Impact of bystander-performed ventilation on functional outcomes after cardiac arrest and factors associated with ventilation-only cardiopulmonary resuscitation: a large observational study

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Word count: 2998

Number of Figures: 5

Number of Tables: 1

Number of Supplementary Table: 1

Number of References: 30

Abstract

Aim: To determine the effectiveness of ventilations in bystander cardiopulmonary resuscitation (BCPR) and to identify the factors associated with ventilation-only BCPR.

Methods: From out-of-hospital cardiac arrest (OHCA) data prospectively collected from 2005 to 2011 in Japan, we extracted data for 210,134 bystander-witnessed OHCAs with complete datasets but no prehospital involvement of physician [no BCPR, 115,733; ventilation-only, 2,093; compression-only, 61,075; and conventional (compressions + ventilations) BCPR, 31,233] and determined the factors associated with 1-month neurologically favourable survival using simple and multivariable logistic regression analyses. In 91,885 patients with known BCPR durations, we determined the factors associated with ventilation-only BCPR.

Results: The rate of survival in the no BCPR, ventilation-only, compression-only and conventional group was 2.8%, 3.9%, 4.5% and 5.0%, respectively. After adjustment for other factors associated with outcomes, the survival rate in the ventilation-only group was higher than that in the no BCPR group (adjusted OR; 95% CI, 1.29; 1.01–1.63), but lower than that in the compression-only (0.76; 0.59–0.96) or conventional groups (0.70; 0.55–0.89). Conventional CPR had the highest OR for survival in almost all OHCA subgroups. The adjusted OR (95% CI) for survival after dividing BCPR into ventilation and compression components were 1.19 (1.11–1.27) and 1.60 (1.51–1.69), respectively. Older guidelines, female sex, younger patient age, bystander-initiated CPR without instruction, early BCPR and short BCPR duration were associated with ventilation-only BCPR.

Conclusions: Ventilation is a significant component of BCPR, but alone is less effective than compression in improving neurologically favourable survival after OHCAs.

Word count: 247

Key words: out-of-hospital cardiac arrest; bystander cardiopulmonary resuscitation; ventilation.

1. Introduction

Emergency medical technicians (EMTs) report the case of out-of-hospital cardiac arrest (OHCA), in which bystanders have performed ventilation-only cardiopulmonary resuscitation (CPR) in victims of EMT-confirmed OHCA. This rare ventilation-only bystander CPR (BCPR) has been believed to be ineffective, and simply grouped as no BCPR or excluded from analysis [1–4]. Consequently, neither the effects of ventilation-only BCPR on bystander-witnessed OHCA outcomes nor the factors associated with ventilation-only BCPR have been studied in a population-based cohort. Conventional CPR is a combination of ventilations and chest compressions. In order to clarify the effectiveness of ventilations, analysis is required for both the additive and independent effects of ventilations.

Since the International Liaison Committee on Resuscitation (ILCOR) and American Heart Association (AHA) Guideline released in 2000 [5], the requirement for laypersons or bystanders to check for a pulse was removed form CPR assessment. Since the ILCOR Consensus 2005 [6] and related guidelines [7, 8], bystanders may initiate chest compressions with or without ventilation in adults who are unresponsive and breathing abnormally. Therefore, most cased with respiratory arrest receive compression-only or conventional (compressions and ventilations) CPR [9].

In infants and children, respiratory arrest is more common than cardiac arrest, and ventilations are considered extremely important in paediatrics resuscitation [5–7, 10–12]. Similarly, ventilations have been believed to be beneficial in some adult OHCAs of non-cardiac aetiology, including asphyxia, trauma and submersion [4–7, 13].

In the present study, we aimed to determine the effectiveness of ventilation in BCPR for bystander-witnessed OHCAs. In addition, we elucidated the factors associated with ventilation-only BCPR.

2. Methods

2.1. Study design and setting

We obtained the consent of the Japanese Fire and Disaster Management Agency (FDMA) to analyze the OHCA data prospectively collected between 2005 and 2011. The study group comprising members of the Ishikawa Medical Control Council (MCC) and their collaborators designed this study, which was approved by the review board of Ishikawa MCC.

Japan has a population of 128 million, of which over 20% are older than 65 years. In 2012, 791 fire departments had 4965 ambulance teams [14]. EMTs must not terminate resuscitation at the scene unless an OHCA patient is obviously dead or presents post-mortem changes. Paramedics may use airway ajuncts, including suprapharyngeal devices and may commence a peripheral venous infusion on Ringer's lactate. However, only authorized and specially trained paramedics are permitted to insert tracheal tubes and to administer intravenous adrenaline to adult OHCA victims.

At the end of 2006, the Japan Resuscitation Council (JRC) announced similar guidelines [15] to those of the AHA [10]. Prior to these, citizens were educated according to the ILCOR/AHA Guidelines 2000 [5]. Therefore, citizens were substantially trained for basic life support (BLS) in accordance to newer guidelines in the period of 2007–2011 and older guidelines in the period of 2005–2006.

2.2. Data selection

We analyzed the FDMA database of 797,422 OHCAs that occurred from January 2005 to December 2011. First, we extracted a dataset comprising 217,969 bystander-witnessed OHCA without any prehospital involvement of physicians due to the following reasons; (1) some of these cases received prehospital advanced life support (ALS) performed by physicians on duty [16], (2) these physicians on duty played primary roles in the treatment and transportation of patients, (3) according to the Utstein Recommendations [17, 18], these physicians on duty should not be categorized as a bystander. Then, we excluded the following cases lacking the essential information for analysis; 160 cases in which the relationship of the bystander to the victim was unknown and 2753 cases in which the provision of dispatcher-assisted CPR (DA-CPR) was unknown. Finally, we selected 210,134 bystander-witnessed cases with a complete dataset available (Figure 1). In these OHCA cases, we determined whether ventilation-only BCPR was as ineffective as no BCPR and whether it was less effective than compression-only or conventional BCPR. Also, we determined the effectiveness of ventilations and compressions as individual BCPR components in an alternative analysis. Furthermore, we performed subgroup analysis for presumed cardiac or non-cardiac OHCAs and for paediatric (<20 years) or adult (≥20 years) OHCAs. For the factors associated with ventilation-only BCPR, we analysed 91,885 BCPR cases with known BCPR durations.

2.3. Methods of Measurement

FDMA databases include the following information recommended at the Utstein International Conference [18, 19]: patient backgrounds, arrest witness, aetiology of OHCA (presumed cardiac or non-cardiac), type of BCPR (ventilation-only, compression-only or conventional), origin of BCPR (with or without DA-CPR instruction), initial cardiac rhythm, estimated time of collapse (obtained from the interviews to bystanders), time of bystander and

EMT CPR initiation and EMT arrival, 1-month (1-M) survival, bystander group (family members and others) and 1-M cerebral performance category [19, 20]. The time points of collapse and BCPR initiation were determined by EMT's interview with the bystander. Cardiac or non-cardiac origin was clinically determined by the physicians in collaboration with EMTs. Fire departments obtained information on 1-M survivals from hospitals.

