REVIEW ARTICLE

The impact of bystander cardiopulmonary resuscitation on patients with out-of-hospital cardiac arrests

Fang-Yu Liou[a], Kun-Chang Lin[a], Chian-Shiu Chien[b,c], Wan-Ting Hung[a], Yi-Ying Lin[b,c], Yi-Ping Yang[b,c], Wei-Yi Lai[b,c], Tzu-Wei Lin[b,c], Shu-Hung Kuo[a], Wei-Chun Huang[a,b,d,e,*]

[a]Department of Critical Care Medicine, Kaohsiung Veterans General Hospital, Kaohsiung, Taiwan, ROC; [b]College of Medicine, National Yang Ming Chiao Tung University, Taipei, Taiwan, ROC; [c]Department of Medical Research, Taipei Veterans General Hospital, Taipei, Taiwan, ROC; [d]Department of Physical Therapy, Fooyin University, Kaohsiung, Taiwan, ROC; [e]Graduate Institute of Clinical Medicine, Kaohsiung Medical University, Kaohsiung, Taiwan, ROC

Abstract: Out-of-hospital cardiac arrest (OHCA) is one of the leading causes of death around the world. Bystander cardiopulmonary resuscitation (CPR) is an independent factor to improve OHCA survival. However, the prevalence of bystander CPR remains low worldwide. Community interventions such as mandatory school CPR training or targeting CPR training to family members of high-risk cardiac patients are possible strategies to improve bystander CPR rate. Real-time feedback, hands-on practice with a manikin, and metronome assistance may increase the quality of CPR. Dispatcher-assistance and compression-only CPR for untrained bystanders have shown to increase bystander CPR rate and increase survival to hospital discharge. After return of spontaneous circulation, targeted temperature management should be performed to improve neurological function. This review focuses on the impact of bystander CPR on clinical outcomes and strategies to optimize the prevalence and quality of bystander CPR.

Keywords: Bystander cardiopulmonary resuscitation rate; Cardiopulmonary resuscitation; Hospital discharge; Out-of-hospital cardiac arrest

1. INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) is a major public health problem, with a global incidence of approximately 55 per 100 000 person-years.[1] In Taiwan, the OHCA incidence rate ranged from 16.4 to 28.2 per 100 000 persons annually.[2] Despite recent improvement in medical technology, the survival to discharge rate of OHCA patients seldom exceeds 10%.[1,3,4] Bystander cardiopulmonary resuscitation (CPR) is known as a critical link in the chain of survival.[5] This review focuses on the impact of bystander CPR on clinical outcomes and strategies to optimize the prevalence and quality of bystander CPR.

2. BYSTANDER CPR AND SURVIVAL

The association between bystander CPR and the survival of OHCAs has been investigated in numerous studies.[6–8] According to a meta-analysis of 16 cohort studies, bystander CPR was associated with approximately 2-fold chance of survival of OHCAs compared to no bystander CPR (odds ratio, 1.95; 95% CI, 1.66-2.30).[7] Factors modifying the effect of bystander CPR on survival was investigated by Holmberg et al.[9] A more marked effect of bystander CPR was found in the following conditions: short interval between collapse and CPR, CPR performed by a nonlayperson, a long delay before ambulance arrived, elderly OHCA victims, and outdoor OHCA.[9] In addition to survival improvement, bystander CPR significantly lowered the 1-year risk of brain damage according to a nationwide data from Denmark (hazard ratio, 0.62; 95% CI, 0.47-0.82).[10]

3. EPIDEMIOLOGY OF BYSTANDER CPR

Bystander CPR rate remained low despite being known as a critical link in the chain of survival for OHCA patients. According to a meta-analysis involving 142 740 patients, 53% of events were witnessed by a bystander, but only 32% received bystander CPR.[8] The Pan Asian Resuscitation Outcomes Study (PAROS) showed that bystander CPR rates in Japan, Taiwan, Singapore were 40.2%, 31.4%, and 24.3%, respectively.[4] In a study including 20 520 cardiac arrests in North American, only 31.4% patients received bystander CPR.[11]

A prospective, observational study revealed that CPR performance was higher in the following situation: witnessed arrest, bystander with more than a high-school education, CPR-trained bystander, and arrest occurred in a public location.[12] Furthermore, several epidemiological studies concluded that bystander CPR rates of OHCA were lower from low-income neighborhood.[13–16]

Effects of coronavirus disease 2019 (COVID-19) pandemic on bystander CPR rates varied between different countries. Three studies from Europe countries showed statistically significant

*Address correspondence. Dr Wei-Chun Huang, Department of Critical Care Medicine, Kaohsiung Veterans General Hospital, 386, Dazhong 1st Road, Kaohsiung 813, Taiwan, ROC. E-mail address: wchuanglulu@gmail.com (W.-C. Huang).

