Factors associated with quality of bystander CPR: The presence of multiple rescuers and bystander-initiated CPR without instruction

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Factors Associated with Quality of Bystander CPR: the Presence of Multiple Rescuers and Bystander-initiated CPR without Instruction

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ABSTRACT

Aims: To identify the factors associated with good-quality bystander cardiopulmonary resuscitation (BCPR).

Methods: Data were prospectively collected from 553 out-of-hospital cardiac arrests (OHCAs) managed with BCPR in the absence of emergency medical technicians (EMT) during 2012. The quality of BCPR was evaluated by EMTs at the scene and was assessed according to the standard recommendations for chest compressions, including proper hand positions, rates and depths.

Results: Good-quality BCPR was more frequently confirmed in OHCAs that occurred in the central/urban region (56.3% [251/446] vs. 39.3% [42/107], p=0.0015), had multiple rescuers (31.8% [142/446] vs. 11.2% [12/107], p<0.0001) and received bystander-initiated BCPR (22.0% [98/446] vs.5.6% [6/107], p<0.0001). Good-quality BCPR was less frequently performed by family members (46.9% [209/446] vs. 67.3% [72/107], p=0.0001), elderly bystanders (13.5% [60/446] vs. 28.0% [30/107], p=0.0005) and in at-home OHCAs (51.1% [228/446] vs. 72.9% [78/107], p<0.0001). BCPR duration was significantly longer in the good-quality group (median, 8 vs.6 min, p=0.0015). Multiple logistic regression analysis indicated that multiple rescuers (odds ratio=2.8, 95% CI: 1.5–5.6), bystander-initiated BCPR (2.7, 1.1–7.3), non-elderly bystanders (1.9, 1.1–3.2), occurrence in the central region (2.1, 1.3–3.3) and duration of BCPR (1.1, 1.0-1.1) were associated with good-quality BCPR. Moreover, good-quality BCPR was initiated earlier after recognition/witness of cardiac arrest compared with poor-quality BCPR (3 vs. 4 min, p=0.0052). The rate of neurologically favourable survival at one year was 2.7% and 0% in the good-quality and poor-quality groups, respectively (p=0.1357).

Conclusions: The presence of multiple rescuers and bystander-initiated CPR are predominantly associated with good-quality BCPR.

Key words: bystander CPR, out-of-hospital cardiac arrest, multiple rescuers, bystander initiative

1. INTRODUCTION

Survival rates after out-of-hospital cardiac arrest (OHCA) remain low [1]. The prognosis of OHCA prominently depends on initial bystander actions as described in the concept of 'chain-of-survival' [2]. Unfortunately, bystanders initiate cardiopulmonary resuscitation (CPR) on their own initiative in less than one-third OHCAs [3-5]. Dispatcher-assisted CPR (DA-CPR) may augment the incidence of bystander CPR (BCPR) [5,6]. However, the benefits of BCPR for survival rates after OHCA may be diminished by the poor quality of BCPR or chest compressions [7,8].

Reportedly, the quality of BCPR is influenced by the age of the bystander [9], DA-CPR [10] and the time passed since the most recent basic life support (BLS) training [10-11]. However, the relationship between the quality of BCPR and other backgrounds remains to be fully investigated in a population-based cohort study. This one-year prospective population-based cohort study aimed to disclose the independent factors associated with BCPR quality.

2. METHODS

Data were collected in accordance with the national guidelines of ethics for epidemiological surveys [12]. This study was approved by the review board of the Ishikawa Medical Control Council.

2.1. Populations and setting

The Ishikawa prefecture encompasses an area of 4,186 km^2 and has a resident population of 1,170,000 along with 11 fire departments. The prefecture is divided into four administrative regions, including one central/urban region and three semi-rural/rural regions. In total, 62% residents are located in the central/urban region, which has an area of 1,432 km^2. The population are older in the semi-rural/rural regions (30.5% vs. 21.6% aged over 65 years, respectively).

Since the beginning of 2004, DA-CPR has been conducted by all fire departments. All fire departments have a one-tiered ambulance dispatch system. Emergency medical technicians (EMTs) resuscitate the patients experiencing OHCAs according to the protocol developed by the Ishikawa Medical Control Council. This protocol is based on the guidelines of the American Heart Association and the Japan Resuscitation Council.