2.4. Outcome

The primary outcome was the 1-M neurologically favourable survival (cerebral performance category, 1 or 2) in the main part of this study [16, 17]. Ventilation-only BCPR was the primary outcome in another part of this study.

2.5. Statistical analysis

Data were analyzed using JMP version 11 Pro (SAS institute, Cary, NC) and/or a computer software by Preacher [21]. Differences across groups for nominal variables were assessed using the χ^2 test with and without Yates' correction and assessments were confirmed by Fisher's exact test. The Kruskal–Wallis test was first applied for nonparametric comparisons of continuous variables. Simple logit analysis was first applied for component analysis of ventilation and compression.

Multivariable logistic regression analysis was employed to confirm the association of the BCPR type or BCPR components with the 1-M neurologically favourable survival and to identify the factors associated with ventilation-only BCPR. For the two 1-M neurologically favourable survival models, we sequentially introduced groups of variables into the model: first, basic variables known to be definitively associated with OHCA outcomes (arrest aetiology, initial rhythm and call−EMS arrival at patients interval), then variables identified as significant in univariate analysis (patient age, patient sex, prehospital tracheal intubation, adrenaline administration, guidelines, bystander-patient relationship, witness−call interval and EMS arrival at patients−EMS arrival at hospital interval) in a stepwise manner to obtain the lowest Bayesian information criterion (BIC). For the ventilation-only CPR model, we first applied multivariable logistic regression analysis for the factors that were significant in univariate analysis, before adding the factors that were not significant in a stepwise manner to obtain the lowest BIC. The root mean square error (RMSE, *Appendix A*) and generalized R^2 (GR^2, *Appendix B*) of the final model were computed to measure the fit of the regression model. For each analysis, the null hypothesis was evaluated at a 2-sided significant level of $p < 0.05$; with 95% CI calculated using profile likelihood.

3. Results

3.1. Effectiveness of ventilation

When the four BCPR types and no BCPR were compared for all OHCA cases that received BCPR, the rate of 1-M neurologically favourable survival in the no BCPR, ventilation-only, compression-only and conventional group was 2.8%, 3.9%, 4.5% and 5.0%, respectively (Figure 2A). When analyzed by multivariable logistic regression analysis (Figure 3A), the rate in ventilation-only group was lower than those in the compression-only group (adjusted OR; 95% CI, 0.76; 0.59–0.96) and the conventional group (0.70; 0.55–0.89) but higher than that in the no BCPR group (1.29; 1.00-1.63). The RMSE and GR^2 of this model were 0.174 and 0.255.

Since a significant interaction between BCPR type and arrest aetiology was detected (interaction test, $p<0.001$), further analyses were made in two subgroups classified by arrest aetiology. The survival rate in the no BCPR, ventilation-only, compression-only and conventional group was 3.8%, 4.8%, 6.5% and 7.0%, respectively in the subgroup of cardiac aetiology, and 1.5%, 2.7%, 1.8% and 2.2%, respectively in the subgroup of non-cardiac aetiology (Figure 2B). In multivariable analysis (Figure 3B), the survival rate in the ventilation-only group was as low as that in no BCPR group for the cardiac aetiology OHCA subgroup (1.13; 0.84–1.50), whereas it was higher than that in the no BCPR group for the non-cardiac aetiology subgroup (1.62; 1.05–2.39). The rate in the ventilation-only group was lower than those in the compression-only (0.63; 0.46–0.86) and conventional groups (0.63; 0.46–0.83) for the cardiac aetiology subgroup. The survival rate in the conventional group was higher than that in the compression-only group for the non-cardiac aetiology subgroup (1.27; 1.09–1.47).

Since a significant interaction between BCPR type and age group was also detected (interaction test, *p*=0.003), analyses were made in the two subgroups classified by age. The survival rate in the no BCPR, ventilation-only, compression-only and conventional group was 4.7%, 10.9%, 10.0% and 13.7%, respectively in the subgroup of paediatric OHCAs (Figure 2C). The survival rates in conventional (2.58; 1.84–3.63), compression-only (1.87; 1.31–2.67) and ventilation-only (2.60; 1.24–5.00) groups were higher than that in the no BCPR group for this OHCA subgroup (Figure 3C). The results of analyses in the subgroup of adult OHCAs were similar to those in all bystander-witnessed OHCAs. Conventional BCPR had the highest OR for survival in almost all subgroups of OHCAs.

Since the interaction between ventilation and compression components was not significant (interaction test, $p = 0.052$), alternative analysis using the two components was likely to be valid. The interaction test disclosed the following significant interactions: arrest aetiology–ventilation, arrest aetiology–compression and age group–ventilation. In simple multinominal logit analysis of two components, unadjusted ORs (95% CI) of ventilation and compression components for survival were 1.13 (1.06–1.20) and 1.64 (1.56–1.72), respectively (Figure 4A). Adjusted OR (95% CI) obtained by multivariable logistic regression analysis including the two components and others was 1.19 (1.11–1.27) for ventilation component and 1.60 (1.51–1.69) for compression component (Figure 4B). RMSE and GR^2 of this model were 0.174 and 0.255. We confirmed that the interaction between ventilation and compression was not significant even when other variables used in the final model were included in the interaction test ($p = 0.147$). As shown in Supplementary Table, unadjusted ORs of ventilation are high in subgroups of non-cardiac aetiology (1.38; 1.19–1.59) and paediatric OHCAs (1.56; 1.13–2.15).

Supplementary Table S1 related to this article can be found, in the online version, at http://dx.doi.org/10.1016/j.resuscitation.2015.02.033.

3.2. Annual incidences of ventilation-only BCPR

Figure 5 shows that the incidence of ventilation-only BCPR decrease sharply after implementation of the JRC guidelines 2005, from 2.1% during 2005–2006 to 0.7% during 2007–2011 (OR; 95% CI, 0.31; 0.28–0.34). In parallel, the incidences of compression-only BCPR and DA-CPR instruction increased from 18.9% and 34.7% during 2005–2006 to 32.7% and 43.6% during 2007–2011, respectively (2.06; 2.01–2.11, 1.46; 1.43–1.49, respectively). Conversely, no BCPR and the incidence of conventional BCPR decreased from 60.2% and 18.8% during 2005–2006 to 53.0% and 13.7% during 2007–2011, respectively (0.76; 0.74–0.77, 0.68; 0.66–0.69, respectively).

3.3. Factors associated with ventilation-only BCPR

As shown in Table 1, univariate analysis revealed that the following were associated with ventilation-only BCPR: younger patients, female patients, family bystander, bystander-initiated CPR without DA-CPR instruction, time period under JRC guidelines 2005 (2005–2006), early BCPR (short interval between witnessing the arrest and CPR initiation) and short BCPR duration (interval from BCPR initiation to EMT arrival at patient). Arrest aetiology and time interval between witnessing the arrest and calling an ambulance were not significantly associated with ventilation-only BCPR. Next, we applied multiple logistic regression analysis for the significant factors in univariate analysis before adding the factors that were not significant; this revealed no improvement of BIC. Therefore, the final model confirmed that the above factors were associated with ventilation-only BCPR.

