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# Chest compression-only cardiopulmonary resuscitation performed by lay rescuers for adult out-of-hospital cardiac arrest due to non-cardiac aetiologies☆

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ABSTRACT

*Objective:* Bystander CPR improves survival in patients with out-of-hospital cardiac arrest (OHCA). For adult sudden collapse, bystander chest compression-only CPR (COCPR) is recommended in some circumstances by the American Heart Association and European Resuscitation Council. However, adults who arrest from non-cardiac causes may also receive COCPR. Because rescue breathing may be more important for individuals suffering OHCA secondary to non-cardiac causes, COCPR is not recommended for these cases. We evaluated the relationship of lay rescuer COCPR and survival after OHCA from non-cardiac causes.

*Methods:* Analysis of a statewide Utstein-style registry of adult OHCA, during a large scale campaign endorsing COCPR for OHCA from presumed cardiac cause. The relationship between lay rescuer CPR (both conventional CPR and COCPR) and survival to hospital discharge was evaluated.

*Results:* Presumed non-cardiac aetiologies of OHCA accounted for 15% of all cases, and lay rescuer CPR was provided in 29% of these cases. Survival to hospital discharge occurred in 3.8% after conventional CPR, 2.7% after COCPR, and 4.0% after no CPR ($p = 0.85$). The proportion of patients receiving COCPR was much lower in the cohort of OHCA from respiratory causes (8.3%) than for those with presumed cardiac OHCA (18.0%; $p < 0.001$).

*Conclusions:* In the setting of a campaign endorsing lay rescuer COCPR for cardiac OHCA, bystanders were less likely to perform COCPR on OHCA victims who might benefit from rescue breathing.

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## 1. Introduction

### 1.1. Background and Importance

Cardiac arrest is a major public health problem across the world and is responsible for approximately 300,000 deaths per year in the US alone.[1–4] Bystander CPR improves survival after out-of-hospital cardiac arrest (OHCA),[5–7] but is generally provided in less than 30–50% of cases.[6–8]

Chest compression-only CPR (COCPR) by lay bystanders has been recommended by both the American Heart Association (AHA) and European Resuscitation Council (ERC), in part to increase bystander CPR rates.[5,9] Because COCPR may provide similar survival rates as conventional CPR, the AHA guidelines encourage lay bystanders to provide chest compressions through either COCPR or conventional CPR for presumed cardiac arrests.[5] In contrast, the ERC guidelines state that COCPR may be sufficient in the first few minutes after cardiac arrest, but the ERC only recommends COCPR for bystanders who are unwilling or unable to provide rescue breaths or when instructed during an emergency call.[9,10] Importantly, AHA and ERC guidelines both state that rescue breathing is an important component of successful resuscitation for OHCA from a non-cardiac cause (e.g., drowning or other primary respiratory problems).[5,9,10]

### 1.2. Goals of this investigation

Since 2004, the state of Arizona has recommended bystander COCPR for adults with a sudden collapse cardiac arrest, but has

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recommended the addition of rescue breathing for children and adults with drowning or other primary respiratory arrests. In this study, we evaluated whether lay rescuers were able to follow recommendations for the use of conventional CPR for non-cardiac aetiology OHCAs. Furthermore, we examined the clinical characteristics and survival rates of victims with OHCA due to presumed *non-cardiac* aetiologies for whom COCPR or conventional CPR were provided.

## 2. Methods

### 2.1. Study design

This was a prospective, observational cohort analysis of OHCAs in Arizona between October 2004, and September 2010. The study population included all adults (age ≥ 18 years) with OHCA. Exclusions were paediatric patients, EMS-witnessed arrests, bystander CPR provided by medical professionals and cases missing either survival or type of bystander CPR data. The arrest was presumed to be of cardiac origin unless it was known to be caused by trauma, respiratory (i.e., asphyxia or drowning) or other causes (drug overdose, suicide, thrombotic stroke, subarachnoid hemorrhage).[11] Patients with obvious evidence of death or Do-Not-Resuscitate orders were also excluded.