Conflicts of interest: The authors declare that they have no conflicts of interest related to the subject matter or materials discussed in this article.

Journal of Chinese Medical Association. (2021) 84: 1078-1083.

Received August 24, 2021; accepted September 22, 2021.

doi: 10.1097/JCMA.0000000000000630.

decline in bystander CPR rates during COVID-19 pandemic.[17–19] In contrast, two studies from North America found that the percentage of bystander CPR were similar between COVID-19 and non-COVID-19 period.[20,21]

4. OBSTACLES TO BYSTANDER CPR

Common reasons for people not doing bystander CPR includes: panic or lack of confidence, CPR skill deficits, worry about being sued, inability to recognize cardiac arrest, and fear of disease transmission via mouth-to-mouth ventilation.[12,22–24] Bystanders may fear to cause harm, especially if the victim is not in cardiac arrest. American Heart Association (AHA) 2020 Guidelines for CPR encouraged early initiation of CPR because the benefit outweighs any potential risk.[25,26] Legal concerns also stop bystanders from doing CPR. However, the risk of facing litigation are higher in nonintervention compared to providing CPR.[27] Mouth-to-mouth ventilation is another reason that dissuades people from performing CPR. Locke et al[28] reported that people significantly decreased their willingness to perform CPR if mouth-to-mouth ventilation was required. The discussion of compression-only CPR vs standard CPR is presented later in this article.

5. TRAINING LAYPEOPLE IN BASIC LIFE SUPPORT

In response to low bystander CPR rate, extensive studies regarding encouraging bystander CPR have been conducted. According to a study from South Korea, participants' willingness to perform CPR significantly increased after basic life support (BLS) training.[29] A study from Australia showed regions with low bystander CPR rates were associated with lower rates of CPR training.[30] Therefore, BLS training can be a powerful way to promote the provision of CPR.

School students are one of the targets of CPR training. World Health Organization has advocated schools to execute CPR training programs.[31] Recently, Taiwan, Canada, many American states, and some European countries have approved mandatory CPR training at school.[32–35] In 2005, Demark government launched a national campaign, requiring mandatory BLS training at elementary schools and for acquiring a driving license, which resulted in a 2-fold increase in bystander CPR rate.[36]

Another group of bystander CPR training target is family members of high-risk cardiac patients. Up to the present, there is no sufficient evidence showing survival benefits in training family members. However, studies have revealed improvement in CPR skills, an increase willingness to perform CPR, and a reduction in stress after family members received CPR training.[37–41]

6. INTERVENTIONS TO IMPROVE THE QUALITY OF CPR

The effect of different interventions on CPR have been analyzed in various studies listed in Table 1. Real-time feedback was proved to improve CPR quality.[42,43] Hands-on practice with a manikin was associated with more adequate compression depth.[44] Using dominant hand against chest wall resulted in similar CPR quality in comparison with using nondominant hand.[45] Playing metronome sounds to the rescuer was shown to enhance a more accurate chest compression rate but does not improve the overall CPR quality.[46,47]

Video-based and smartphone application-based learning are considered substitute methods for classroom-based learning in rural communities. There was heterogeneity of results in different studies comparing instructor-guided to video-guided training. Some studies demonstrated statistically significant better CPR performance in instructor-guided training[40,48] while others found no significant between-group differences.[49–51] In a randomized noninferiority trial, virtual reality training smartphone application, compared with face-to-face training, had comparable chest compression rate but inferior compression depth.[52]

7. CHEST COMPRESSION-ONLY CPR VS STANDARD CHEST COMPRESSION CPR

The effect of continuous chest compression CPR (CCC-CPR) vs standard chest compression CPR (STD-CPR) have been widely studied. STD-CPR provides chest compressions and rescue breaths in a 30:2 ratio. However, interrupted rescue breaths such as mouth-to-mouth ventilation has several potential disadvantages: dissuading bystander from performing CPR, hyperventilation of the victim, and sacrifice of the precious time to perform chest compression.[28,53,54]

A meta-analysis of three randomized controlled trials[55–57] showed that bystander CCC-CPR was associated with increased survival to hospital discharge compared to bystander STD-CPR (14.1% vs 11.6%; 95% CI, 1.01-1.46).[58] Current CPR guidelines from AHA and European Resuscitation Council encouraged compression-only CPR for untrained bystander.[5,25] Nevertheless, both chest compressions and rescue breathing are recommended in cases of children and asphyxia arrests (eg, drowning, drug overdose).[5,25]