4. Discussion

Sufficient analysis has been lacking for both the additive and the independent effects of ventilations in CPR. Furthermore, no study has demonstrated components analysis of ventilation and compression in BCPR. Bystanders often fail to distinguish respiratory arrest from cardiac arrest because checking the pulse is no longer required. Ventilations have long been considered critical to paediatric CPR [10–12], adult OHCAs of non-cardiac aetiology [4] and adult respiratory arrest without cardiac arrest [5–8]. A few bystanders [4, 9] who are aware of this have been performed ventilation-only BCPR, which they continue until the EMT arrival.

In this study, we analysed the effectiveness of ventilations in bystander-witnessed and EMT-confirmed OHCAs without any involvement of physicians because the quality and type of CPR may be affected by the physician involvement [16] and the time of collapse (witness) can be estimated only in bystander-witnessed cases. After adjustment for well-known factors related for survival, we found that the ventilation-only group was 1.29 times more likely to survive with CPC = 1 or 2 than the no BCPR group, but less likely to survive than the compression-only and conventional groups. Furthermore, we showed that ventilations are a significant component of BCPR, despite their apparently inferior effectiveness compared to compression. These clinically novel findings are in agreement with the results of one animal study [11] and suggest the importance of ventilation in BCPR. As reported previously [4, 11], the importance of ventilation component in BCPR was pronounced for presumed non-cardiac OHCA. However, ventilation component was less important for OHCAs of presumed cardiac aetiology, as shown by the previous studies [2]. The proportion of patients with non-cardiac aetiology arrest may affect overall survival rates of out-of-hospital cardiac arrest, and varied in our and previous investigations on the effects of BCPR type on OHCA survival [4, 12].

When the additive effect was defined as the sum of each independently significant component, additive benefit of ventilations was small but evident in all bystander-witnessed OHCAs and adult OHCAs. Furthermore, as reported previously [12], the effectiveness of ventilations was definitively evident in paediatric OHCAs. These results contradict the recent report in Arizona [21], and support the more recent report in Japan [4] suggesting that conventional BCPR combining ventilations and compressions may be ideal for overall bystander-witnessed OHCAs and that citizens with potential intension for BLS and healthcare providers should be primarily trained to provide effective conventional CPR.

One meta-analysis study showed that there was no significant difference between compression-only CPR and conventional CPR in neurologically favourable outcomes [13]. However, other meta-analysis studies suggested that compression-only CPR was associated with improved survival rate compared with conventional CPR [3, 23]. The latter meta-analysis included prospective randomized studies that compared dispatcher-assisted compression-only CPR with conventional CPR; these randomized studies revealed the superiority of compression-only CPR to conventional CPR [1, 3]. The former meta-analyses included observational studies investigating the difference in outcomes between compression-only CPR and conventional CPR, in all OHCA having bystander CPR [13].

The current recommendations for compression-only CPR is partially based on the perception that many bystanders do not want to perform ventilation as they believe it can only be performed via mouth-to-mouth and may transmit many fear disease [8]. Another basis of the recommendation is that conventional CPR may be associated with delayed initiation of BCPR and consequently diminished effect of BCPR, particularly when dispatchers provided DA-CPR instruction on bystanders [1, 9]. This study showed that the incidence of ventilation-only BCPR decreased after implementation of the new JRC guidelines 2005 released at the end of 2006. This decrease was accompanied by increased incidences of compression-only BCPR and DA-CPR and decreased incidence of no BCPR. These findings suggest that increased incidence of DA-CPR instructing compression-only BCPR may be a main cause of these alternations and that it may be effective in increasing the overall rate of BCPR.

However, it is questionable whether DA-CPR instructing compression-only BCPR should be applied in OHCA cases that are witnessed by bystanders with suitable training and willingness for conventional CPR. The newest JRC guidelines 2010 [24] stated that conventional CPR following ventilation-only CPR should be instructed when well-trained bystanders witnessed OHCA precipitated by asphyxia. This study showed that family member were more likely to perform ventilation-only BCPR and that ventilation-only CPR was more frequently initiated without DA-CPR instruction. Furthermore, the BCPR duration and the interval between arrest witness and BCPR initiation were shorter for ventilation-only BCPR. Therefore, it is likely that educated bystanders who have strong will to save the victims but insufficient skill in checking the pulse [25] perform ventilation-only BCPR. It has been shown that healthcare providers also have difficulty in pulse detection [26, 27]. Once bystanders judge the presence of respiratory arrest and initiate ventilation-only BCPR, transition to cardiac arrest may be more difficult to detect [9], and ventilation-only BCPR may be continued until EMT arrival.

Experienced dispatchers are able to correct inadequate ventilation-only BCPR by requesting these trained callers to re-check for signs of spontaneous circulation. It may be reasonable that this correction should involve converting ventilation-only BCPR to conventional rather than compression-only BCPR.

Our study has several limitations. The greatest limitation is low incidence of ventilation-only BCPR (Figure 6): it was approximately 1% of the analysed data set and was declining over time. No data on BCPR quality were collected, which is a major factor affecting OHCA outcome [28]; an undetermined difference in quality may affect the results of this study. The final outcomes were assessed at 1-M, and a longer observation period may be recommended [29]. The time factors calculated from the estimated times of collapse and BCPR initiation may be inaccurate [30]. The type of BCPR was determined by EMT observations and interview; thus, the initial BCPR may have been different. Because ALS is not universally permitted for all Japanese paramedics, extrapolating our findings to other systems with broader protocols may be limited. Finally, as in previous cohort studies, it is unknown how frequently bystanders witnessed respiratory arrest, which was followed by EMT-confirmed cardiac arrest.

5. Conclusions

Ventilation is a significant component of BCPR, but alone is less effective than compression in improving neurologically favourable survival after OHCAs. Conventional BCPR is ideal in all subgroups of OHCAs.

6. Conflict of Interest

The authors declare no conflicts of interest associated with this manuscript.

7. Acknowledgement

We would like to thank all of the EMS personnel and the FDMA in Japan for their great cooperation in collecting and managing the Utstein-style database. TM and TK equally contributed to this article as the first author.

Appendix A.

Root mean square of error (RMSE): the root mean square error, where the differences are between the response and p (the fitted probability for the event that actually occurred).

$= \sqrt{\ } \Sigma (y[j]- \rho [j])^2/n$

Smaller RMSE values indicate a better fit.

Appendix B.

Generalized R^2 (GR^2): a generation of the R^2 reported by Cox and Snell.

= (1-(L(0)/L(model))^(2/n))/(1-L(0)^(2/n))

Values closer to 1 indicate a better fit.