Paramedics are authorised to perform the following procedures during resuscitation: (1) use of supra-pharyngeal airways, (2) Ringer's lactate infusion and (3) use of semi-automated external defibrillators. Since July 2004, specially trained paramedics have been permitted to insert tracheal tubes under limited indication criteria, and since April 2006, they have been permitted to administer intravenous adrenaline. In all fire departments, each ambulance is usually boarded by three or more EMTs, including at least one paramedic. EMTs are not permitted to terminate resuscitation in the field. DA-CPR is actively conducted in all fire departments

2.2. Patient data

Base line data from all age groups of patients were prospectively collected by the fire departments in the Ishikawa prefecture for OHCAs from January to December 2012. The quality of chest compressions was evaluated by EMTs on arrival at the scene. EMT requested bystanders to continue their BCPR and made a subjective assessment based on their short observation following arrival at the scene. They classified BCPR into two categories "good" and "poor". Quality was judged to be "good" when the following criteria were satisfied: 1) appropriate hand positions or finger positions for infants, 2) compression rates of at least 100/min, 3) compression depths of at least 2-inches (5 cm) or at least one third of the anterior–posterior diameter of the chest. Because BCPR predominantly covers chest-compression alone in this prefecture, the quality of chest compressions was used as the primary measure of CPR quality (Figure 1).

The other OHCA data were collected according to the Utstein template [13,14] and included region, location, patient's age, patient's gender, witness status, aetiology of arrest (presumed cardiac or not), origin of BCPR (bystander-initiated

CPR without DA-CPR [or bystander CPR on their own initiative] and dispatch-assisted initiation of BCPR following the instruction), type of BCPR (chest compression only and conventional [chest compression combined with ventilation at a compression/ventilation ratio of 30:2]), bystanders' BLS training experience, initial cardiac rhythm, estimated time of collapse, time-points of initiation of CPR by bystanders and EMTs, time interval between emergency calls and arrival at the patient, sustained return of spontaneous circulation (SROSC), one-month (1-M) survival, one-year (1-Y) survival and 1-Y survival with neurologically favourable outcomes according to the Glasgow–Pittsburgh cerebral performance categories (CPC). Bystander BLS training experience was divided into the following two categories: (i) BLS training experience within the last three years with clear memory of the experience and (ii) Other BLS training experience mostly without clear memory or no experience. SROSC was defined as the continuous presence of palpable pulses for more than 20 min. Survival rates at 1-Y were defined as the patient being alive in a hospital at 1-Y, or as the patient being discharged alive from hospital to home or rehabilitation facilities within 1-Y. In addition, 1-Y survival with neurologically favourable outcomes was defined as CPC of one (good recovery) or two (moderate disability) in patients without any neurological disturbance before the arrest event and when the best CPC was equal to the pre-arrest category in patients with neurological disturbances. The primary end point was 1-Y survival with neurologically favourable outcomes. The secondary end-points were SROSC, 1-M survival, 1-Y survival. Patients who survived from OHCA were followed up by fire departments for up to 1 year in the hospital.

The time points of emergency call and EMT arrival at the scene was recorded in sec by dispatchers and EMTs, respectively [15]. Thus, response time (interval between emergency call and EMT arrival at the scene) was calculated in sec but expressed in min to first decimal place. The time points of arrest recognition/witness and BCPR initiation were estimated by the EMTs by interviewing bystanders, as previously described [16]. Bystanders' relationship to the OHCA patient, bystander's age and gender of bystanders, bystanders' BLS training experience and total number of rescuers were also identified by the EMTs by interviewing bystanders, as previously described [17]. The time of dispatch-assisted initiation of BCPR following DA-CPR was identified by dispatch records. The interview was generally performed during transportation and after arrival at the hospital.

2.3. Statistical analysis

Statistical analyses were performed using JMP ver.10 for Windows (SAS institute, Cary, NC). Univariate analyses included chi-squared tests with and without Pearson's correction and Fisher's exact probability tests. The Kruskal–Wallis test was used for non-parametric comparisons. Moreover, multiple logistic regression analyses were performed to identify the factors associated with good-quality BCPR. First, we applied the regression analyses for those factors that were significant by univariate analyses. Then, we added other factors that were not significant by univarate analysis in a stepwise manner way to obtain the best-fit model with the lowest BIC (Bayesian information criterion). Finally, we assessed the fitness of the best-fit model using R-squared measure of goodness-of-fit model. In all analyses, the differences and associations were considered significant when $p < 0.05$. Odds ratios (OR) and 95% confidential intervals (95% CI) are presented.

