Effect of Prior Cardiopulmonary Resuscitation Knowledge on Compression Performance by Hospital Providers

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Supervising Section Editor: Christopher Kahn, MD, MPH
Submission history: Submitted September 15, 2013; Revision received December 19, 2013; Accepted January 27, 2014
Electronically published April 4, 2014
Full text available through open access at http://escholarship.org/uc/uciem_westjem
DOI: 10.5811/westjem.2014.1.19636

Introduction: The purpose of this study was to determine cardiopulmonary resuscitation (CPR) knowledge of hospital providers and whether knowledge affects performance of effective compressions during a simulated cardiac arrest.

Methods: This cross-sectional study evaluated the CPR knowledge and performance of medical students and ED personnel with current CPR certification. We collected data regarding compression rate, hand placement, depth, and recoil via a questionnaire to determine knowledge, and then we assessed performance using 60 seconds of compressions on a simulation mannequin.

Results: Data from 200 enrollments were analyzed by evaluators blinded to subject knowledge. Regarding knowledge, 94% of participants correctly identified parameters for rate, 58% for hand placement, 74% for depth, and 94% for recoil. Participants identifying an effective rate of ≥100 performed compressions at a significantly higher rate than participants identifying <100 ($\mu=117$ vs. 94, $p<0.001$). Participants identifying correct hand placement performed significantly more compressions adherent to guidelines than those identifying incorrect placement ($\mu=86\%$ vs. 72%, $p<0.01$). No significant differences were found in depth or recoil performance based on knowledge of guidelines.

Conclusion: Knowledge of guidelines was variable; however, CPR knowledge significantly impacted certain aspects of performance, namely rate and hand placement, whereas depth and recoil were not affected. Depth of compressions was poor regardless of prior knowledge, and knowledge did not correlate with recoil performance. Overall performance was suboptimal and additional training may be needed to ensure consistent, effective performance and therefore better outcomes after cardiopulmonary arrest. [West J Emerg Med. 2014;15(4):404–408.]

INTRODUCTION

Cardiopulmonary arrest (CPA) is a major public health problem, and despite advances in cardiopulmonary resuscitation (CPR), survival and recovery remain suboptimal.[1] Early and effective CPR has been shown to improve survival after CPA.[2] However, both out-of-hospital and in-hospital providers often fail to provide high quality CPR.[3-5] Poor quality CPR has been shown to have similar outcomes to patients receiving no CPR, whereas increased survival is associated with high quality CPR, particularly the quality of chest compressions (CCs).[5,6] Therefore, recent recommendations have focused on CCs as the focus of compression optimization, which is reflected in the *2010 AHA Guidelines for CPR and ECC*[7], as well as the *ERC Guidelines for Resuscitation 2010*[8] and *2010 CoSTR Guidelines*.[9]

Specific components of CCs, including rate, depth, and recoil, have been found to affect outcome measures. Rates below published guidelines are associated with poor return of spontaneous circulation, which is particularly concerning given that many providers deliver CCs at suboptimal rates.[4]

Inadequate compression depth is associated with defibrillation failure.[10] In animal models, incomplete (< than 75%) chest recoil, as compared to full (100%) recoil between CCs, impeded venous return and resulted in lower mean arterial pressures and decreased cerebral and coronary blood flow.[11]

Despite training in effective CPR techniques, providers often fail to perform CCs that adhere to AHA guidelines.[4] Studies have found that both knowledge of guidelines and motor skills for CPR are not well retained and degrade in relation to time since last training, with extensive decline and suboptimal performance within 6 to 12 months after training.[12-15]

One study showed that knowledge of guidelines correlated with better performance of CCs, namely compression rate; however, overall knowledge as well as performance was poor.[16] Another study found that kinesthetic memory, i.e. motor skills, as well as overall performance of CPR, degrades faster than knowledge of guidelines.[12] These findings would suggest that although retention of guidelines is poor, this has little impact on performance, and instead, the decay of motor skills is the cause for degradation of CPR performance.[12,13] These studies also found that increased training, experience, and more frequent performance of CPR leads to better performance.[12,13] However, at least one other study opposed this finding.[16]

The objective of our analysis was therefore 2-fold. First, we sought to evaluate the CPR knowledge and CC performance in a representative sample of in-hospital providers with various levels of training and experience. In addition, we investigated whether knowledge of CPR parameters, as defined by correct identification of current AHA guidelines[7], affected the performance of effective CCs during a simulated cardiac arrest scenario.