### 2.2. Setting and selection of participants

Arizona has approximately 6.6 million residents and is comprised of 15 counties with demographics varying from urban to wilderness areas.[12] In 2005, there were 30 Emergency Medical Services (EMS) agencies statewide participating in the state-sponsored OHCA quality improvement (QI) program: the Save Hearts in Arizona Registry and Education (SHARE) Program.[13,14] Participation increased each year of the program and by 2010, 104 EMS agencies (serving approximately 80% of the population) reported their OHCA data to the SHARE Program. During the time period of this study, Arizona did not have a structured 911 dispatcher-assisted CPR program.

The Arizona Department of Health Services Human Subjects Review Board and The University of Arizona Institutional Review Board have approved the SHARE program and the publication of de-identified data in this report.

### 2.3. Method of measurement

Data were collected prospectively and entered into an Utstein-style database.[11,15] Data elements include: sex, age, location of arrest, if arrest was bystander-witnessed, presumed aetiology of arrest, EMS dispatch-to-scene arrival ("response") interval, initial prehospital electrocardiographic (EKG) rhythm, whether bystander CPR was being provided upon paramedic arrival, type of bystander CPR (COCPR versus conventional), type of EMS resuscitation protocol used (minimally interrupted cardiac resuscitation [MICR],[16] versus conventional BLS/ACLS), cerebral performance category score (CPC), and survival-to-hospital discharge. CPC scores were assigned based upon neurologic status at hospital discharge and are as follows: (1) good cerebral performance, (2) moderate cerebral disability, (3) severe cerebral disability, (4) coma or vegetative state, and (5) death. The detailed methodology of data collection and database management for the SHARE registry has been published elsewhere.[14]

Because a core question of this effort is related to the type of CPR provided, EMS providers received special training, including a documentation aid on how to code bystander CPR.[17] This training included instruction in documenting the person performing CPR as well as the type of CPR performed by bystanders. For this analysis, because we were specifically interested in "true" lay rescuer CPR, we excluded cases that had CPR performed by bystanders with formal medical training (whether on or off duty) and arrests occurring at medical facilities. However, to assess the possibility of ascertainment bias, we compared the proportion of COCPR versus conventional CPR over time in both lay rescuers and bystanders with formal medical training.

### 2.4. Interventions

The SHARE Program initiated a multifaceted, statewide public COCPR education campaign in 2005. The effort included multiple approaches to training and information dissemination that has been described previously.[17] We estimate that at least 40,000 people have been directly trained in the COCPR technique and that more than 550,000 were exposed to at least one COCPR media forum.

In March of 2008, the American Heart Association (AHA) released an advisory statement supporting Hands-Only CPR[18] which was widely publicized in Arizona as an additional aspect of the ongoing effort.

### 2.5. Outcome measures

The primary outcomes measured were survival to hospital discharge and the frequency and type of lay rescuer CPR provided for OHCA with a non-cardiac aetiology. Survival outcomes were obtained through hospitals and the Office of Vital Statistics at the Arizona Department of Health Services. Addressing the association between survival and CPR type in both cardiac and non-cardiac arrest aetiologies was established a priori because this was a key part of the safety analysis for this public health intervention. An important predetermined sub-group for additional analyses was the population of adults with a witnessed collapse.

### 2.6. Primary data analysis

Proportions were calculated for categorical data while mean and standard deviation (SD), or median and interquartile range (IQR), as appropriate, were calculated for continuous data. Statistical significance for categorical data was assessed using Fisher's exact test. Statistical significance was set a priori at $\alpha \leq 0.05$ (two-tailed). All statistical analyses were performed using Stata v.11.1 (StataCorp™, College Station, TX).

## 3. Results

During the study period, 7652 adult OHCAs not witnessed by EMS were entered into the Utstein style database (Fig. 1). After removing all arrests with bystander CPR by medical professionals and those occurring in medical facilities, the remaining population of all adult arrests unwitnessed by EMS was 6460. After removal of 345 (5.3%) subjects missing key endpoint data and 322 arrests due to trauma, the final study populations for cardiac and non-cardiac OHCAs were 4913 and 880, respectively (Fig. 1).

