0.8612 |
| 2) Female - No. (%) | 2635 (51.5) | 438 (47.2) | 442 (47.6) | −0.8612 |
| Witness | | | | |
| 1) No witness - No. (%) | 4762 (93.0) | 827 (89.1) | 835 (90.0) | −2.8116 |
| 2) By family member - No. (%) | 117 (2.3) | 34 (3.7) | 29 (3.1) | 2.9269 |
| 3) By non-family member - No. (%) | 242 (4.7) | 67 (7.2) | 64 (6.9) | 1.2493 |
| Dispatcher's instruction for CPR | | | | |
| 1) Yes - No. (%) | 4070 (79.5) | 711 (76.6) | 726 (78.2) | −3.8517 |
| 2) No - No. (%) | 1051 (20.5) | 217 (23.4) | 202 (21.8) | 3.8517 |
| Initial rhythm | | | | |
| Shockable rhythm | | | | |
| 1) VF - No. (%) | 150 (2.9) | 27 (2.9) | 27 (2.9) | 0.0000 |
| 2) VT - No. (%) | 1 (0.0) | 0 (0.0) | 0 (0.0) | 0.0000 |
| Non-shockable rhythm | | | | |
| 3) PEA - No. (%) | 293 (5.7) | 81 (8.7) | 76 (8.2) | 1.9405 |
| 4) Asystole - No. (%) | 4456 (87.0) | 747 (80.5) | 749 (80.7) | −0.5311 |
| Others | | | | |
| 5) Others (e.g., Bradycardia) - No. (%) | 221 (0.4) | 73 (7.9) | 76 (8.2) | −1.1775 |
| Year of arrest | | | | |
| 1) 2013 - No. (%) | 1215 (23.7) | 230 (24.8) | 249 (26.8) | −4.6863 |
| 2) 2014 - No. (%) | 1352 (26.4) | 245 (26.4) | 243 (26.2) | 0.4770 |
| 3) 2015 - No. (%) | 1320 (25.8) | 242 (26.1) | 233 (25.1) | 2.2229 |
| 4) 2016 - No. (%) | 1234 (24.1) | 211 (22.7) | 203 (21.9) | 2.0658 |
| Season of arrest | | | | |
| 1) Spring (March, April, May) - No. (%) | 1248 (24.4) | 227 (24.5) | 242 (26.1) | −3.7286 |
| 2) Summer (June, July, August) - No. (%) | 778 (15.2) | 209 (22.5) | 203 (21.9) | 1.5400 |
| 3) Autumn (September, October, November) - No. (%) | 896 (17.5) | 150 (16.2) | 151 (16.2) | −0.2984 |
| 4) Winter (December, January, February) - No. (%) | 2199 (42.9) | 342 (36.8) | 332 (35.8) | 2.2251 |
| Time of arrest | | | | |
| 1) Daytime (7:00-22:59) - No. (%) | 4290 (83.8) | 803 (86.5) | 813 (87.6) | −3.2192 |
| 2) Nighttime (23:00-6:59) - No. (%) | 831 (16.2) | 125 (13.5) | 115 (12.4) | 3.2192 |
| Region of arrest | | | | |
| 1) North - No. (%) | 441 (8.6) | 97 (10.5) | 99 (10.7) | −0.7159 |
| 2) East - No. (%) | 2870 (56.0) | 430 (46.3) | 399 (43.0) | 6.7221 |
| 3) West - No. (%) | 1765 (34.5) | 381 (41.1) | 413 (44.5) | −6.9571 |
| 4) South (Okinawa, Amami) - No. (%) | 45 (0.9) | 20 (2.2) | 17 (1.8) | 2.3602 |
| Prehospital care by healthcare professionals | | | | |
| Prehospital life support | | | | |
| 1) BLS only - No. (%) | 1773 / 4850 (36.6) | 279 / 849 (32.9) | 351 / 892 (39.4) | NA |
| 2) ALS by EMS personnel - No. (%) | 2670 / 4850 (55.0) | 456 / 849 (53.7) | 456 / 892 (51.1) | NA |
| 3) ALS by physician - No. (%) | 407 / 4850 (8.4) | 114 / 849 (13.4) | 85 / 892 (9.5) | NA |