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Legends of figures

Figure 1. Cohort summary and data selection

*lack of information regarding patient background and time factors.

Figure 2. Differences in 1-month 1eurologically favourable survival among the bystander cardiopulmonary resuscitation types

Panel A: All OHCAs, Panel B: Aetiology of arrest, Panel C: Patient age group.

Paediatric OHCAs were defined as OHCAs in patients with age of < 20 years.

As shown in Panel B, a significant interaction between BCPR type and arrest aetiology was detected (interaction test, p<0.001). As shown in Panel C, a significant interaction between BCPR type and arrest aetiology was detected (interaction test, p=0.003)

Figure 3. Multivariable logistic regression analyses: adjusted odds ratio for 1-month neurologically favourable survival

Root mean square error (RMSE) was 0.174, 0.204, 0.128, 0.260 and 0.174 for all bystander-witnessed OHCAs (Panel A), and the cardiac aetiology (Panel B), the non-cardiac aetiology (Panel B), the paediatric OHCA (Panel C), and the adult OHCA (Panel C) subgroups, respectively. Generalized R^2 (GR^2) was 0.255, 0.280, 0.080, 0.172, and 0.234 for all bystander-witnessed OHCAs (Panel A), and the cardiac aetiology (Panel B), the non-cardiac aetiology (Panel B), the paediatric OHCA (Panel C), and the adult OHCA (Panel C) subgroups, respectively. Because paramedics are allowed to provide tracheal intubation and epinephrine administration only on adult OHCA victims, these procedures were excluded from analysis in the subgroup of paediatric OHCA (Panel C). Only common factors in the remaining four regressions are shown.

Figure 4. Component analysis of ventilation and compression

Panel A: The rate of 1-month neurologically favourable survival and odds ratio determined by multinominal (ventilations and compressions) logit analysis.

The interaction between ventilation and compression components was not significant (interaction test, $p = 0.052$)

Panel B: Multivariable logistic regression analyses: adjusted odds ratio for 1-month neurologically favourable survival.

Root mean square error (RMSE) and Generalized R^2 (GR^2) of this model were 0.174 and 0.255.

Figure 5. Annual Incidences of the Bystander Cardiopulmonary Resuscitation Types and Dispatcher-assisted Instruction.

P for trends of all parameters was <0.001 (χ^2 test and Fisher’s exact test)

Table 1. Factors Associated With Ventilation-only Bystander Cardiopulmonary Resuscitation in Out-of-hospital Cardiopulmonary Arrests

	BCPR		Unadjusted odds ratio (95% CI) for ventilation-only BCPR or *p* value by univariable analysis[b)]	Adjusted odds ratio (95% CI) for ventilation-only BCPR by multivariavle logistic regression analysis[c)]
	Standard BCPR[a)] N = 89,931	Ventilation-only BCPR N = 1,954		
Aetiology of arrest, % (N)				Excluded
Presumed cardiac	57.6% (51,180)	56.7% (1,108)	Reference	
Non-cardiac	42.4% (38,101)	43.3% (846)	1.04 (0.95–1.14)	
Patient age	79 (66–87)	76 (61–85)	0.88 (0.86–0.90) [d)]	0.89 (0.87–0.91) [d)]
Patient sex, % (N)				
Male	57.1% (51,364)	54.6% (1,067)	Reference	Reference
Female	42.9% (38,567)	45.4% (887)	1.11 (1.01–1.21)	1.29 (1.17–1.41)
Relation of bystander to victim, % (N)			$p < 0.001$	
Others	44.8% (40,308)	31.4% (614)	Reference	Reference
Family member	55.2% (49,623)	68.6% (1,340)	1.77 (1.61–1.95)	2.00 (1.80–2.21)
Origin of BCPR, % (N)				
In compliance with DA-CPR instruction	62.2% (55,962)	55.8% (1,090)	Reference	Reference
Bystander-initiated CPR without instruction	37.8% (33,969)	44.2% (864)	1.31 (1.19–1.43)	1.46 (1.32–1.61)
Time period, % (N)				
After JRC Guidelines 2005 (2005–2006)	78.5% (70,589)	48.3% (944)	Reference	Reference
Before JRC Guidelines 2005 (2007–2008)	21.5% (19,342)	51.7% (1,010)	3.91 (3.57–4.27)	3.68 (3.36–4.03)
Time intervals, min, median (10–25–75–90%)				
Witness – BCPR	2 (0-0-5-11)	1 (0–0–5–10)	0.93 (0.86–0.99)[e)]	0.88 (0.80–0.94) [e)]
Duration of BCPR	7 (3–5–11–15)	6 (3–4–10–14)	0.96 (0.92–0.99) [e)]	0.89(0.82–0.96) [e)]

a) Compression-only and conventional BCPR

b) Odds ratio determined by simple logistic regression analysis following 2 × 2 chi-square analysis with Yates' correction.

c) Multivariable logistic regression analysis was used to identify the factors associated with ventilation-only BCPR. Generalized R^2 of the final model was 0.067.