The demographics of OHCA victims are shown in Table 1. Patients with cardiac aetiologies of arrest were older than those with non-cardiac aetiologies at (65.1 ± 15.3 years versus 50.5 ± 19.5 years, $p < 0.001$). Patients with cardiac causes were more likely to present with witnessed arrests and shockable rhythms than patients with non-cardiac causes ($p < 0.001$) (Table 1). Patients with cardiac causes were also more likely to receive bystander CPR (32.8%) than those with non-cardiac causes (29.1%), $p < 0.05$. Patients with non-cardiac causes were less likely to arrest in public (10.3%) versus those with cardiac causes (18.2%), $p < 0.001$.

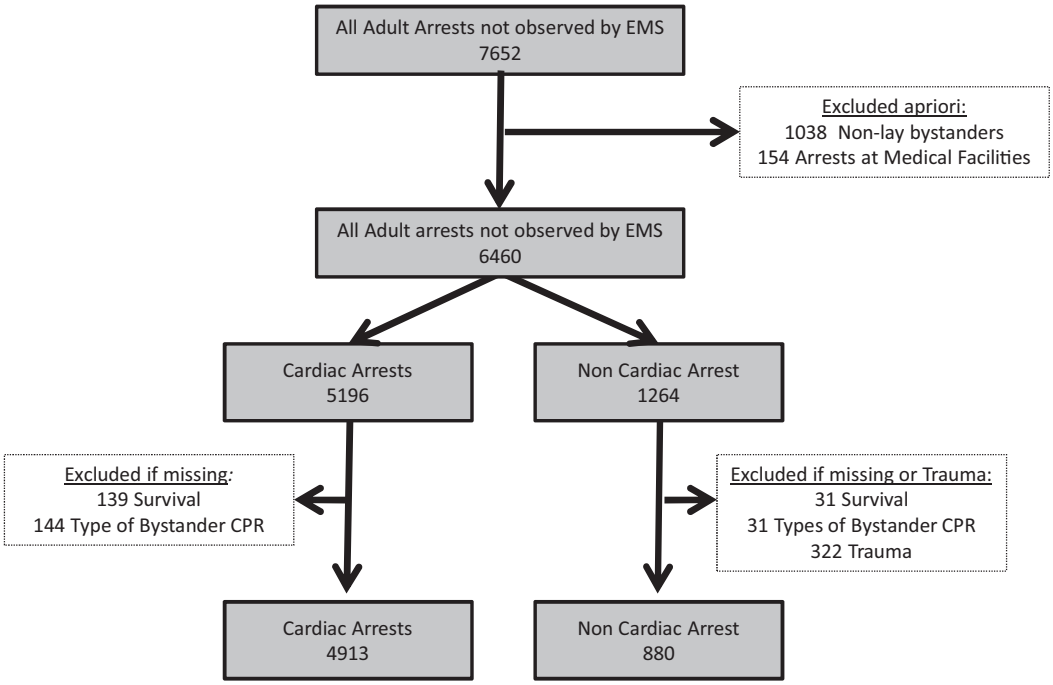


**Fig. 1.** Out-of-hospital arrest cases.

**Table 1**
Patient demographics and clinical characteristics.

| | Presumed cardiac cause (total population = 4913) | | | Presumed non-cardiac cause (total population = 880) | | | *p*-Values |
|---|---|---|---|---|---|---|---|
| | Frequency (%) | 95% CI | Number missing | Frequency (%) | 95% CI | Number missing | |
| Age (mean ± SD) | 65.1 ± 15.3 | 64.7–65.6 | – | 50.5 ± 19.5 | 49.2–51.8 | – | <0.001 |
| Male | 3259/4913 (66.3) | 65.0–67.7 | – | 337/543 (61.7) | 58.5–64.9 | – | 0.009 |
| Median response interval (IQR)[a] | 5 (4, 7) | 5.8–6.0 | 82 | 5 (4, 7) | 5.6–6.0 | 14 | 0.073 |
| Witnessed arrest | 2179/4899 (44.5) | 43.1–45.9 | 14 | 252/879 (28.7) | 25.7–31.7 | 1 | <0.001 |
| Shockable rhythm (VF/VT) | 1577/4891 (32.2) | 30.9–33.6 | 22 | 37/880 (4.2) | 2.9–5.5 | – | <0.001 |
| Bystander CPR | 1609/4913 (32.8) | 31.4–34.1 | – | 256/880 (29.1) | 26.1–32.1 | – | 0.034 |
| Arrest in public | 894/4912 (18.2) | 17.1–19.3 | 1 | 91/880 (10.3) | 8.3–12.4 | – | <0.001 |
| MICR performed by EMS | 1880/4913 (38.3) | 36.9–39.6 | – | 127/880 (14.4) | 12.1–16.8 | – | <0.001 |
| Survival to hospital discharge | 346/4913 (7.0) | 6.3–7.8 | – | 33/880 (3.8) | 2.5–5.0 | – | <0.001 |