8. DISPATCHER-ASSISTED CPR

Dispatcher-assisted CPR (DA-CPR) refers to the system in which dispatchers provide "just-in-time" CPR instructions to emergency callers over the telephone. This action aims to achieve early bystander CPR before emergency medical services arrival and ultimately improve survival. However, dispatchers may be unable to recognize cardiac arrest by several atypical presentations of cardiac arrests (ie, agonal gasps or seizure-like activity).[59,60] AHA suggested that instructions of prearrival CPR should be provided to the caller if the patient is unresponsive and not breathing or not breathing normally.[61]

Numerous studies have proved that DA-CPR significantly increased the prevalence of bystander CPR in the community.[62–68] The impact of DA-CPR on clinical outcomes was also widely studied. The result from a meta-analysis conveyed that DA-CPR, compared with no bystander CPR, was associated with increased survival to hospital discharge, survival with favorable neurologic outcome, and return of spontaneous circulation (ROSC).[69] However, there are conflicting results in terms of DA-CPR vs bystander CPR without dispatcher assistance.[69]

The efficacy of dispatcher assistance in improving CPR quality was investigated by a randomized controlled trial.[70] In comparison with CPR without dispatcher assistance, DA-CPR was associated with more accurate compression rate, while the results of CPR compression depth, complete release of pressure between compressions, and hand location were similar between two groups.[70]

9. POST-RESUSCITATION CARE

Adequate post-resuscitation care plays a crucial role in improving survival and prognosis after cardiac arrest. The quality of life of OHCA survivors is highly associated with their neurological outcomes.[71] Targeted temperature management (TTM) has shown to be associated with decreasing mortality and improving neurological function according to several randomized controlled trials.[72,73] AHA guideline recommended maintaining a constant temperature between 32°C and 36°C for at

Table 1

Main studies of the effect of interventions in CPR training

Author (y), nation	Study design	Study populations	Study design	Main outcomes
Baldi et al[42] (2017), Italy	Randomized controlled trial	Laypersons over 18 y old with no previous training in CPR	1. Group A: simple BLS/AED course without any feedback (n = 150) 2. Group B: BLS/AED course with 1 min of training with real-time visual feedback manikin (n = 150) 3. Group C: BLS/AED course with 10 min of training with real-time visual feedback manikin (n = 150)	Group A vs Group B vs Group C: 1. Compressions with correct depth (%): 66.6 vs 77.8 vs 75.7 ($p = 0.012$) 2. Compressions with a complete chest recoil (%): 71.7 vs 86.6 vs 88.8 ($p < 0.001$) 3. Compressions with the correct hand position (%): 93.2 vs 98.2 vs 99.3 ($p < 0.001$) 4. Compression rate (per minute): 119 vs 117 vs 118 ($p = 0.592$)
Buléon et al[43] (2013), France	Randomized crossover study	Students (University of Caen Basse Normandie France) who had never had basic life support formation before enrolment family members of patients with high-risk cardiac condition	1. Group A: feedback information provided by the CPRmeter device (n = 154) 2. Group B: CPRmeter device with the screen masked by an opaque adhesive (n = 154)	Group A vs Group B: 1. Efficient CC rate (%): 71 vs 26 ($p < 0.0001$) 2. Adequate depth rate (%): 85 vs 43 ($p < 0.0001$) 3. Adequate CC rate (%): 81 % vs 56% ($p < 0.0001$) 4. Adequate CC recoil/release (%): 100 vs 99 (p: NS)
Blewer et al[44] (2016), United States	Prospective, cluster randomized trial		1. Group A: video along with an inflatable manikin (n = 285) 2. Group B: video-only training without a manikin (n = 237)	Group A vs Group B: 1. Mean CC rate (per minute): 89.3 vs 87.7. Mean difference (95% CI), -1.6 (-5.2 to 2.1) 2. Mean CC depth (mm): 45.8 vs 40.2. Mean difference (95% CI), -5.6 (-7.6 to -3.7)
Nikandish et al[45] (2008), Iran	Randomized crossover study.	First year public heath students (Fasa University of Medical Sciences)	1. Group A: subject's dominant hand was in contact with the sternum (n = 59) 2. Group B: subject's nondominant hand was in contact with the sternum (n = 59)	Group A vs Group B: 1. Total number of correct chest compressions (mean ± SD): 183 ± 152 vs 152 ± 135 ($p = 0.09$) 2. Total number of ECC with inadequate depth (mean ± SD): 197 ± 174 vs 196 ± 173 ($p = 0.1$)
Park et al[46] (2013), Korea	Randomized controlled trial	Adult (age >18) laypersons who had no BLS training within the preceding 5 y	1. Group A: metronome sounds (110 ticks/min) were played to the rescuer through the speaker during the COCPR (n = 33) 2. Group B: verbal encouragement was given repeatedly during the COCPR (n = 34)	Group A vs Group B: 1. Compression rate (per minute): 111.9 vs 96.7 ($p = 0.018$) 2. Accurate chest compression rate (%): 97.0 vs 14.7 ($p < 0.0001$) 3. Mean compression depth (mm): 45.9 vs 46.8 ($p = 0.692$) 4. Shallow compressions (%): 69.2 vs 15.7 ($p = 0.035$)
Scott et al[47] (2018), United States	Prospective, randomized, controlled study	Laypersons aged 14 y and older	1. Group A: instructions for performing compression-only CPR with the use of the metronome tool, which included the EMD counting aloud for each compression at a repeating cadence of "one, two, three, four" and instructing the caller to follow along 2. Group B: exactly the same scripted instructions for compressions, eliminating only the "count out loud" instruction and the use of the tool itself	Group A vs Group B: 1. Target compression rate (%): 45.9 vs 22.2 2. Median compression rate (per minute): 100 vs 89 ($p = 0.013$) 3. Median compression depth (mm): 81 vs 61 (p: NS)