3. Results

Data selection (Fig 1)

Of the 1,131 OHCAs that occurred during the study period, only 73 were witnessed by EMTs, and BCPR was performed in 645 of the 1,058 non-EMT-witnessed OHCAs. The quality of BCPR and/or the backgrounds of bystanders were unknown in 92 of the 645 non-EMT-witnessed OHCAs managed with BCPR; however, complete data sets were obtained for the remaining 553 cases (children (<16y): 8cases, infant: 1 case). These data were divided into two groups

according to the quality of BCPR, which was assessed by EMTs at the scene.

Factors associated with good-quality BCPR (Table 1)

As presented in Table 1, good-quality BCPR was more frequently confirmed when OHCAs occurred in the central/urban region (56.3% [251/446] vs. 39.3% [42/107], $p = 0.0015$), had multiple rescuers (31.8% [142/446] vs. 11.2% [12/107], $p < 0.0001$) and received bystander-initiated CPR (22.0% [98/446] vs. 5.6% [6/107], $p < 0.0001$); Moreover, good-quality BCPR was less frequently performed by family members (46.9% [209/446] vs. 67.3% [72/107], $p = 0.0001$), elderly bystanders (13.5% [60/446] vs. 28.0% [30/107], $p = 0.0005$) and during at-home OHCAs (51.1% [228/446] vs. 72.9% [78/107], $p < 0.0001$); Furthermore, the incidence of conventional CPR was significantly higher in the good-quality BCPR group (15.5% [70/446] vs. 6.5% [7/107], $p = 0.0140$). The interval between BCPR initiation and EMT arrival at the scene was significantly longer in the good-quality group (median, 8 vs. 6 min, $p = 0.0015$). Multiple logistic regression analysis disclosed that multiple rescuers (OR = 2.785, 95% CI = 1.501–5.588), bystander-initiated CPR (OR = 2.666, 95% CI = 1.145–7.316), occurrence in the central/urban region (OR = 2.093, 95% C.I. = 1.323–3.347), non-elderly bystanders (OR = 1.859, 95% CI = 1.071–3.195) and duration time of BCPR (OR = 1.059, 95%CI = 1.004–1.124) were independent factors associated with good-quality BCPR.

Comparisons of BLS responses (Table 2)

The time factors for BLS response were compared between the two categories of BCPR quality (Table 2). The time between arrest recognition/witness and emergency calls did not differ significantly between the two groups ($p = 0.6699$); However, the interval between arrest recognition/witness and the initiation of BCPR was significantly shorter in the good-quality BCPR group than in the poor-quality group (median, 3 vs. 4 min, $p = 0.0052$).

At-home OHCAs (Table 3)

Occurrence of OHCAs at home was not independently associated with poor-quality BCPR, although it was a significant factor in univariate analyses. As indicated in Table 3, incidences of non-elderly bystanders (73.9% [226/306]) and multiple rescuers (21.6% [66/306]) were low for at-home OHCAs and were significantly lower than those for out-of-home OHCAs, with non-elderly bystanders in 96.0% (237/247) cases and multiple rescuers present in 35.6% (88/247) cases. Notably, very few bystanders (6.2% [9/306]) initiated BCPR on their own initiative during at-home.

In logistic regression analyses of the at-home OHCA subgroup (Table 3), bystander-initiated CPR (OR = 5.784, 95% CI = 1.140–105.540) and multiple rescuers (OR = 2.272, 95% CI = 1.097–5.195) were significantly associated with good-quality BCPR.

Effects of BCPR quality on outcomes (Fig. 2)

As presented in Fig. 2, the overall rate of 1-Y survival with neurologically favourable outcomes (CPC = 1 or 2) was 2.7% (12/446) and 0% (0/107) in the good- and poor-quality groups, respectively; however, this rate did not significantly differ between both groups ($p = 0.1357$; Fisher's exact probability tests). These observations were the same in analyses of the 231 OHCAs with presumed cardiac aetiology.