[a] Response interval is the time elapsed from EMS dispatch until arrival at the scene. CI refers to 95% confidence interval; IQR, inter-quartile range; SD, standard deviation; CPR, cardiopulmonary resuscitation; MICR, minimally interrupted cardiac resuscitation provided by EMS; VF, ventricular fibrillation; VT, ventricular tachycardia; COCPR, compression-only CPR.

Overall survival to hospital discharge was lower among patients with non-cardiac causes versus patients with cardiac causes [(3.8% versus 7.0%, respectively, $p < 0.001$) (Table 1)]. Overall survival to hospital discharge did not vary by whether they received bystander CPR or not, or, by CPR type (no CPR, 4.0%; conventional, 3.8%; COCPR, 2.7%; $p = 0.85$; Table 2). There were no differences in survival per bystander CPR types (none, COCPR, or conventional) between witnessed or non-witnessed cardiac arrests (Table 2).

Survival to discharge for presumed non-cardiac aetiology arrests did not differ significantly across non-cardiac categories [respiratory: 10/193, 5.2%, 95% confidence interval (CI): 2.0–8.3; other causes: 23/687, 3.4%, CI: 2.0–4.7; ($p = 0.28$)].

Table 3 shows the variations of CPR performance and type by the specific categories of cardiac, respiratory and other causes of arrest. The rate of COCPR for OHCA from the respiratory category was (8.3%) compared with OHCA from presumed cardiac causes (18.0%) and other causes (19.5%), $p < 0.001$. Conventional CPR was provided more often for the respiratory category compared to the other aetiologies (Table 3).

Among witnessed arrests, the rate of COCPR was 7.0% (6/86, CI: 1.5–12.5) for the respiratory cause group versus 20.4% (444/2179,

**Table 2**
Survival to hospital discharge after OHCA[a] of non-cardiac aetiologies by bystander CPR type.

| | Frequency | Percent | 95% CI | *p*-Values |
|---|---|---|---|---|
| All non-cardiac arrests | | | | |
| No bystander CPR | 25/624 | 4.0 | 2.5–5.5 | |
| Conventional CPR | 4/106 | 3.8 | 0.1–7.5 | 0.847 |
| COCPR[b] | 4/146 | 2.7 | 0.1–5.3 | |
| Witnessed arrests | | | | |
| No bystander CPR | 11/190 | 5.8 | 2.4–9.1 | |
| Conventional CPR | 4/29 | 13.8 | 0.4–27.1 | 0.199 |
| COCPR | 1/33 | 6.3 | −3.1 to 9.2 | |
| Non-witnessed arrests | | | | |
| No bystander CPR | 14/433 | 3.2 | 1.6–4.9 | |
| Conventional CPR | 0/77 | 0.0 | 0 | 0.322 |
| COCPR | 3/117 | 2.6 | −3.4 to 5.5 | |

[a] OHCA refers to out-of-hospital cardiac arrest.
[b] COCPR refers to Compression-only CPR.

**Table 3**
Bystander CPR performance for OHCA[a] of cardiac, respiratory and other causes. Respiratory refers to specifically respiratory arrest (i.e., asphyxia or drowning); other causes refers to drug overdose, suicide, thrombotic stroke, or subarachnoid hemorrhage.