METHODS

Study Design

This was a cross-sectional analysis of pre-intervention data from an experimental study measuring the effect of prior CPR knowledge and simulation-based training on the performance of CCs. The research was approved via exemption by the human subjects research protection board.

Participants

Between July 2011 and October 2011, we enrolled emergency department (ED) personnel and medical students who had completed a Basic Life Support course in the previous two years. All participants were 18 years of age or older. Participation was voluntary and represented a convenience sample.

Protocol

During enrollment periods in the ED, potential study participants (technicians, nurses, physicians) were asked to participate if time permitted. Arrangements were made for staff members to participate at a later time if requested. We recruited all medical and nursing students by e-mail for participation. Interested students were enrolled at the Clinical Simulation Center. We assessed knowledge of guidelines through a pre-intervention questionnaire, asking them to identify the AHA guidelines for rate, hand placement, depth, and recoil.[16] An example is given in Appendix A.

Participants were then informed that a nearby mannequin (Laerdal Resusci Anne® Simulator, #150-0001, Wappingers Falls, NY) was "experiencing" a CPA with a known shockable rhythm. All subjects were asked to complete 1 minute of CCs on the simulation mannequin. The mannequin was located on a stretcher with a fixed height. A stool was made available to all participants, but its use was not required.

Measurements

Following performance of CCs, we collected data regarding depth, recoil, hand placement, and rate for each participant (Laerdal PC SkillReporting System, #317000, Wappingers Falls, NY). The rate was defined as the number of CCs performed in 1 minute. We considered a rate of over 100 CCs per minute to be effective. Depth was defined as the percentage of CCs that achieved a depth between 38 and 51 mm. We defined recoil as the percentage of CCs that allowed the chest to return to the fully expanded position prior to starting the next compression. Hand placement was defined as the percentage of CCs for which the hands were placed midline and at the nipple-line.

We collected and managed study data using Research Electronic Data Capture (REDCap) electronic data capture tools hosted at our facility. REDCap is a secure, web-based application designed to support data capture for research studies.

Table 1. Demographics of participants in study measuring the effect of prior cardiopulmonary resuscitation (CPR) knowledge and simulation-based training on the performance of chest compressions (n = 200)*

Mean age ± SD, years	28.5 ± 8.2
Gender (male)	93 (46.5)
Previous CPR experience	97 (48.5)
Level of training	
Medical student	102 (49)
Nursing student	9 (4.5)
EMT-Basic, EMT-Paramedic	18 (9.0)
Registered nurse	54 (27.0)
Physician assistant	1 (0.5)
Doctor of medicine (resident)	16 (8.0)

*Data are presented as # (%) unless otherwise specified.
n: sample size; #: number of subjects; %: percentage of subjects; *SD*, standard deviation; *EMT,* emergency medical technician

Table 2. Cardiopulmonary resuscitation chest compression guidelines, survey responses, and performance (n = 200).

	Guidelines	Survey correct, # (%)*	Performance outcomes, mean (95% CI)
Rate	≥ 100 beats per minute (bpm)	187 (93.5%)	115 bpm (113 – 118)
Hand placement	Centered on chest, along nipple line	116 (58.0%)	80% (75 – 85)**
Depth	≥ 2 in (~51 mm)	148 (74.0%)	41% (35 – 46)**
Recoil	Fully recoil between compressions	187 (93.5%)	83% (79 – 88)**

* Number and percentage of subjects; Based on *2010 AHA Guidelines for CPR & ECC*[1]
** Percentage of compressions performed which meet AHA criteria for each respective chest compression component
n: sample size; #: number of subjects; %: percentage of subjects or chest compressions as indicated; *CI*, confidence interval

Table 3. Analysis of chest compression performance by survey response.