4. DISCUSSION

In the present study, the presence of multiple rescuers, bystander-initiated CPR, the presence of non-elderly bystanders, residence in the central/urban region and duration of BCPR were independent factors associated with good-quality BCPR. It is expected that the multiple rescuers/bystanders who are more confident in performing CPR will initiate the high-quality procedure; however, this assumption has not yet been confirmed in population-based studies. To our knowledge, this is the first population-based cohort study to reveal that the presence of multiple rescuers and bystander-initiated CPR were independently associated with BCPR quality.

In our previous study [17], the presence of multiple rescuers was associated with improved 1-Y survival after

OHCAs; similarly, in the present study, the presence of multiple rescuers was independently associated with good-quality BCPR. Presumably, the presence of multiple bystanders increases the chances of bystander initiative from individuals who are able to provide good-quality CPR.

Two simulation studies reported that previously untrained bystanders receiving DA-CPR are able to perform CPR with a quality comparable to that of formally trained individuals [10,18]; However, another study reported that CPR quality was very poor among elderly females [9]. In agreement with the present study, bystander-initiated CPR without instruction was reported to produce a higher incidence of good-quality of BCPR than DA-CPR [10]. Previous simulation studies reported that the time passed since the most recent BLS training affects CPR quality [19,20]; However, the present analyses revealed no association between BCPR quality and the duration of BLS training of bystanders within the last three years. In reality, bystander initiative may be more predictive of CPR quality than the time passed since BLS training because even trained bystanders suffer physical and emotional stress during OHCAs [21-23].

The present study concluded that high-quality BCPR was more frequently performed in central/urban regions. However, previous studies from other countries suggest that regional variation in the quality of EMS systems, including differences in OHCA outcomes and bystander characteristics may differ among countries [24-26]. One of those studies reported the findings exactly the opposite of what we reported in the present study [24]. The reasons for this difference are unclear.

The duration of BCPR was included in the factors analysed for the quality of BCPR because prolonged BCPR was reported to induce bystanders' fatigue [27,28]. This study showed that shorter duration of BCPR was associated with poor-quality BCPR. This observation suggests that poor-quality BCPR is primarily caused by immature skill but not by bystanders' fatigue. In addition, we found that poor-quality BCPR was initiated by bystanders later than good-quality BCPR. Usually, DA-CPR is initiated a few minutes after making emergency calls [29]. Because poor-quality BCPR is significantly associated with DA-CPR, it is likely that the delayed initiation of poor-quality BCPR following DA-CPR may be a main reason why duration of BCPR was shorter in the poor-quality group. Dispatchers should make every effort to improve the quality of BCPR by keeping the line to bystanders' mobile or cordless phone (desirably activated with speaker function) and encouraging bystanders until the EMT arrival at the scene.

Previous studies have confirmed the association between good-quality BCPR and better OHCA outcomes [7,8]. In this study, poor-quality BCPR produced no survivors with neurologically favourable outcomes after a year, although no significant differences in survival rates were identified between both groups.

A majority of OHCAs occur at home [16,30] and are witnessed by single and elderly family members. The present data indicates that multiple rescuers and non-elderly bystanders are strongly associated with good-quality BCPR, but these were rarely present for at-home OHCAs. Very few bystanders (6.2%) in at-home OHCAs initiated BCPR on their own initiative. The high incidence of low-quality BCPR during at-home OHCAs may reflect the absence of independent factors associated with good-quality BCPR. In fact, multiple logistic regression analysis of at-home OHCAs revealed that only two factors, i.e. the presence of multiple rescuers and bystander-initiated BCPR without instruction are independently associated with good-quality BCPR for at-home OHCAs. These results warrant the implementation of strategies that improve CPR quality for at-home OHCAs. In particular, the shortening of response time [15] and recruitment of well-trained, highly motivated rescuers to scenes of at-home OHCAs [31-33] may be necessary.