| | Frequency | Percent | 95% CI | *p*-Values |
|---|---|---|---|---|
| Cardiac arrests | | | | |
| No bystander CPR | 3304/4913 | 67.3 | 66.0–68.6 | |
| Conventional CPR | 724/4913 | 14.7 | 13.7–15.7 | |
| COCPR[b] | 885/4913 | 18.0 | 16.9–19.1 | |
| Respiratory arrests | | | | |
| No bystander CPR | 147/193 | 76.2 | 70.1–82.2 | |
| Conventional CPR | 30/193 | 15.5 | 10.4–20.7 | $p < 0.001$ |
| COCPR | 16/193 | 8.3 | 4.4–12.2 | |
| Other causes | | | | |
| No bystander CPR | 477/687 | 69.4 | 66.0–72.9 | |
| Conventional CPR | 76/687 | 11.1 | 8.7–13.4 | |
| COCPR | 134/687 | 19.5 | 16.5–22.5 | |

[a] OHCA refers to out-of-hospital cardiac arrest.
[b] COCPR refers to Compression-only CPR.

CI: 18.7–22.1) for the cardiac group and 16.3% (27/166, CI: 10.6–21.9) for other causes ($p < 0.001$).

Neurological outcomes were obtained for 99.5% (876/880) of non-cardiac cases and 97.8% (4807/4913) of cardiac aetiologies of OHCA. CPC scores of 1 or 2 at hospital discharge was obtained in 1.5% (13/876, CI: 0.7–2.3) of patients with non-cardiac causes versus 4.1% (197/4807, CI: 3.5–4.7) for cardiac causes of OHCA ($p < 0.001$). Neurologically intact survival (CPC 1 or 2) did not vary by whether they received conventional CPR or COCPR [conventional: 2/106, 1.9%, CI: −0.7 to 4.5; COCPR: 1/148, 0.7%, CI: −0.7 to 2.0; $p = 0.668$].

To evaluate for ascertainment bias, we compared the type of bystander CPR provided by off duty medical professionals with that provided by lay rescuers in non-cardiac arrests. In the off duty medical professional group, the total number of non-cardiac arrests was 223 with COCPR provided in 4.0% (9/223) of cases versus 16.7% COCPR in the lay rescuer group (Table 3). Further, there were no differences in the type of bystander CPR provided by medical professionals based on the presumed aetiology of OHCA ($p = 0.257$).

## 4. Discussion

We recently reported improvement in survival following adult sudden cardiac arrest in Arizona from the statewide bystander COCPR campaign.[17] However, one of the potential concerns is the possible detrimental effect on victims whose arrests were due to causes other than cardiac, especially respiratory arrests.[9,19,20] In this six year statewide study, 40 of the 1202 (3.8%) adults with OHCA from non-cardiac causes survived to hospital discharge, compared with 346 of the 4913 (7%) adults with OHCAs from cardiac causes. Consistent with the intent of the formal statewide bystander CPR educational program, bystanders were substantially less likely to provide COCPR for OHCAs from a respiratory cause (8.3%) compared with a cardiac cause (18%).

In our present study, 15% of the eligible 5793 adult OHCAs were attributed to non-cardiac aetiologies compared with 10–45% in other investigations.[19,21–25] Our 3.3% survival-to-hospital discharge rate was similar to the 2–11% in other investigations.[19,22–25] As noted above, this 3.8% survival rate is substantially lower than the 7% survival rate among the much larger group of patients with OHCA from a cardiac cause (Table 1). Importantly, the total number of survivors from OHCA from non-cardiac causes was an order of magnitude lower than the total number from cardiac causes (33 versus 346).

There is a paucity of data evaluating the effect of the type of bystander CPR on survival among adult OHCAs from non-cardiac causes. Rea et al. in a study of dispatch initiated bystander CPR demonstrated a rate of non-cardiac OHCA survival of 5.0% with instructions to perform COCPR as compared to 7.2% with instructions to perform conventional CPR ($p = 0.29$).[26] However, this study was limited due to the use of dispatch assisted CPR and may not readily apply to lay responders who may have training in CPR. Recent data from an observational study by Kitamura et al. in Japan demonstrated a small improvement in 30-day survival (7.2% versus 6.3%) and neurologically-intact survival (1.8% versus 1.5%) with conventional bystander CPR versus bystander COCPR for adults with a witnessed OHCA from a non-cardiac cause.[19] However, a key difference between our study and the Japanese study is that COCPR in Arizona was endorsed and taught to the public specifically for OHCA from a cardiac cause whereas the COCPR in Japan was provided by bystanders (20.5%) despite no endorsement or teaching.[19] Unfortunately, none of these studies was able to address the quality of CPR by bystanders before trained rescuers arrived.