d) Odds ratio per 10 y

e) Odds ratio per 10 min

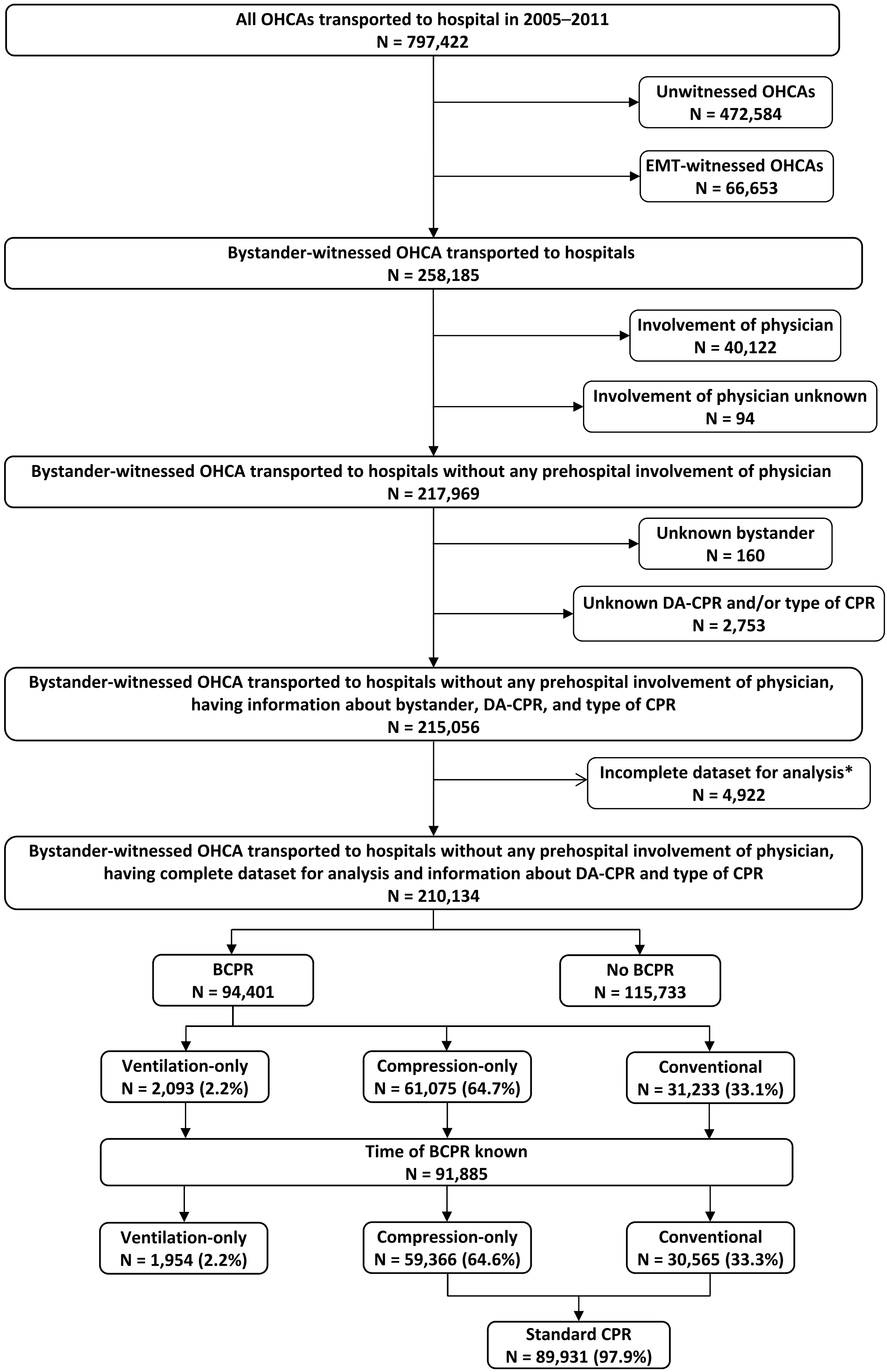
BCPR, bystander cardiopulmonary resuscitation; CPR, cardiopulmonary resuscitation; DA-CPR, Dispatcher-assisted CPR; JRC, Japan Resuscitation Council; OHCAs, out-of-hospital cardiac arrests; 95% CI, 95% confidence interval.

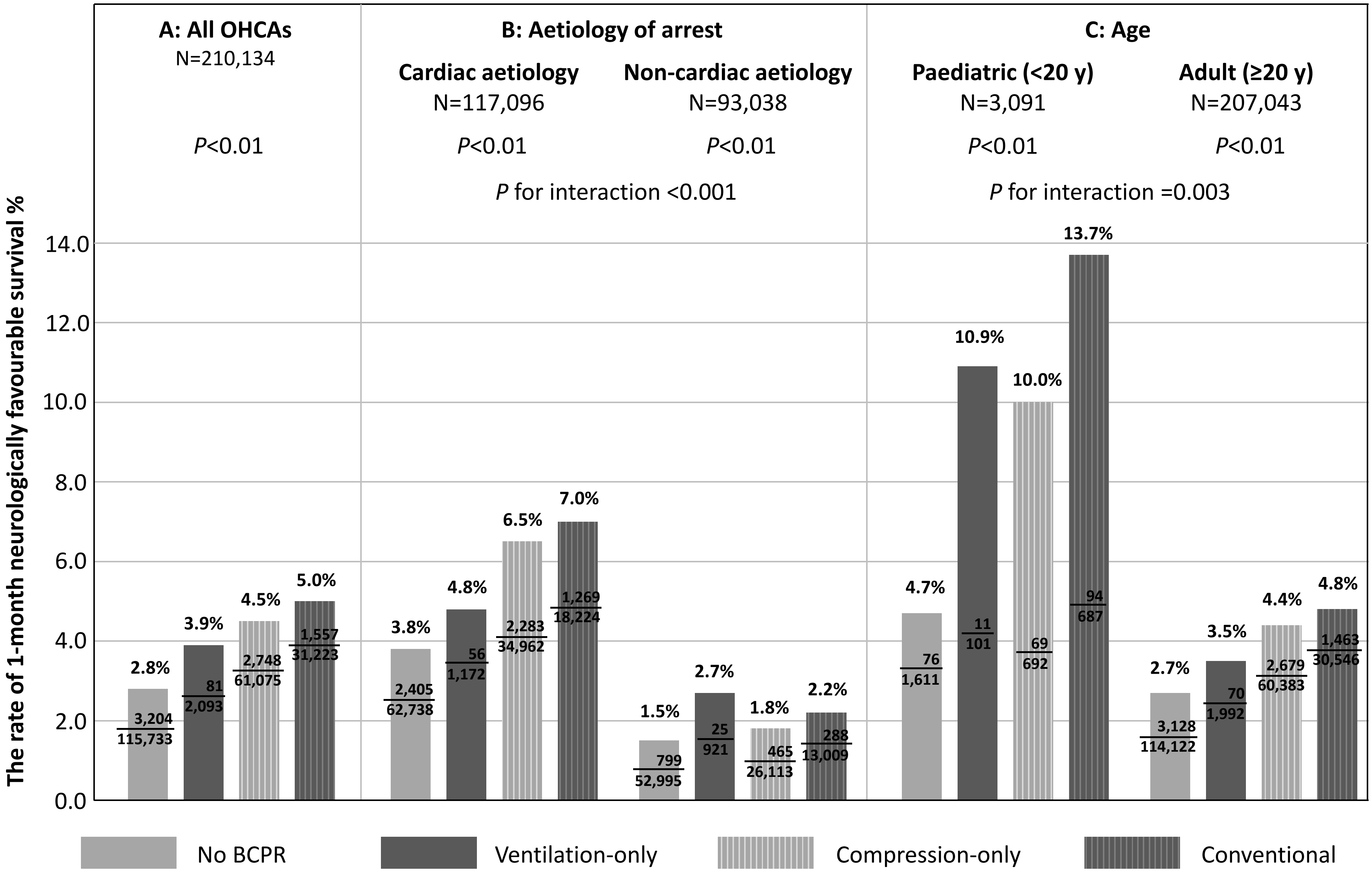
Supplementary Table. Component analyses in subgroups of bystander-witnessed OHCAs.

