THE EFFECTS OF A NOVEL QUARTERLY CPR TRAINING PROGRAM ON HOSPITAL BASIC LIFE SUPPORT PROVIDERS' ADULT AND INFANT CPR SKILLS

by

Alex Klacman

DISSERTATION

Submitted in partial fulfillment of requirements for the degree of

Doctor of Philosophy

at

The University of Texas at Arlington

May 2021

Arlington, Texas

Supervising Committee:

Donelle M. Barnes, Ph.D., RN, Committee Chair

Jing Wang, PhD

Tia Raymond, MD

Abstract

The Effects of a Novel Quarterly CPR Training Program on Hospital Basic Life Support Providers' Adult and Infant CPR Skills

Alex Klacman, Ph.D.

Supervising Professor: Donelle M. Barnes, Ph.D., RN

This article-based dissertation consists of two manuscripts related to the effects of a novel quarterly cardiopulmonary resuscitation (CPR) training program on hospital basic life support (BLS) providers' adult and infant CPR skills over time at one hospital in Texas. The first manuscript was a retrospective cohort study of 109 BLS providers enrolled in the training program at the study hospital who completed four quarters of adult CPR skills with audiovisual feedback between January 1, 2017, and December 31, 2018. The primary purpose of the study was to examine the effect of the training program on BLS providers' ability to obtain and maintain adult CPR skills over four quarters of the training program. The study utilized an existing analytics database that contained study participants' adult CPR skill data. Analysis of the data revealed that BLS providers who failed to meet the CPR skill measures during the first quarter quickly improved their skills to meet the measure during the second quarter and maintained that performance over subsequent quarters. BLS providers who met the CPR skill measure during the first quarter maintained their performance over time. The results of this study suggest that the training program may be a viable option to help BLS providers obtain and maintain quality CPR skill performance over time.

The second manuscript was a retrospective cohort study of 116 BLS providers enrolled in the training program at the study hospital between April 1, 2020, and February 1, 2021, who completed a baseline infant CPR skill test without audiovisual feedback followed by three

consecutive quarters of infant CPR skills with audiovisual feedback. The primary purpose of this study was to examine the effect of audiovisual feedback on infant CPR skills during three consecutive quarters as compared to their baseline skill test without audiovisual feedback. The study utilized an existing analytics database that contained study participants infant CPR skill data. Analysis of the data revealed that during quarter 1 of the training program, as compared to baseline, providers were more likely to meet the recommended infant CPR skill measure, suggesting that audiovisual feedback helps to correct poor infant CPR skill performance. During quarters 2 and 3, there were minimal to no improvements in CPR skill performance, suggesting that audiovisual feedback helps providers to maintain their performance over time. The results of this study suggest that the training program may be a viable option to help BLS providers obtain and maintain quality infant CPR skill performance over time.

This article-based dissertation concludes with the limitations of both studies and the implications for nursing practice. Future research directions are also discussed. In light of the findings of both studies, staff nurse educators should consider incorporating innovative CPR training programs that focus on spaced learning with immediate feedback, including use of the novel quarterly CPR training programs.

Acknowledgements

There are so many people that I want to acknowledge that have helped me along my journey in life and in nursing. Even when I have not believed in myself there was always someone there to believe in me. I would first like to thank my parents, Robert and Rebecca Klacman. Although Robert is no longer here with us, I know that he would be so proud of my accomplishments, as he always set the tone for my education and expected nothing but the best from me. To my mom, you have always been a support to me and have always been a champion for me continuing my education. To the nursing leaders who have always stood by me during my good times and my bad times: Dr. Meera Ananthaswamy, Dr. Sarah Moody, Dr. June Marshall, Dr. Cole Edmonson, Earika Harris, and Dr. Deborah Stabell-Tran, you all are the reason that I am where I am today. Each of you always saw the bright future that I had in store, and although it was not always easy, you always taught me to do better and be better. Thank you. Know that I will always carry with me every day the wisdom that each of you have imparted to me.

I would also like to thank my dissertation committee, Drs. Barnes, Wang, and Raymond for their time and dedication to seeing me through this program and my dissertation. I can never thank you enough for your time reviewing and helping me revise my papers. Dr. Barnes- I will never use first person in scholarly writing again! Dr. Wang- thank you for always answering my late-night questions with my “statistical” ideas, and thank you for imparting a love of statistics in me. Dr. Raymond- thank you for saying “yes” to helping me along this journey, it has been an honor to have someone of your caliber on my committee to share your expertise in infant and pediatric CPR.

Dedication

This dissertation is dedicated first and foremost to my father, Robert Klacman, who suffered a heart attack and cardiac arrest in February 1997. I also dedicate this to anyone who has ever lost a loved one to cardiac arrest, or who has suffered a cardiac arrest. I am here for you, and I will dedicate my life's work to improving care for cardiac arrest victims. We are making improvements every day, and I am honored to be a part of that journey. Finally, I dedicate this to the staff at the study organization who championed bold change, supported new and innovative CPR training methods, and have the desire every day to improve patient care- you all are the reason that I have made it through this program.