**Table 1 *(continued)***

| Characteristic | Full cohort | Propensity score-matched cohort | | |
|---|---|---|---|---|
| | n = 5121 | Conventional CPR n = 928 | Compression-only CPR n = 928 | Standardized difference (%) |
| Defibrillation - No. (%) | 180 / 4918 (3.7) | 40 / 792 (5.1) | 45 / 916 (4.9) | NA |
| Intravenous catheter insertion - No. (%) | 1826 / 5002 (36.5) | 332 / 839 (39.6) | 331 / 921 (35.9) | NA |
| Epinephrine administration - No. (%) | 795 / 4969 (16.0) | 152 / 808 (18.8) | 144 / 918 (15.7) | NA |
| Advanced airway management - No. (%) | 2269 / 4704 (48.2) | 409 / 801 (51.1) | 381 / 866 (44.0) | NA |
| Response time, min | | | | |
| -Mean (SD) | 9.7 (4.8) | 10.3 (5.0) | 10.1 (5.5) | NA |
| -Median (IQR) | 9 (7–11) | 9 (7–12) | 9 (7–12) | NA |
| Transport time, min | | | | |
| -Mean (SD) | 24.6 (9.6) | 25.2 (10.1) | 24.0 (9.2) | NA |
| -Median (IQR) | 23 (18–30) | 23 (18–31) | 23 (17–29) | NA |

The data are expressed as the number (%) of patients, the mean (SD), or the median (IQR), unless otherwise indicated.
Standardized differences within ± 10% were considered as inconsequential.
Abbreviations: ALS, Advanced life support; BLS, Basic life support; CPR, Cardiopulmonary resuscitation; IQR, Interquartile range; SD, Standard deviation; PEA, Pulseless electrical activity; VF, ventricular fibrillation; VT, Ventricular tachycardia.

**Table 2 – Outcomes of patients with bystander-initiated conventional versus compression-only CPR in the propensity score-matched cohort.**

| Outcome | Propensity Score-Matched Analysis | | | |
|---|---|---|---|---|
| | Conventional CPR n = 928 | Compression-only CPR n = 928 | RR (95%CI) | *P* value |
| Favorable neurologic outcome (CPC 1 or 2) - No. (%) | 70 (7.5) | 61 (6.6) | 1.15 (0.82–1.60) | 0.4147 |
| CPC 1 - No. (%) | 62 (6.7) | 55 (5.9) | NA | NA |
| CPC 2 - No. (%) | 8 (0.8) | 6 (0.7) | NA | NA |
| CPC 3 - No. (%) | 4 (0.4) | 7 (0.7) | NA | NA |
| CPC 4 - No. (%) | 22 (2.4) | 10 (1.1) | NA | NA |
| CPC 5 - No. (%) | 831 (89.6) | 848 (91.4) | NA | NA |
| CPC unknown - No. (%) | 1 (0.1) | 2 (0.2) | NA | NA |
| One-month survival - No. (%) | 97 (10.5) | 80 (8.6) | 1.21 (0.91–1.61) | 0.1791 |
| Prehospital ROSC - No. (%) | 98 (10.6) | 83 (8.9) | 1.18 (0.89–1.56) | 0.2405 |

The data are expressed as the number (%), unless otherwise indicated.
The association between the type of bystander CPR and outcomes were reported as RRs with 95% CIs.
*Abbreviations*: CI, Confidence interval; CPC, Glasgow-Pittsburgh cerebral performance category; CPR, Cardiopulmonary resuscitation; RR, Risk ratio; ROSC, Return of spontaneous circulation.

In our pre-planned subgroup analyses, no significant associations were observed between the type of bystander CPR and one-month favorable neurologic outcomes in all subgroups. However, the subgroup analyses showed other intriguing associations between the given subgroups and one-month favorable neurologic outcomes after OHCA due to drowning. Surprisingly, regardless of the type of bystander CPR, the chance of neurologically favorable survival was remarkably high in children (< 18 y), witnessed events, or OHCA patients whose recorded initial rhythm was others (e.g., bradycardia), although such population might account for only a small proportion of OHCA due to drowning. This tendency is not inconsistent with the past studies which examined the factors associated with outcomes after OHCA due to drowning.[36,37] In the US study,[36] younger age (adjusted OR [per 1 increment of year] 0.97, 95% CI 0.96–0.98, $P < 0.0001$) and witness (adjusted OR 3.27, 95%CI 2.00–5.36, $P < 0.0001$) were independently associated with increased chance of neurologically favorable survival. In the Sweden study,[37] younger age (adjusted OR [per 1 increment of year] 0.98, 95%CI 0.97-0.99) and witness (adjusted OR 2.50, 95%CI 1.38–4.52) were respectively associated with increased chance of one-month survival and survival to hospital admission. In both studies, the initial rhythm was only categorized as shockable or non-shockable rhythm, and the category others (e.g., bradycardia) was not considered. In the post-hoc sensitivity analysis based on response time interval (<10 min or ≥10 min), unlike the previous studies,[34,35] the association between the type of bystander CPR