AED = automated external defibrillator; BLS = basic life support; CC = chest compression; COCPR = compression-only cardiopulmonary resuscitation; CPR = cardiopulmonary resuscitation; ECC = external chest compressions; EMD = emergency medical dispatcher; NS = nonsignificant.

least 24 hours for comatose patients with ROSC after OHCA.[74] Zhang et al[75] investigated the patients treated with TTM after cardiac arrest, finding that favorable neurological outcome was associated with significantly higher odds of bystander CPR (odds ratio, 1.44; 95% CI, 1.14-1.82). For patients with ST-elevation myocardial infarction or high suspicion of acute myocardial infarction, early coronary angiography and percutaneous coronary intervention were recommended in AHA guideline.[74]

In conclusion, bystander CPR is an independent factor to improve OHCA survival. However, the prevalence of bystander CPR remains low worldwide. Community interventions such as mandatory school CPR training or targeting CPR training to family members of high-risk cardiac patients are possible strategies to improve bystander CPR rate. Real-time feedback, hands-on practice with a manikin, and metronome assistance may increase the quality of CPR. Dispatcher-assistance and compression-only CPR for untrained bystanders have shown to increase bystander CPR rate and increase survival to hospital discharge. After ROSC, TTM could improve neurological function.

ACKNOWLEDGMENTS

This study was supported by grants from the Kaohsiung Veterans General Hospital, Kaohsiung, Taiwan, ie, Grant Nos. VGHKS108-D01-2 and the Ministry of Science and Technology, ie, Grants 108-2314-B-075B-007 -MY2.