	Correct survey response		Incorrect survey response	*p*-value
Rate	***≥ 100 bpm***		***< 100***	
Mean (95% CI), beats per minute (bpm)	117 (114-119)		94 (80-107)	< 0.001
# (%)*	160 (86%)		6 (46%)	< 0.01
Hand placement	***Centered on chest***		***All others***	
Mean (95% CI), % CCs**	86 (80–92)		72 (63-80)	0.01
Depth	***2 inches***	***> 2 inches***	**< 2 inches**	
Mean (95% CI), % CCs**	41 (35-47)	44 (32-56)	25 (5-45)	0.24
Recoil	***Fully recoil***		**Partial recoil**	
Mean (95% CI), % CCs**	83 (78-87)		97 (93-100)	0.42

* Number and percentage of subjects meeting criteria, ≥100 bpm, during performance of chest compression (CC)
** % CCs = Percentage of compressions performed meeting criteria for respective CC component
#: number of subjects; %: percentage of subjects or CC as indicated; *CI*, confidence interval

Statistical Methods

Distributions of outcomes variables were non-normal; therefore, we used Mann-Whitney U-Test, and Kruskal Wallis H-Test to compare compression performance for rate, hand placement, depth, and recoil between questionnaire response groups. We used Fisher Exact Test for categorical analysis of rate. All analyses were performed using Microsoft Excel 2011 (Microsoft Corporation) with 2011 MegaStat 10.2 Add-in (McGraw Hill).

RESULTS

During the period of July 2011 to October 2011, we recruited a total of 200 students and staff for participation in this study. Demographic data for all study participants are shown in Table 1. While most participants were medical students, subjects also included nursing students, technicians, nurses, and physicians. The participant mix was considered potentially representative of hospital-based resuscitation team membership. Roughly half of all subjects reported having previously performed CCs during a real patient resuscitation and were noted as "experienced providers." However, there was no significant difference in performance between "experienced" and "novice" providers for any of the measured outcomes.

Knowledge of guidelines pertaining to components of effective CCs was variable as shown in Table 2. Of all participants, 93.5% (187) correctly identified an effective rate, 58% (116) correctly identified an effective hand placement, 74% (148) correctly identified an effective depth, and 93.5% (187) correctly identified an effective recoil.

Overall performance is shown in Table 2. For rate, participants performed CCs at a mean rate of 115 bpm with 83% (166) of participants performing CCs at a rate ≥ 100. Of all CCs performed during the study, 80% met criteria for hand placement, 41% met criteria for depth, and 83% met criteria for recoil.

Table 3 presents the differences in performance outcomes between questionnaire response groups. Participants who identified an effective rate of ≥100 performed CCs at a significantly higher rate than participants who felt an effective rate was <100 (μ=117 bpm vs. 94 bpm, $p<0.001$). In addition, a greater percentage of participants in the ≥100 response group met rate criteria during performance of CCs (86% vs. 46%, p<0.01). Participants who knew appropriate hand placement performed a greater number of CCs adherent to guidelines than those who did not know the correct placement (μ=86% vs. 72%, p=0.01). There were no significant differences in adherence to depth guidelines based on prior knowledge (p=0.24) with all groups achieving an effective depth in less than 50% of CCs performed. For recoil, those identifying incorrect parameters achieved full recoil in 97% of CCs versus 83% for those responding correctly; however, this difference was not significant (p=0.42).