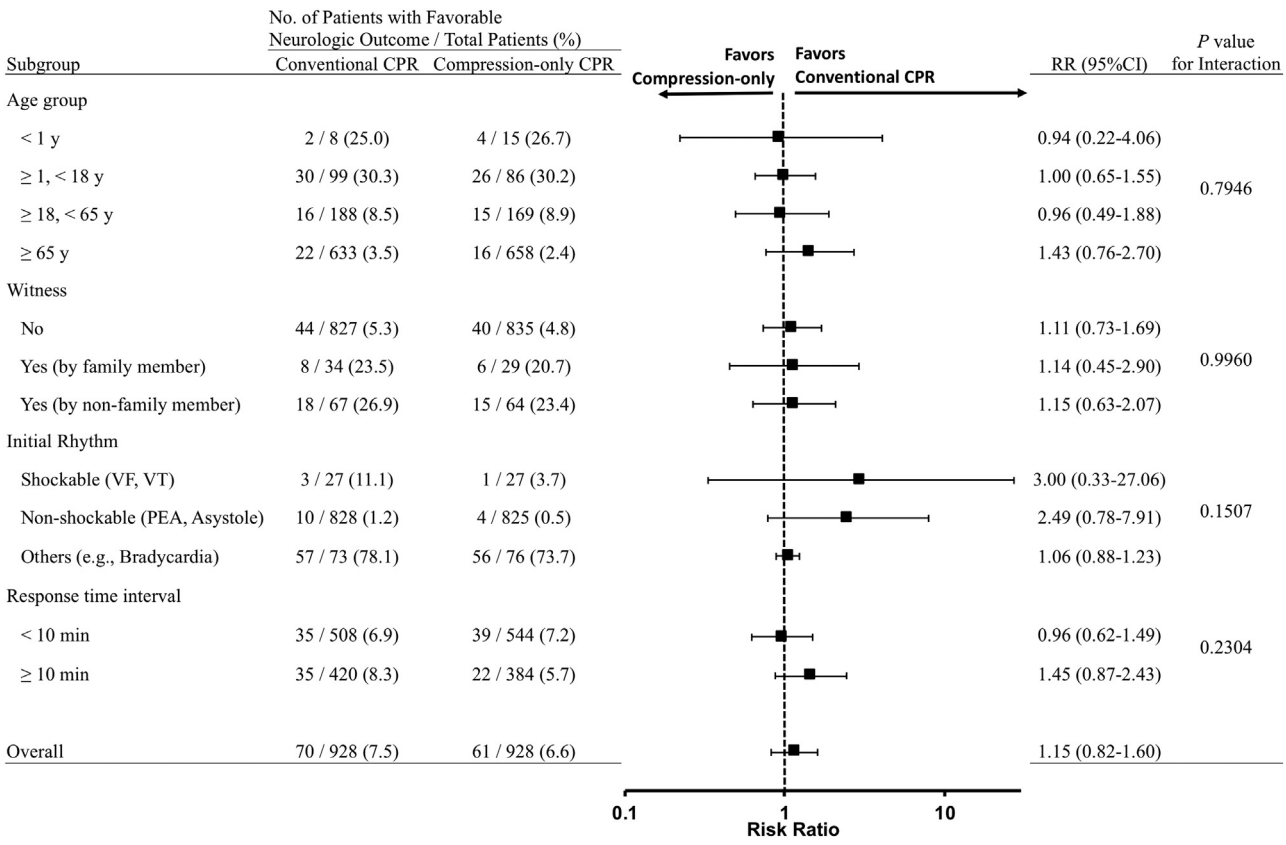


**Fig. 2 – Subgroup analyses for one-month neurologically favorable survival in the propensity score-matched cohort. The associations between the type of bystander CPR (conventional vs. compression-only CPR) and one-month neurologically favorable survival were reported as RRs with 95% CIs for subgroup analysis according to age group (< 1, 1–17, 18–64, or ≥ 65 year), witness (no witness, witness by family member, or witness by non-family member), initial rhythm (shockable [VF or VT], non-shockable rhythm [PEA or asystole], or others), and response time interval (< 10 min or ≥ 10 min).**