REFERENCES

1. Berdowski J, Berg RA, Tijssen JG, Koster RW. Global incidences of out-of-hospital cardiac arrest and survival rates: systematic review of 67 prospective studies. *Resuscitation* 2010;**81**:1479–87.
2. Wang CY, Wang JY, Teng NC, Chao TT, Tsai SL, Chen CL, et al. The secular trends in the incidence rate and outcomes of out-of-hospital cardiac arrest in Taiwan–a nationwide population-based study. *PLoS One* 2015;**10**:e0122675.
3. Gräsner JT, Lefering R, Koster RW, Masterson S, Böttiger BW, Herlitz J, et al; EuReCa ONE Collaborators. EuReCa ONE-27 Nations, ONE Europe, ONE Registry: a prospective one month analysis of out-of-hospital cardiac arrest outcomes in 27 countries in Europe. *Resuscitation* 2016;**105**:188–95.
4. Ong ME, Shin SD, De Souza NN, Tanaka H, Nishiuchi T, Song KJ, et al; PAROS Clinical Research Network. Outcomes for out-of-hospital cardiac arrests across 7 countries in Asia: the Pan Asian Resuscitation Outcomes Study (PAROS). *Resuscitation* 2015;**96**:100–8.
5. Perkins GD, Handley AJ, Koster RW, Castrén M, Smyth MA, Olasveengen T, et al; Adult basic life support and automated external defibrillation section Collaborators. European Resuscitation Council Guidelines for Resuscitation 2015: section 2. Adult basic life support and automated external defibrillation. *Resuscitation* 2015;**95**:81–99.
6. Yan S, Gan Y, Jiang N, Wang R, Chen Y, Luo Z, et al. The global survival rate among adult out-of-hospital cardiac arrest patients who received cardiopulmonary resuscitation: a systematic review and meta-analysis. *Crit Care* 2020;**24**:61.
7. Song J, Guo W, Lu X, Kang X, Song Y, Gong D. The effect of bystander cardiopulmonary resuscitation on the survival of out-of-hospital cardiac arrests: a systematic review and meta-analysis. *Scand J Trauma Resusc Emerg Med* 2018;**26**:86.
8. Sasson C, Rogers MA, Dahl J, Kellermann AL. Predictors of survival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. *Circ Cardiovasc Qual Outcomes* 2010;**3**:63–81.
9. Holmberg M, Holmberg S, Herlitz J; Swedish Cardiac Arrest Registry. Factors modifying the effect of bystander cardiopulmonary resuscitation on survival in out-of-hospital cardiac arrest patients in Sweden. *Eur Heart J* 2001;**22**:511–9.
10. Kragholm K, Wissenberg M, Mortensen RN, Hansen SM, Malta Hansen C, Thorsteinsson K, et al. Bystander efforts and 1-year outcomes in out-of-hospital cardiac arrest. *N Engl J Med* 2017;**376**:1737–47.
11. Nichol G, Thomas E, Callaway CW, Hedges J, Powell JL, Aufderheide TP, et al; Resuscitation Outcomes Consortium Investigators. Regional variation in out-of-hospital cardiac arrest incidence and outcome. *JAMA* 2008;**300**:1423–31.
12. Swor R, Khan I, Domeier R, Honeycutt L, Chu K, Compton S. CPR training and CPR performance: do CPR-trained bystanders perform CPR? *Acad Emerg Med* 2006;**13**:596–601.
13. Sasson C, Magid DJ, Chan P, Root ED, McNally BF, Kellermann AL, et al; CARES Surveillance Group. Association of neighborhood characteristics with bystander-initiated CPR. *N Engl J Med* 2012;**367**:1607–15.
14. Starks MA, Schmicker RH, Peterson ED, May S, Buick JE, Kudenchuk PJ, et al; Resuscitation Outcomes Consortium (ROC). Association of neighborhood demographics with out-of-hospital cardiac arrest treatment and outcomes: where you live may matter. *JAMA Cardiol* 2017;**2**:1110–8.