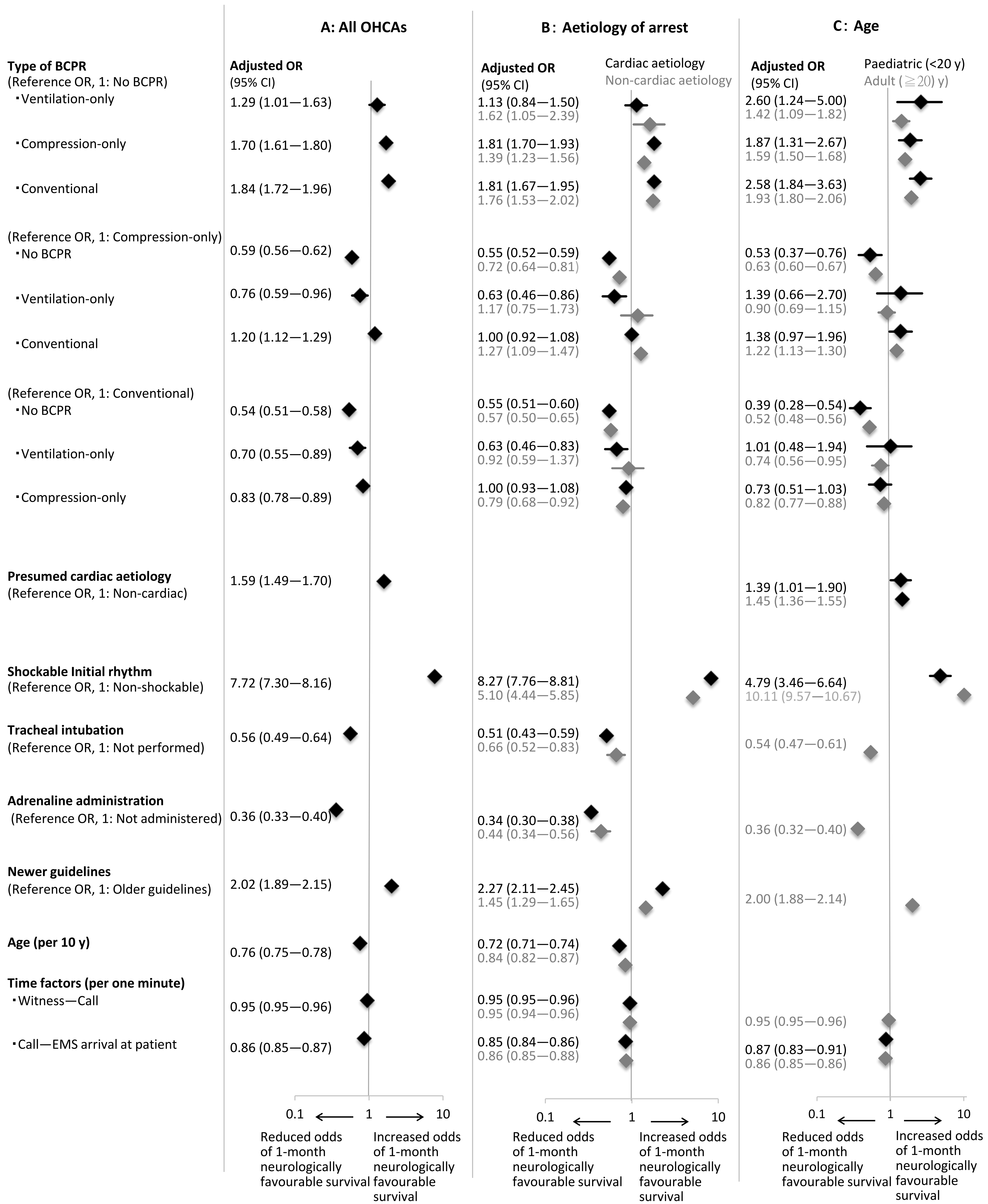
Multivariable logistic regression analysis	Aetiology of arrest				Age			
	Presumed cardiac		Presumed non-cardiac		Paediatric (<20 y)		Adult (≥20 y)	
	Ventilation	Compression	Ventilation	Compression	Ventilation	Compression	Ventilation	Compression
Adjusted OR (95% CI)	1.14 (1.05–1.23)	1.67 (1.56–1.78)	1.38 (1.19–1.59)	1.31 (1.17–1.47)	1.56 (1.13–2.15)	1.73 (1.25–2.40)	1.18 (1.10–1.26)	1.53 (1.45–1.62)
RMSE	0.203		0.128		0.260		0.173	
Generalized R^2	0.291		0.082		0.167		0.236	
Other variables included in analysis	Patient age Initial rhythm Tracheal intubation Adrenalin administration Bystander- patient relationship Guidelines Time intervals Call–EMS arrival at patient Witness–Call		Patient age Initial rhythm Tracheal intubation Adrenalin administration Guidelines Time intervals Call – EMS arrival at patient Witness – Call		Aetiology of arrest Initial rhythm Time interval Call – EMS arrival at patient		Aetiology of arrest Initial rhythm Tracheal intubation Adrenalin administration Bystander- patient relationship Guidelines Time intervals Call – EMS arrival at patient Witness – Call	

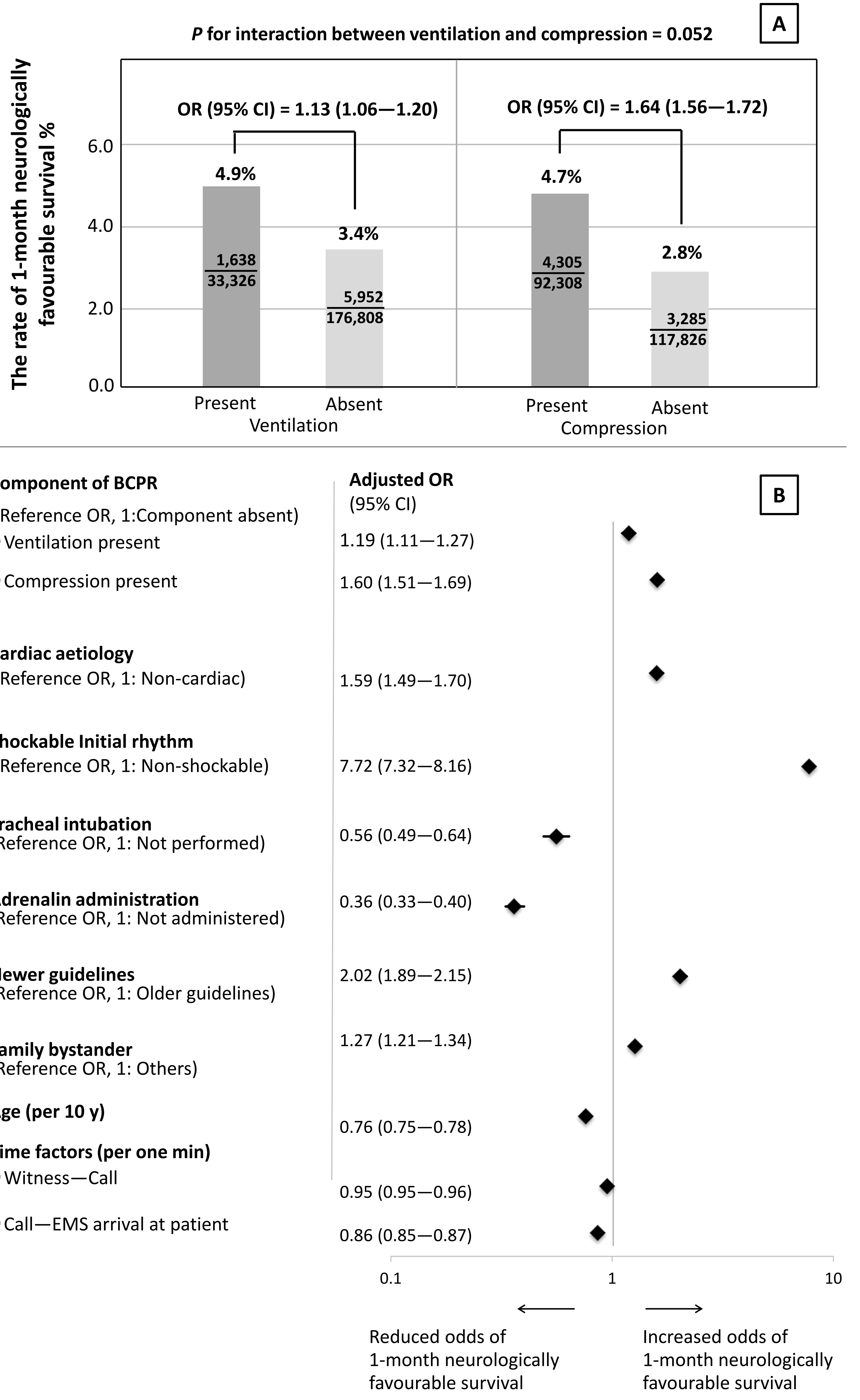
RMSE: Root mean square of error.