**The *P* value represents the *P* value for the interaction between the type of bystander CPR and a given subgroup.**

***Abbreviations*: CI, Confidence interval; CPR, Cardiopulmonary resuscitation; PEA, Pulseless electrical activity; RR, Risk ratio; VF, ventricular fibrillation; VT, Ventricular tachycardia.**

(conventional vs. compression-only CPR) and one-month favorable neurologic outcomes did not change regardless of response time in OHCA due to drowning. These data suggest that both conventional and compression-only bystander CPR may be lifesaving regardless of the subgroup characteristics in OHCA due to drowning. Given our previous study with bystander-initiated CPR preferred over no CPR in OHCA due to drowning,[21] it may be essential to provide any bystander CPR depending on the bystanders' capability.

This study had several limitations. First, our registry was not based on the Utstein reporting template for drowning, but on the Utstein reporting template for cardiac arrest. Thus, we could not address several important data (e.g., water temperature, submersion duration, or body of water) recommended to collect in the Utstein reporting guidelines for drowning,[20] although such factors could affect the outcomes after OHCA due to drowning.[48,49] With regard to the body of water (e.g., bath, pool, ocean, or river), even the information on the location of cardiac arrest (i.e., public or residential locations) could not be obtained from this registry. Second, the potential for unmeasured confounding and residual selection bias remain, despite efforts to control for selection bias and confounders using a variety of analytical techniques. Thus, our findings may not necessarily derive causality but association. Third, the generalizability of our findings to other countries is unknown. Different CPR practices, training programs, or EMS systems may lead to different results. In addition, the characteristics of drowned patients (e.g., common age and site of occurrence) in Japan may differ from those in other countries. Fourth, similar to other registry-based studies, the recorded etiologies of cardiac arrest in this registry were less well validated than those in planned prospective studies. We could not know why the etiology of cardiac arrest was determined to be drowning in this registry because it was impossible to compare the registry data with the medical record data at the patient level due to the anonymization of patient data. Fifth, detailed information on bystander CPR (e.g., quality of CPR) was not available. It was also unknown whether the recorded data on bystander CPR were based on visual confirmation by EMS personnel or interviews with bystanders. In addition, we could not assess dispatcher's instruction in detail (e.g., whether bystanders changed the type of bystander CPR based on dispatcher's instruction). Sixth, detailed data on in-hospital or post-resuscitation care were unavailable, although patients with OHCA are usually transported to a tertiary emergency medical center in each region and those centers have similar levels of capability in Japan. Seventh, data on complications

and longer-term outcomes were not available in this registry. Finally, we acknowledge that the point estimates for the treatment effect favor conventional CPR and might have been statistically different with a much larger sample size. An adequately powered RCT would be required to determine which is superior, conventional or compression-only CPR, in OHCA due to drowning.

## Conclusion and policy implications

The results of this nationwide population-based observational study of OHCA due to drowning from 2013 to 2016 indicated that there was no significant difference between bystander-initiated conventional and compression-only CPR after statistical adjustments in the chance of neurologically favorable survival, regardless of age, witness, initial rhythm, and response time. Although there was a trend favoring conventional CPR, these data suggest that bystander-initiated compression-only CPR may be as lifesaving as conventional CPR in OHCA due to drowning. An adequately powered RCT is needed to determine which is superior, conventional or compression-only CPR, in OHCA due to drowning.

## Author contributions

TF is the guarantor and takes responsibility for the integrity of the data and the accuracy of the data analysis.

TF conceived and designed the study. TF and IK acquired the data. TF, NO-F, KH, YK, and IK contributed substantially to the analysis or interpretation of data. TF authored the initial and final drafts of the manuscript. All authors revised drafts of the manuscript.

All authors approved the final, submitted version of the manuscript.

## Role of the sponsors

This study was supported by University of the Ryukyus. Funding sources had no role in the study design, analysis and interpretation of the data, and writing of the paper.

## Other contributions

We thank the Fire and Disaster Management Agency who collected and managed the All-Japan Utstein Registry data.

## Funding sources

This study was supported by University of the Ryukyus.

## Prior abstract publication/presentation

None.

## Conflict of interest

None.

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