DISCUSSION

To our knowledge, this study represents the first to quantify the effect of knowledge on performance for all CC components outlined in the AHA guidelines, expanding on previous work by Brown et al.[16] This studied included an analysis of recoil and hand placement in addition to compression rate and depth, which was investigated previously. Additionally, rather than EMS providers outside of the hospital, our study investigated the efficacy of CPR administered by in-hospital providers including medical students. Our analysis shows that knowledge of guidelines has a significant impact on CPR performance for at least some components, namely rate and hand placement, which supports prior findings. Of participants identifying a rate of greater than or equal to 100 bpm, 86% met guidelines and the overall mean rate exceeded 100 bpm. Also, participants correctly identifying hand placement administered a greater percent of CCs meeting these guidelines. However, for rate and recoil we saw no significant differences in performance based on knowledge of guidelines.

Our study showed that there is variable retention of guidelines, with rate and recoil parameters being correctly identified by almost all participants, but deficiencies in knowledge for depth and hand placement. In addition, for rate, depth, and recoil, participants demonstrated better retention of guidelines than performance of these CC components. However, despite poor knowledge of guidelines for hand placement, this component was performed unexpectedly well.

Data for effective CC rate in our study were similar to those of Albella et al[3] and Losert et al,[17] which looked at ED staff. In contrast, participants in our study performed a greater amount of effective CCs than participants of 2 previous studies.[4,16] However, one of those studies with poorer performance assessed CC rate during an actual resuscitation and for longer than 1 minute,[4] which was beyond the scope of our study. Although both knowledge and performance were relatively high for this component, in light of the focus on importance of CC rate, even these results are suboptimal.

Unlike rate, depth performance in our study did not parallel the high quality performance of participants in the Losert et al[17] study; instead performance was poor, similar to Abella et al[3] and Brown et al.[16] Depth was the least well performed component in our study, and this could be due to fact that the computer software available at the time of data collection was set to recognize the 2005 AHA recommendations for appropriate compression depth (38-51 mm, approx. 1.5-2 in) and did not discriminate between CCs that were too shallow versus too deep. The newest guidelines have since changed the recommendation to achieve a minimum depth of 51 mm. While it is likely that many of the participants who registered an ineffective depth were too shallow, it is possible that a fraction of participants were compressing too deep. Thus, it is possible that the reported mean percentage of CCs reaching appropriate depth was lower than it would have been if the software had recognized the updated guidelines. However, even with this in mind, performance was relatively poor, and there is significant room for improvement in performance of CCs with appropriate depth as well as retention of depth guidelines.

Despite a high recall for recoil guidelines and a good overall performance, these results are suboptimal in light of studies that show small decreases in complete recoil can affect outcomes.[11] To our knowledge there are no previous studies recording data on hand placement. Even though it was the least correctly identified guideline, overall accuracy of hand placement was good,; however, there was still room for improvement on an individual basis.

There have been several studies on the effectiveness of different teaching methods for CPR training and knowledge retention, suggesting that additional and/or more frequent training may be required to improve retention of guidelines, both in knowledge and performance.[18-20] Additional studies are needed to determine best practice for retention of guidelines, which this study shows would help ensure efficacious CPR performance and therefore improved outcomes, including survival.

LIMITATIONS

This study had several limitations. Foremost, the software recognized 2005 AHA guidelines rather than the most current 2010 guidelines. Additionally, this study was conducted in the controlled environment of a simulation laboratory and CCs were performed on a mannequin. The pre-CPR knowledge survey may have spurred on some recall by participants, but is largely no different than other reminder strategies that have failed to improve CPR performance. Additional factors, such as patient size and number of available providers, may prevent adequate CCs during an actual patient resuscitation. A large portion of the participants in this study were medical students; therefore, the sample of providers studied may not be reflective of the usual makeup of resuscitation teams at some hospitals. Data regarding patient outcomes and the performance of CCs during true resuscitations should be collected to determine the impact of guideline retention on resuscitation.

CONCLUSION

This analysis illustrates that identification of current

AHA guidelines correlates with better performance of at least some components of CPR, namely rate and hand placement, whereas other parameters such as depth and recoil are not affected. Overall, retention of guidelines is variable and performance is suboptimal. As quality of CCs influence efficacy of CPR, more frequent reinforcement may be needed to ensure consistent, effective performance.