15. Brown TP, Booth S, Hawkes CA, Soar J, Mark J, Mapstone J, et al. Characteristics of neighbourhoods with high incidence of out-of-hospital cardiac arrest and low bystander cardiopulmonary resuscitation rates in England. *Eur Heart J Qual Care Clin Outcomes* 2019;**5**:51–62.
16. Dahan B, Jabre P, Karam N, Misslin R, Tafflet M, Bougouin W, et al. Impact of neighbourhood socio-economic status on bystander cardiopulmonary resuscitation in Paris. *Resuscitation* 2017;**110**:107–13.
17. Paoli A, Brischigliaro L, Scquizzato T, Favaretto A, Spagna A. Out-of-hospital cardiac arrest during the COVID-19 pandemic in the Province of Padua, Northeast Italy. *Resuscitation* 2020;**154**:47–9.
18. Ortiz FR, Del Valle PF, Knox EC, Fábrega XJ, Pascual JMN, Rodríguez IM, et al. Influence of the Covid-19 pandemic on out-of-hospital cardiac arrest. A Spanish nationwide prospective cohort study. *Resuscitation* 2020;**157**:230-40.
19. Baldi E, Sechi GM, Mare C, Canevari F, Brancaglione A, Primi R, et al; Lombardia CARe researchers. COVID-19 kills at home: the close relationship between the epidemic and the increase of out-of-hospital cardiac arrests. *Eur Heart J* 2020;**41**:3045–54.
20. Lai PH, Lancet EA, Weiden MD, Webber MP, Zeig-Owens R, Hall CB, et al. Characteristics associated with out-of-hospital cardiac arrests and resuscitations during the novel coronavirus disease 2019 pandemic in New York City. *JAMA Cardiol* 2020;**5**:1154–63.
21. Sayre MR, Barnard LM, Counts CR, Drucker CJ, Kudenchuk PJ, Rea TD, et al. Prevalence of COVID-19 in out-of-hospital cardiac arrest: implications for bystander cardiopulmonary resuscitation. *Circulation* 2020;**142**:507–9.
22. Keim SM, Anderson K, Siegel E, Spaite DW, Valenzuela TD. Factors associated with CPR certification within an elderly community. *Resuscitation* 2001;**51**:269–74.
23. Vaillancourt C, Stiell IG, Wells GA. Understanding and improving low bystander CPR rates: a systematic review of the literature. *CJEM* 2008;**10**:51–65.
24. Case R, Cartledge S, Siedenburg J, Smith K, Straney L, Barger B, et al. Identifying barriers to the provision of bystander cardiopulmonary resuscitation (CPR) in high-risk regions: a qualitative review of emergency calls. *Resuscitation* 2018;**129**:43–7.
25. Panchal AR, Bartos JA, Cabañas JG, Donnino MW, Drennan IR, Hirsch KG, et al; Adult Basic and Advanced Life Support Writing Group. Part 3: adult basic and advanced life support: 2020 American Heart Association Guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation* 2020;**142**(16_Suppl_2):366–468.
26. White L, Rogers J, Bloomingdale M, Fahrenbruch C, Culley L, Subido C, et al. Dispatcher-assisted cardiopulmonary resuscitation: risks for patients not in cardiac arrest. *Circulation* 2010;**121**:91–7.
27. Murphy TW, Windermere S, Morris T, Slish J, Holtzman L, Becker TK. Risk and ROSC - legal implications of bystander CPR. *Resuscitation* 2020;**151**:99–102.
28. Locke CJ, Berg RA, Sanders AB, Davis MF, Milander MM, Kern KB, et al. Bystander cardiopulmonary resuscitation. Concerns about mouth-to-mouth contact. *Arch Intern Med* 1995;**155**:938–43.
29. Lee MJ, Hwang SO, Cha KC, Cho GC, Yang HJ, Rho TH. Influence of nationwide policy on citizens' awareness and willingness to perform bystander cardiopulmonary resuscitation. *Resuscitation* 2013;**84**:889–94.
30. Bray JE, Straney L, Smith K, Cartledge S, Case R, Bernard S, et al. Regions with low rates of bystander cardiopulmonary resuscitation (CPR) have lower rates of CPR training in Victoria, Australia. *J Am Heart Assoc* 2017;**6**:e005972.