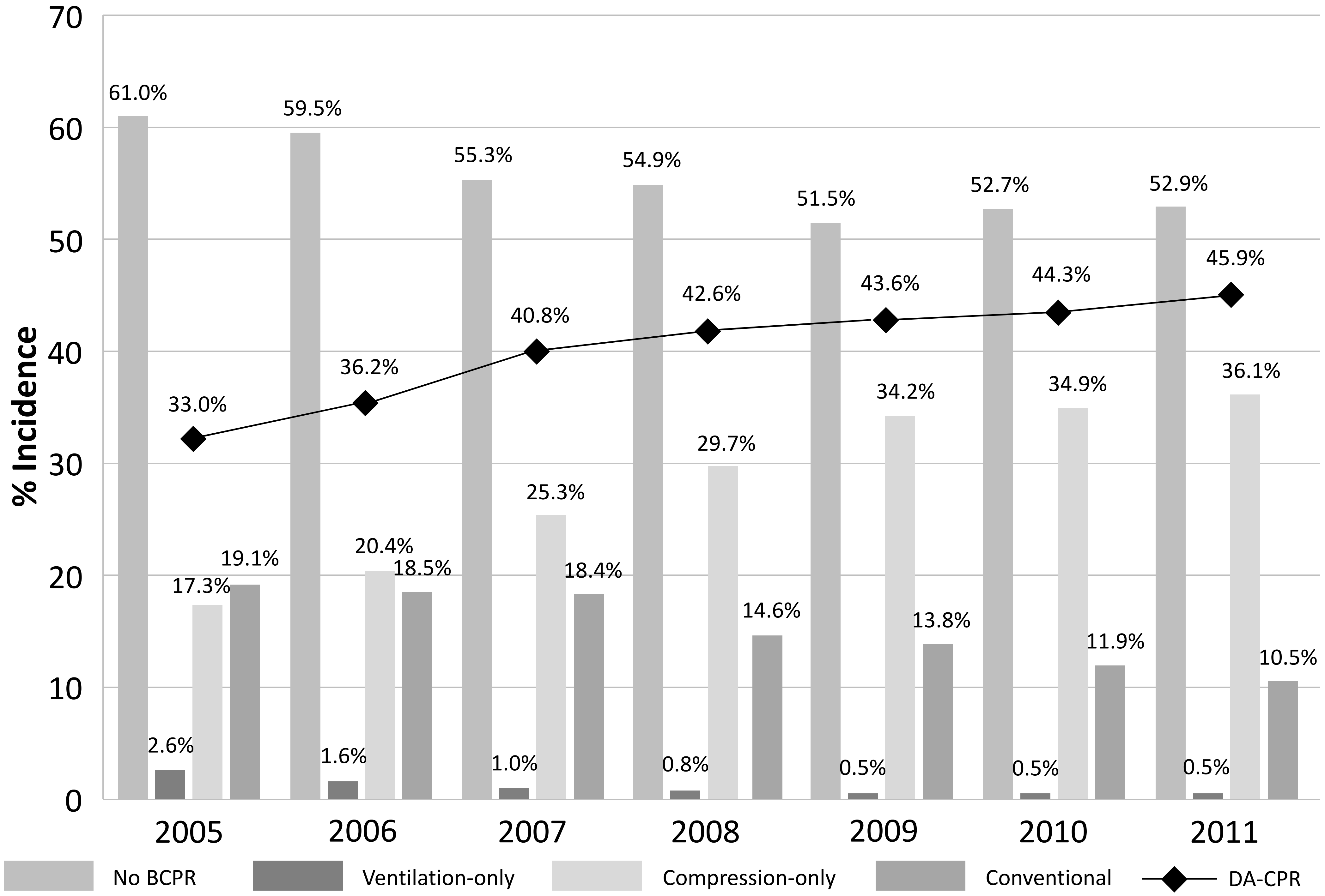
Because paramedics are allowed to provide tracheal intubation and epinephrine administration only on adult OHCA victims, these procedures were excluded from analysis in the subgroup of paediatric OHCA.


All OHCAs transported to hospital in 2005–2011
N = 797,422
Unwitnessed OHCAs
N = 472,584
EMT-witnessed OHCAs
N = 66,653
Bystander-witnessed OHCA transported to hospitals
N = 258,185
Involvement of physician
N = 40,122
Involvement of physician unknown
N = 94
Bystander-witnessed OHCA transported to hospitals without any prehospital involvement of physician
N = 217,969
Unknown bystander
N = 160
Unknown DA-CPR and/or type of CPR
N = 2,753
Bystander-witnessed OHCA transported to hospitals without any prehospital involvement of physician, having information about bystander, DA-CPR, and type of CPR
N = 215,056
Incomplete dataset for analysis*
N = 4,922
Bystander-witnessed OHCA transported to hospitals without any prehospital involvement of physician, having complete dataset for analysis and information about DA-CPR and type of CPR
N = 210,134
BCPR
N = 94,401
No BCPR
N = 115,733
Ventilation-only
N = 2,093 (2.2%)
Compression-only
N = 61,075 (64.7%)
Conventional
N = 31,233 (33.1%)
Time of BCPR known
N = 91,885
Ventilation-only
N = 1,954 (2.2%)
Compression-only
N = 59,366 (64.6%)
Conventional
N = 30,565 (33.3%)
Standard CPR
N = 89,931 (97.9%)