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Conflicts of Interest: By the *West*JEM article submission agreement, all authors are required to disclose all affiliations, funding sources and financial or management relationships that could be perceived as potential sources of bias. The authors disclosed none.

REFERENCES

1. Field JM, Hazinski MF, Sayre MR, et al. Part 1: Executive summary: 2010 Guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation*. 2010; 122:S640-656.
2. Cummins RO, Ornato JP, Thies WH, et al. Improving survival from sudden cardiac arrest: the 'chain of survival' concept. *Circulation*. 1991; 83:1832-47.
3. Abella BS, Alvarado JP, Myklebust H, et al. Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. *JAMA*. 2005; 293:305-310.
4. Abella BS, Sandbo N, Vassilatos P, et al. Chest compression rates during cardiopulmonary resuscitation are suboptimal: a prospective study during in-hospital cardiac arrest. *Circulation*. 2005; 111:428-434.
5. Wik L, Kramer-Johansen J, Myklebust H, et al. Quality of cardiopulmonary resuscitation during out-of-hospital cardiac arrest. *JAMA*. 2005; 293:299-304.
6. Gallagher EJ, Lombardi G, Gennis P. Effectiveness of bystander cardiopulmonary resuscitation and survival following out-of-hospital cardiac arrest. *JAMA*. 1995; 274:1922-1925.
7. Berg RA, Hemphill R, Abella BS, et al. Part 5: Adult basic life support: 2010 Guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation*. 2010 ;122:S685-705.
8. Koster RW, Baubin MA, Bossaert LL, et al. Section 2: Adult basic life support and use of automatic defibrillators: European Resuscitation Council Guidelines for Resuscitation 2010. *Resuscitation*. 2010; 81:1277-1292.
9. Sayre MR, Koster RW, Botha M, et al. Part 5: Adult basic life support: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Circulation*. 2010; 122:S298-S324.
10. Edelson DP, Abella BS, Kramer-Johansen J, et al. Effects of compression depth and pre-shock pauses predict defibrillation failure during cardiac arrest. *Resuscitation*. 2006; 71:137-145.
11. Yannopoulos D, McKnite S, Aufderheide TP, et al. Effects of incomplete chest wall decompression during cardiopulmonary resuscitation on coronary and cerebral perfusion pressures in a porcine model or cardiac arrest. *Resuscitation*. 2005; 64:363-72.
12. Latman NS,Wooley K. Knowledge and skill retention of emergency care attendants, EMT-A's, and EMT-P's. *Ann Emerg Med*. 1980; 9:183-189.
13. Deliere HM, Schneider LE. A study of cardiopulmonary resuscitation technical skill retention among trained EMT-A's. *EMT Journal.* 1980; 4:57-60.
14. McKenna SP, Glendon AI. Occupational first aid training: Decay in cardiopulmonary resuscitation (CPR) skills. *J Occupational Psych*. 1985; 58:109-117.
15. Smith K, Gilcreast D, Pierce K. Evaluation of staff's retention of ACLS and BLS skills. *Resuscitation*. 2008; 78:59-65.
16. Brown TB, Dias JA, Saini D, et al. Relationship between knowledge of cardiopulmonary resuscitation guidelines and performance. *Resuscitation*. 2006; 69:253-261.
17. Losert H, Sterz F, Köhler K, et al. Quality of cardiopulmonary resuscitation among highly trained staff in the emergency department setting. *Arch Intern Med*. 2006; 166:2375-2380.
18. Coleman S, Dracup K, Moser DK. Comparing methods of cardiopulmonary resuscitation instruction on learning and retention. *J Nurs Staff Dev*. 1991; 7:82-87.
19. Moser DK, Coleman S. Recommendations for improving cardiopulmonary resuscitation skills retention. *Heart Lung*. 1992; 21:372-380.
20. Sarac L, Ok A. The effects of different instructional methods on students' acquisition and retention of cardiopulmonary resuscitation skills. *Resuscitation*. 2010; 81;555-561.