31. Böttiger BW, Van Aken H. Kids save lives–training school children in cardiopulmonary resuscitation worldwide is now endorsed by the World Health Organization (WHO). *Resuscitation* 2015;**94**:A5–7.
32. Cave DM, Aufderheide TP, Beeson J, Ellison A, Gregory A, Hazinski MF, et al; American Heart Association Emergency Cardiovascular Care Committee; Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation; Council on Cardiovascular Diseases in the Young; Council on Cardiovascular Nursing; Council on Clinical Cardiology, and Advocacy Coordinating Committee. Importance and implementation of training in cardiopulmonary resuscitation and automated external defibrillation in schools: a science advisory from the American Heart Association. *Circulation* 2011;**123**:691–706.
33. Lockey AS, Georgiou M. Children can save lives. *Resuscitation* 2013;**84**:399–400.
34. Semeraro F, Wingen S, Schroeder DC, Ecker H, Scapigliati A, Ristagno G, et al. KIDS SAVE LIVES implementation in Europe: a survey through the ERC Research NET. *Resuscitation* 2016;**107**:e7–9.
35. Sorets TR, Mateen FJ. Mandatory CPR training in US high schools. *Mayo Clin Proc* 2015;**90**:710–2.
36. Wissenberg M, Lippert FK, Folke F, Weeke P, Hansen CM, Christensen EF, et al. Association of national initiatives to improve cardiac arrest management with rates of bystander intervention and patient survival after out-of-hospital cardiac arrest. *JAMA* 2013;**310**:1377–84.
37. Moser DK, Dracup K. Impact of cardiopulmonary resuscitation training on perceived control in spouses of recovering cardiac patients. *Res Nurs Health* 2000;**23**:270–8.
38. Blewer AL, Leary M, Decker CS, Andersen JC, Fredericks AC, Bobrow BJ, et al. Cardiopulmonary resuscitation training of family members before hospital discharge using video self-instruction: a feasibility trial. *J Hosp Med* 2011;**6**:428–32.
39. Cartledge S, Bray JE, Leary M, Stub D, Finn J. A systematic review of basic life support training targeted to family members of high-risk cardiac patients. *Resuscitation* 2016;**105**:70–8.
40. Kim HS, Kim HJ, Suh EE. The effect of patient-centered CPR education for family caregivers of patients with cardiovascular diseases. *J Korean Acad Nurs* 2016;**46**:463–74.
41. Cartledge S, Finn J, Bray JE, Case R, Barker L, Missen D, et al. Incorporating cardiopulmonary resuscitation training into a cardiac rehabilitation programme: a feasibility study. *Eur J Cardiovasc Nurs* 2018;**17**:148–58.
42. Baldi E, Cornara S, Contri E, Epis F, Fina D, Zelaschi B, et al. Real-time visual feedback during training improves laypersons' CPR quality: a randomized controlled manikin study. *CJEM* 2017;**19**:480–7.
43. Buléon C, Parienti JJ, Halbout L, Arrot X, De Facq Régent H, Chelarescu D, et al. Improvement in chest compression quality using a feedback device (CPRmeter): a simulation randomized crossover study. *Am J Emerg Med* 2013;**31**:1457–61.
44. Blewer AL, Putt ME, Becker LB, Riegel BJ, Li J, Leary M, et al; CHIP Study Group*. Video-only cardiopulmonary resuscitation education for high-risk families before hospital discharge: a multicenter pragmatic trial. *Circ Cardiovasc Qual Outcomes* 2016;**9**:740–8.
45. Nikandish R, Shahbazi S, Golabi S, Beygi N. Role of dominant versus non-dominant hand position during uninterrupted chest compression CPR by novice rescuers: a randomized double-blind crossover study. *Resuscitation* 2008;**76**:256–60.
46. Park SO, Hong CK, Shin DH, Lee JH, Hwang SY. Efficacy of metronome sound guidance via a phone speaker during dispatcher-assisted compression-only cardiopulmonary resuscitation by an untrained layperson: a randomised controlled simulation study using a manikin. *Emerg Med J* 2013;**30**:657–61.
47. Scott G, Barron T, Gardett I, Broadbent M, Downs H, Devey L, et al. Can a software-based metronome tool enhance compression rate in a realistic 911 call scenario without adversely impacting compression depth for dispatcher-assisted CPR? *Prehosp Disaster Med* 2018;**33**:399–405.
48. de Vries W, Turner NM, Monsieurs KG, Bierens JJ, Koster RW. Comparison of instructor-led automated external defibrillation training and three alternative DVD-based training methods. *Resuscitation* 2010;**81**:1004–9.
49. Mpotos N, Lemoyne S, Calle PA, Deschepper E, Valcke M, Monsieurs KG. Combining video instruction followed by voice feedback in a self-learning station for acquisition of Basic Life Support skills: a randomised non-inferiority trial. *Resuscitation* 2011;**82**:896–901.
50. Mancini ME, Cazzell M, Kardong-Edgren S, Cason CL. Improving workplace safety training using a self-directed CPR-AED learning program. *AAOHN J* 2009;**57**:159–67; quiz 168–9.
51. Jones I, Handley AJ, Whitfield R, Newcombe R, Chamberlain D. A preliminary feasibility study of a short DVD-based distance-learning package for basic life support. *Resuscitation* 2007;**75**:350–6.
52. Nas J, Thannhauser J, Vart P, van Geuns RJ, Muijsers HEC, Mol JQ, et al. Effect of face-to-face vs virtual reality training on cardiopulmonary resuscitation quality: a randomized clinical trial. *JAMA Cardiol* 2020;**5**:328–35.