Limitations

BCPR quality was evaluated only after EMT arrival at the scene but not during the time between bystander initiation of CPR and EMT arrival. Only the quality of chest compressions was evaluated in conventional BCPR (ventilation + chest compressions). Moreover, EMTs did not determine interruptions of chest compressions by ventilation because upon arrival at the scene, they usually request that bystanders continue providing chest compressions only. Further,

bystanders' background was not evaluated in all cases. Records of BLS training histories of bystanders were poor and may have influenced BCPR quality. In fact, it was difficult for EMTs to accurately determine the number of years since the most recent BLS training. Therefore, it was assumed that most bystanders had little memory of their training, and bystanders were categorised according to their memory of BLS training experience within the last three years. The time of arrest recognition/witness and time of BCPR initiation were estimated by interview. Although the EMTs made every effort to obtain precise information during transportation and after arriving at the hospital, both under- and overestimation of interval may have occurred. Apparently, size of the study population was not large enough to detect a difference in survival with neurologically favourable outcome. Further investigations are necessary to elucidate the relationship between BCPR quality and OHCA outcomes.

5. CONCLUSION

The presence of multiple rescuers, bystander initiative and non-elderly bystanders are associated with good-quality BCPR. However, further investigations are necessary to elucidate the relationship between BCPR quality and OHCA outcomes.

6. CONFLICTS OF INTEREST STATEMENT

The authors have no conflicts of interest to disclose.

7. ACKNOWLEDGEMENTS

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9. FIGURE LEGENDS

Fig 1. Summary of cohort with data selection

OHCAs out-of-hospital cardiac arrests, EMT emergency medical technician, BCPR bystander cardiopulmonary resuscitation

Children was defined as an age group of less than 16 years and infant less than one year..

Fig 2. Effects of good-quality BCPR on OHCA outcomes

OHCAs out-of-hospital cardiac arrests, BCPR bystander cardiopulmonary resuscitation, M month, Y year.

Cleaned database for all OHCAs transported to hospital in 2012
N = 1,131

OHCAs after EMT arrival at patients
EMT-witnessed OHCAs
N = 73

EMT-unwitnessed OHCA transported to hospitals
N = 1,058

No bystander CPR
N = 413

EMT-unwitnessed OHCA transported to hospitals Bystander CPR
N = 645 [children: 8, infant: 1]

Incomplete information
on bystander
N = 24

EMT-unwitnessed OHCA transported to hospitals
having bystander CPR and information about bystander
N = 621 [children: 8, infant: 1]
(chest compression-only = 537, 86.5%)

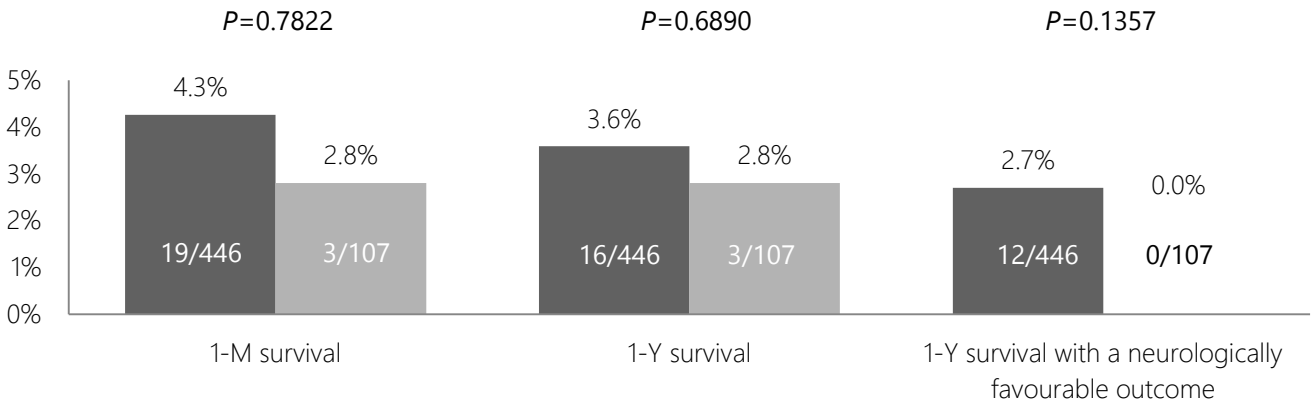
Unknown quality of bystander CPR
N = 68

EMT-unwitnessed OHCA transported to hospitals
having bystander CPR and complete dataset for analysis
N = 553 [children: 8, infant: 1]
(chest compression-only = 476, 86.1%)