A: All OHCAs
N=210,134
P<0.01
B: Aetiology of arrest
Cardiac aetiology
N=117,096
P<0.01
Non-cardiac aetiology
N=93,038
P<0.01
P for interaction <0.001
C: Age
Paediatric (<20 y)
N=3,091
P<0.01
Adult (≥20 y)
N=207,043
P<0.01
P for interaction =0.003
The rate of 1-month neurologically favourable survival %
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
2.8%
3,204
115,733
3.9%
81
2,093
4.5%
2,748
61,075
5.0%
1,557
31,223
3.8%
2,405
62,738
4.8%
56
1,172
6.5%
2,283
34,962
7.0%
1,269
18,224
1.5%
799
52,995
2.7%
25
921
1.8%
465
26,113
2.2%
288
13,009
4.7%
76
1,611
10.9%
11
101
10.0%
69
692
13.7%
94
687
2.7%
3,128
114,122
3.5%
70
1,992
4.4%
2,679
60,383
4.8%
1,463
30,546
No BCPR
Ventilation-only
Compression-only
Conventional


A: All OHCAs
B: Aetiology of arrest
C: Age
Type of BCPR
(Reference OR, 1: No BCPR)
・Ventilation-only
・Compression-only
・Conventional
(Reference OR, 1: Compression-only)
・No BCPR
・Ventilation-only
・Conventional
(Reference OR, 1: Conventional)
・No BCPR
・Ventilation-only
・Compression-only
Presumed cardiac aetiology
(Reference OR, 1: Non-cardiac)
Shockable Initial rhythm
(Reference OR, 1: Non-shockable)
Tracheal intubation
(Reference OR, 1: Not performed)
Adrenaline administration
(Reference OR, 1: Not administered)
Newer guidelines
(Reference OR, 1: Older guidelines)
Age (per 10 y)
Time factors (per one minute)
・Witness—Call
・Call—EMS arrival at patient
Adjusted OR
(95% CI)
1.29 (1.01—1.63)
1.70 (1.61—1.80)
1.84 (1.72—1.96)
0.59 (0.56—0.62)
0.76 (0.59—0.96)
1.20 (1.12—1.29)
0.54 (0.51—0.58)
0.70 (0.55—0.89)
0.83 (0.78—0.89)
1.59 (1.49—1.70)
7.72 (7.30—8.16)
0.56 (0.49—0.64)
0.36 (0.33—0.40)
2.02 (1.89—2.15)
0.76 (0.75—0.78)
0.95 (0.95—0.96)
0.86 (0.85—0.87)
Adjusted OR
(95% CI)
Cardiac aetiology
Non-cardiac aetiology
1.13 (0.84—1.50)
1.62 (1.05—2.39)
1.81 (1.70—1.93)
1.39 (1.23—1.56)
1.81 (1.67—1.95)
1.76 (1.53—2.02)
0.55 (0.52—0.59)
0.72 (0.64—0.81)
0.63 (0.46—0.86)
1.17 (0.75—1.73)
1.00 (0.92—1.08)
1.27 (1.09—1.47)
0.55 (0.51—0.60)
0.57 (0.50—0.65)
0.63 (0.46—0.83)
0.92 (0.59—1.37)
1.00 (0.93—1.08)
0.79 (0.68—0.92)
8.27 (7.76—8.81)
5.10 (4.44—5.85)
0.51 (0.43—0.59)
0.66 (0.52—0.83)
0.34 (0.30—0.38)
0.44 (0.34—0.56)
2.27 (2.11—2.45)
1.45 (1.29—1.65)
0.72 (0.71—0.74)
0.84 (0.82—0.87)
0.95 (0.95—0.96)
0.95 (0.94—0.96)
0.85 (0.84—0.86)
0.86 (0.85—0.88)
Adjusted OR
(95% CI)
Paediatric (<20 y)
Adult (≧20) y)
2.60 (1.24—5.00)
1.42 (1.09—1.82)
1.87 (1.31—2.67)
1.59 (1.50—1.68)
2.58 (1.84—3.63)
1.93 (1.80—2.06)
0.53 (0.37—0.76)
0.63 (0.60—0.67)
1.39 (0.66—2.70)
0.90 (0.69—1.15)
1.38 (0.97—1.96)
1.22 (1.13—1.30)
0.39 (0.28—0.54)
0.52 (0.48—0.56)
1.01 (0.48—1.94)
0.74 (0.56—0.95)
0.73 (0.51—1.03)
0.82 (0.77—0.88)
1.39 (1.01—1.90)
1.45 (1.36—1.55)
4.79 (3.46—6.64)
10.11 (9.57—10.67)
0.54 (0.47—0.61)
0.36 (0.32—0.40)
2.00 (1.88—2.14)
0.95 (0.95—0.96)
0.87 (0.83—0.91)
0.86 (0.85—0.86)
0.1
1
10
Reduced odds of 1-month neurologically favourable survival
Increased odds of 1-month neurologically favourable survival


A
P for interaction between ventilation and compression = 0.052
The rate of 1-month neurologically favourable survival %
OR (95% CI) = 1.13 (1.06—1.20)
OR (95% CI) = 1.64 (1.56—1.72)
6.0
4.0
2.0
0.0
4.9%
1,638
33,326
3.4%
5,952
176,808
4.7%
4,305
92,308
2.8%
3,285
117,826
Present
Absent
Ventilation
Present
Absent
Compression
B
Component of BCPR
(Reference OR, 1:Component absent)
·Ventilation present
·Compression present
Adjusted OR
(95% CI)
1.19 (1.11—1.27)
1.60 (1.51—1.69)
Cardiac aetiology
(Reference OR, 1: Non-cardiac)
1.59 (1.49—1.70)
Shockable Initial rhythm
(Reference OR, 1: Non-shockable)
7.72 (7.32—8.16)
Tracheal intubation
(Reference OR, 1: Not performed)
0.56 (0.49—0.64)
Adrenalin administration
(Reference OR, 1: Not administered)
0.36 (0.33—0.40)
Newer guidelines
(Reference OR, 1: Older guidelines)
2.02 (1.89—2.15)
Family bystander
(Reference OR, 1: Others)
1.27 (1.21—1.34)
Age (per 10 y)
0.76 (0.75—0.78)
Time factors (per one min)
·Witness—Call
0.95 (0.95—0.96)
·Call—EMS arrival at patient
0.86 (0.85—0.87)
0.1
1
10
Reduced odds of 1-month neurologically favourable survival
Increased odds of 1-month neurologically favourable survival



70
60
50
40
30
20
10
0
% Incidence
61.0%
59.5%
55.3%
54.9%
51.5%
52.7%
52.9%
33.0%
36.2%
40.8%
42.6%
43.6%
44.3%
45.9%
2.6%
17.3%
19.1%
1.6%
20.4%
18.5%
1.0%
25.3%
18.4%
0.8%
29.7%
14.6%
0.5%
34.2%
13.8%
0.5%
34.9%
11.9%
0.5%
36.1%
10.5%
2005
2006
2007
2008
2009
2010
2011
No BCPR
Ventilation-only
Compression-only
Conventional
DA-CPR