53. Aufderheide TP, Sigurdsson G, Pirrallo RG, Yannopoulos D, McKnite S, von Briesen C, et al. Hyperventilation-induced hypotension during cardiopulmonary resuscitation. *Circulation* 2004;**109**:1960–5.
54. Bobrow BJ, Clark LL, Ewy GA, Chikani V, Sanders AB, Berg RA, et al. Minimally interrupted cardiac resuscitation by emergency medical services for out-of-hospital cardiac arrest. *JAMA* 2008;**299**:1158–65.
55. Hallstrom A, Cobb L, Johnson E, Copass M. Cardiopulmonary resuscitation by chest compression alone or with mouth-to-mouth ventilation. *N Engl J Med* 2000;**342**:1546–53.
56. Rea TD, Fahrenbruch C, Culley L, Donohoe RT, Hambly C, Innes J, et al. CPR with chest compression alone or with rescue breathing. *N Engl J Med* 2010;**363**:423–33.
57. Svensson L, Bohm K, Castrèn M, Pettersson H, Engerström L, Herlitz J, et al. Compression-only CPR or standard CPR in out-of-hospital cardiac arrest. *N Engl J Med* 2010;**363**:434–42.
58. Zhan L, Yang LJ, Huang Y, He Q, Liu GJ. Continuous chest compression versus interrupted chest compression for cardiopulmonary resuscitation of non-asphyxial out-of-hospital cardiac arrest. *Cochrane Database Syst Rev* 2017;**3**:CD010134.
59. Bobrow BJ, Zuercher M, Ewy GA, Clark L, Chikani V, Donahue D, et al. Gasping during cardiac arrest in humans is frequent and associated with improved survival. *Circulation* 2008;**118**:2550–4.
60. Clawson J, Olola C, Scott G, Heward A, Patterson B. Effect of a medical priority dispatch system key question addition in the seizure/convulsion/fitting protocol to improve recognition of ineffective (agonal) breathing. *Resuscitation* 2008;**79**:257–64.
61. Lerner EB, Rea TD, Bobrow BJ, Acker JE 3rd, Berg RA, Brooks SC, et al; American Heart Association Emergency Cardiovascular Care Committee; Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Emergency medical service dispatch cardiopulmonary resuscitation prearrival instructions to improve survival from out-of-hospital cardiac arrest: a scientific statement from the American Heart Association. *Circulation* 2012;**125**:648–55.
62. Vaillancourt C, Verma A, Trickett J, Crete D, Beaudoin T, Nesbitt L, et al. Evaluating the effectiveness of dispatch-assisted cardiopulmonary resuscitation instructions. *Acad Emerg Med* 2007;**14**:877–83.
63. Culley LL, Clark JJ, Eisenberg MS, Larsen MP. Dispatcher-assisted telephone CPR: common delays and time standards for delivery. *Ann Emerg Med* 1991;**20**:362–6.
64. Rea TD, Eisenberg MS, Culley LL, Becker L. Dispatcher-assisted cardiopulmonary resuscitation and survival in cardiac arrest. *Circulation* 2001;**104**:2513–6.
65. Eisenberg MS, Hallstrom AP, Carter WB, Cummins RO, Bergner L, Pierce J. Emergency CPR instruction via telephone. *Am J Public Health* 1985;**75**:47–50.
66. Ng YY, Leong SH, Ong ME. The role of dispatch in resuscitation. *Singapore Med J* 2017;**58**:449–52.
67. Harjanto S, Na MX, Hao Y, Ng YY, Doctor N, Goh ES, et al; PAROS study group. A before-after interventional trial of dispatcher-assisted cardio-pulmonary resuscitation for out-of-hospital cardiac arrests in Singapore. *Resuscitation* 2016;**102**:85–93.
68. Song KJ, Shin SD, Park CB, Kim JY, Kim DK, Kim CH, et al. Dispatcher-assisted bystander cardiopulmonary resuscitation in a metropolitan city: a before-after population-based study. *Resuscitation* 2014;**85**:34–41.
69. Nikolaou N, Dainty KN, Couper K, Morley P, Tijssen J, Vaillancourt C; International Liaison Committee on Resuscitation's (ILCOR) Basic Life Support and Pediatric Task Forces. A systematic review and meta-analysis of the effect of dispatcher-assisted CPR on outcomes from sudden cardiac arrest in adults and children. *Resuscitation* 2019;**138**:82–105.
70. Teo MHN, Wong WEJ, Daniel PCN, Kweh RHC, Ho RYJ, Koh JH, et al. The use of dispatcher assistance in improving the quality of cardiopulmonary resuscitation: a randomised controlled trial. *Resuscitation* 2019;**138**:153–9.
71. Tiainen M, Poutiainen E, Oksanen T, Kaukonen KM, Pettilä V, Skrifvars M, et al. Functional outcome, cognition and quality of life after out-of-hospital cardiac arrest and therapeutic hypothermia: data from

a randomized controlled trial. *Scand J Trauma Resusc Emerg Med* 2015;**23**:12.

72. The Hypothermia after Cardiac Arrest Study Group. Mild therapeutic hypothermia to improve the neurologic outcome after cardiac arrest. *N Engl J Med* 2002;**346**:549–56.
73. Bernard SA, Gray TW, Buist MD, Jones BM, Silvester W, Gutteridge G, et al. Treatment of comatose survivors of out-of-hospital cardiac arrest with induced hypothermia. *N Engl J Med* 2002;**346**:557–63.
74. Callaway CW, Donnino MW, Fink EL, Geocadin RG, Golan E, Kern KB, et al. Part 8: post-cardiac arrest care: 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation* 2015;**132**(18 Suppl 2):S465–82.
75. Zhang Q, Qi Z, Liu B, Li C. Predictors of survival and favorable neurological outcome in patients treated with targeted temperature management after cardiac arrest: a systematic review and meta-analysis. *Heart Lung* 2018;**47**:602–9.