Good-quality bystander CPR
N = 446 [children: 8, infant: 1] (80.7%)
（chest compression-only = 376, 84.3%)

Poor-quality bystander CPR
N = 107 [children: 0, infant: 0] (19.3%)
（chest compression-only = 100, 93.5%)

All OHCAs receiving BCPR



Of presumed cardiac aetiology

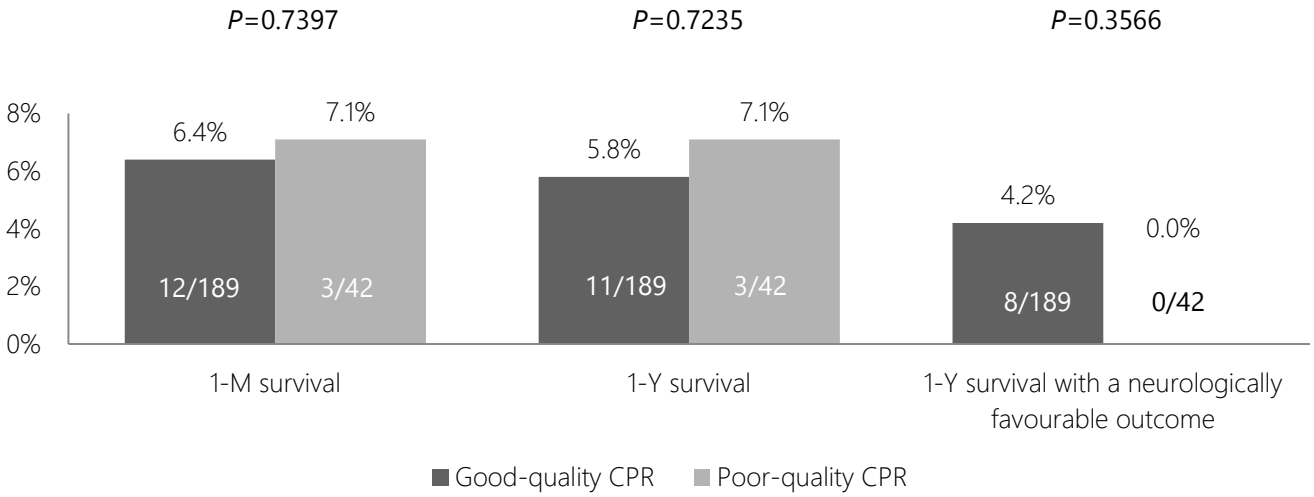


Table 1. Characteristics, background and factors associated with good-quality BCPR

Characteristics	BCPR quality		*p*-value	Odds ratio (95% CI) by multiple logistic regression analysis [a)]
	Good (*n* = 446)	Poor (*n* = 107)		
Region - Central/urban (%)	251 (56.3%)	42 (39.3%)	0.0015	**2.093 (1.323-3.347)**
Location - Home (%)	228 (51.1%)	78 (72.9%)	<0.0001	0.746 (0.342-1.658)
Patient's gender - Male (%)	239 (53.6%)	60 (56.1%)	0.6426	Excluded
Patient's age, y, median (25%–75%)	81 (70–88)	80 (70–88)	0.8906	Excluded
Aetiology - Presumed cardiac origin (%)	189 (42.4%)	42 (39.3%)	0.6329	Excluded
Arrest - Witnessed (%)	159 (35.7%)	37 (34.6%)	0.8350	Excluded
Bystander's gender - Male (%)	188 (42.2%)	39 (36.4%)	0.2790	Excluded
Bystander's age - Elderly (>65 years) (%)	60 (13.5%)	30 (28.0%)	0.0005	**0.538 (0.313-0.934)**
BLS experience of bystanders - Within the last three years, remaining in their memory (%)	63 (14.1%)	8 (7.5%)	0.0648	Excluded
Number of rescuers (bystanders) - Multiple rescuers (%)	142 (31.8%)	12 (11.2%)	<0.0001	**2.785 (1.501-5.588)**
BCPR performer - Family members (%)	209 (46.9%)	72 (67.3%)	0.0001	0.863 (0.399-1.820)
Initiation of BCPR - On bystander's own initiative (%)	98 (22.0%)	6 (5.6%)	<0.0001	**2.666 (1.145-7.316)**
Type of BCPR - Conventional CPR (%)	70 (15.7%)	7 (6.5%)	0.0140	1.302 (0.575-3.348)
Duration of BCPR (Interval between BCPR initiation and EMT arrival at the scene; min), median (25%–75%)	8 (6–11)	6 (5–9)	0.0015	**1.059 (1.004-1.124)**
Response time [b)] (Interval between emergency call and EMT arrival at the scene; min), median (25%–75%)	6.7 (5.1–8.1)	7.1 (5.4–9.6)	0.0540	Excluded