Our study may have been underpowered to demonstrate a difference in outcome. In the Kitamura study, they evaluated 43,246 bystander-witnessed OHCAs of non-cardiac cause.[19] Nevertheless, the authors noted that the apparent benefit of conventional bystander CPR for their large population translated into a number needed to treat of 290 patients with conventional bystander CPR versus COCPR to save one life with favorable neurological outcome. Those authors concluded that the incremental benefit of rescue breathing for OHCAs of non-cardiac cause was small. In light of the substantial benefits of lay rescuer COCPR for OHCA of cardiac cause and the potentially small benefit of conventional CPR for OHCA of non-cardiac cause, Kitamura et al. recommended COCPR training for most people.[19] Our data support their recommendation.

Another potential effect of specific, intentional COCPR endorsement is that it provides the lay public with information to encourage the use of COCPR in the population for whom it was intended. This may decrease the likelihood that COCPR will be used in presumed non-cardiac arrests. Some have assumed that it is difficult for lay rescuers to accurately identify the arrest aetiology.[27] However, in our study, when the lay public was taught and encouraged to provide COCPR *for adults who suddenly collapse*, the rate of COCPR in the presumed cardiac aetiology cohort was 18.0% compared to only 8.3% in OHCA from respiratory causes (Table 3) ($p < 0.001$). Furthermore, when the sub-groups with witnessed arrests were compared, this apparent ability to discriminate between arrest types was even more pronounced (COCPR for witnessed OHCA from cardiac cause was 20.4% versus 7.0% for a witnessed OHCA from respiratory cause, $p < 0.001$). This is not surprising since a witnessed arrest would presumably be in the setting in which a lay rescuer would be most likely to identify a distinction (sudden collapse and presence of agonal breaths versus drowning or other respiratory causes). Thus, training the general public

to perform COCPR may help bystanders to accurately choose to perform conventional CPR versus COCPR. To our knowledge, this is the first report demonstrating that public training and official promulgation of COCPR is associated with effective lay rescuer discrimination of aetiology-specific CPR-type.

## 5. Limitations

This study has several limitations. First, it is observational and not randomized, thereby precluding attribution of causality. However, the logistics of a randomized controlled trial of CPR by bystanders is an enormous barrier. Notably, other investigators have randomized a special type of bystander CPR, dispatcher-assisted CPR instruction for bystanders, and have shown that COCPR results in similar outcomes or better outcomes compared with conventional CPR in that setting.[26,28,29] Unfortunately, the number of patients with OHCA of non-cardiac causes did not allow adequate power to evaluate outcomes optimally.[26,28,29] Although the numbers of non-cardiac OHCAs were higher in our study, power was an issue, as noted above. Consistent with all studies of OHCA, our data was limited by the difficulty to verify the true aetiology of OHCA in each patient.[11,30] In addition, OHCA bystander CPR studies have an inherent risk of ascertainment bias in documenting the type of bystander CPR performed. We attempted to mitigate this by intentionally and specifically training EMS personnel on how to document the presence and type of bystander CPR. The finding that lay rescuers performed COCPR 18.0% of the time for non-cardiac OHCA overall (Table 3) compared with medical professional bystanders (4.0%) argues against a systematic bias in the documentation of CPR type. It is unlikely that EMS personnel would misclassify type of CPR by lay rescuers differently than that by health care professionals.

## 6. Conclusions

This is the first report, to our knowledge, of non-cardiac aetiologies of OHCA in the setting of a statewide campaign endorsing and teaching COCPR for victims of sudden cardiac arrest. In the setting of a campaign endorsing lay rescuer COCPR for cardiac OHCA, bystanders were less likely to perform COCPR on OHCA victims who might benefit from rescue breathing.

## Conflict of interest statement

Drs Bobrow, Ewy, and Spaite reported that the University of Arizona has received support from the Medtronic Foundation involving community-based translation of resuscitation science. Dr Bobrow reported in the past having received a grant from the American Heart Association to study ultrabrief CPR video training. No other disclosures were reported.

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