BCPR, bystander cardiopulmonary resuscitation; BLS, basic life support; EMT, emergency medical technician

a) First, we applied the regression analyses for those factors that were significant by univariate analyses. Then, we added other factors that were not significant by univarate analysis in a stepwise manner way to obtain the best-fit model with the lowest BIC (Bayesian information criterion). Generalized R-square of this final model was 0.1643.
b) Response time was calculated in sec but expressed in min to first decimal place.

Table 2. Relationship between BCPR quality and early emergency calls or early BCPR

	BCPR quality		*p*-value
	Good (n = 446)	Poor (n = 107)	
Early emergency call (Interval between recognition/collapse and call; min), median (25%–75%)	3 (1-6)	3 (1-6)	0.6699
Early BCPR (Interval between recognition/collapse and BCPR initiation; min), median (25%–75%)	3 (1–5)	4 (2–7)	0.0052

BCPR, bystander cardiopulmonary resuscitation

Table 3. Characteristics, background and factors associated with good-quality BCPR for at-home OHCAs

Characteristics	BCPR quality		*p*-value	Odds ratio (95% CI) by multiple logistic regression analysis [a)]
	Good (*n* = 228)	Poor (*n* = 78)		
Region - Central/urban (%)	125 (54.8%)	35 (44.9%)	0.1288	Excluded
Patient's gender - Male (%)	130 (57.0%)	49 (62.8%)	0.3674	Excluded
Patient's age, y, median (25%–75%)	80 (70–87)	79 (67–82)	0.1286	Excluded
Aetiology - Presumed cardiac origin (%)	109 (47.8%)	30 (38.5%)	0.1942	Excluded
Arrest - Witnessed (%)	70 (30.7%)	25 (32.1%)	0.8244	Excluded
Bystander's gender - Male (%)	92 (40.4%)	30 (38.5%)	0.7683	Excluded
Bystander's age - Elderly (>65 years) (%)	53 (23.2%)	27 (34.6%)	0.0459	0.619 (0.350-1.107)
BLS experience of bystanders - Within the last three years, remaining in their memory (%)	19 (8.3%)	3 (3.8%)	0.1592	Excluded
Number of rescuers (bystanders) - Multiple rescuers (%)	57 (25.0%)	9 (11.5%)	0.0126	**2.272 (1.097-5.195)**
BCPR performer - Family members (%)	195 (85.5%)	70 (89.7%)	0.3333	Excluded
Initiation of BCPR - On bystander's own initiative (%)	18 (7.9%)	1 (1.3%)	0.0367	**5.784 (1.140-105.540)**
Type of BCPR - Conventional CPR (%)	16 (7.0%)	3 (3.8%)	0.4209	Excluded
Duration of BCPR (Interval between BCPR initiation and EMT arrival at the scene; min), median (25%–75%)	7 (6-10)	7 (5-8)	0.0369	1.069 (0.995-1.156)
Response time [b)] (Interval between emergency call and EMT arrival at the scene; min), median (25%–75%)	7.2 (5.4–9.7)	6.7 (5.3–7.9)	0.0781	Excluded

BCPR, bystander cardiopulmonary resuscitation; BLS, basic life support; EMT, emergency medical technician

a) First, we applied the regression analyses for those factors that were significant by univariate analyses. Then, we added other factors that were not significant by univarate analysis in a stepwise manner way to obtain the best-fit model with

the lowest BIC (Bayesian information criterion). For this table, no improvement of BIC was achieved. Generalized R-square of this final model was 0.0751.

b) Response time was calculated in sec but expressed in min to first decimal place.