Table of Contents

The Effects of a Novel Quarterly CPR Training Program on Hospital Basic Life Support Providers' Adult and Infant CPR Skills

Chapter 1

Introduction

Each year in the United States, approximately 292,000 adult and 15,200 pediatric patients will experience an in-hospital cardiac arrest (IHCA; Holmberg, Ross, et al., 2019). Despite improvements in IHCA survival rates over time, only 25.6% of adult patients who suffer an IHCA will survive (Benjamin et al., 2018). In pediatric patients, only 38% of those who suffer a pulseless arrest, and 66% of those who suffer a non-pulseless arrest will survive (Holmberg, Wiberg, et al., 2019).

Critical to improving survival rates following cardiac arrest is the provision of high-quality cardiopulmonary resuscitation (CPR). Even with the delivery of high-quality CPR, only 10%-30% of normal blood flow to the heart and 30%-40% of normal blood flow to the brain is achieved (Meaney et al., 2013). To achieve this critical but small fraction of blood flow during cardiac arrest, CPR providers must adhere to the most current evidence-based basic life support guidelines. Even though guidelines exist that direct providers on how to perform effective CPR, researchers have demonstrated that adherence to the guidelines is poor during both adult and pediatric cardiac arrests (Abella, Alvarado, et al., 2015; Abella, Sando, et al., 2005; Auerbach et al., 2018; Sutton et al., 2018; Sutton et al., 2019). Poor adherence to basic life support guidelines could be a contributing factor to the low survival rates following an IHCA. Poor adherence raises the possibility that CPR education may not be adequate to allow providers to obtain and maintain high-quality CPR skill performance.

Significance of Cardiac Arrest

Although rates of survival to hospital discharge following an IHCA are improving, important consideration must be given to the functional and cognitive status of patients at the time of hospital discharge. Providing high-quality CPR during a cardiac arrest is important to optimize the chances of obtaining a favorable neurological status following cardiac arrest. The most current statistical updates on heart disease from the American Heart Association (AHA) revealed that only 21.2% of adults and 14.2% of children left the hospital with favorable neurological outcome status post-cardiac arrest (Virani et al., 2020). In adults, neurologic status appears to improve during the first six months following cardiac arrest, with a slowing of improvements after six months (Raina et al., 2015). Even though neurological status appears to improve over time, disabilities in activities of daily living continue at one-year post-cardiac arrest.

Few studies were found in the literature that focused on the cognitive status of adults following an IHCA. In adult out-of-hospital cardiac arrest survivors, cognitive status appears to be favorable (Beesems et al., 2014; Tiainen et al., 2018). The majority of studies on cognitive status post-cardiac arrest have demonstrated that patients have Cerebral Performance Category scores of one to two, indicating good cognitive function (Sabedra et al., 2015; Tiainen et al., 2018). Adult patients with poor cognitive function following cardiac arrest appear to have significant memory and executive function impairments (Chew et al., 2018; Sabedra et al., 2015).

In children, there were few studies found that focused on functional outcomes following an IHCA. However, Wolfe et al. (2019) demonstrated that relative to baseline functional status, those with good function prior to cardiac arrest tended to have worse functional outcomes following cardiac arrest. This may be due to the difficulty in detecting functional changes in those with poor functional status at baseline. In children with out-of-hospital cardiac arrest, greater cognitive disability was noted in children with higher cognitive functioning at baseline (Slomine et al., 2016). Like functional changes, this may be due to the difficulty in detecting cognitive changes in those with pre-existing cognitive disabilities. Cognitive dysfunction in children following cardiac arrest appears to persist at one-year post-arrest (Slomine et al., 2016).

Background on Poor Quality Cardiopulmonary Resuscitation

Over the past few years, increasing attention has focused on CPR education as a contributing factor to poor-quality CPR skill performance. Until recently, the majority of CPR education occurred once every two years in a classroom setting (massed learning) where focus was placed on obtaining a BLS card as validation of competence in performing CPR. In 2015, the AHA shifted its' two-year training paradigm to place more emphasis on spaced learning with a focus on mastery of the skills required to perform effective high-quality CPR (Bhanji et al., 2015). Although the optimal timing of these spaced learning sessions is not known, it appears to be between one and three months (Anderson et al., 2019; Lin et al., 2018; Niles et al., 2017; Oermann et al., 2011; Sullivan et al., 2015). Even though researchers have demonstrated improvements in CPR skill quality with frequent refresher training, the resources needed to sustain such training programs may make them difficult to implement at some healthcare organizations.

In 2018, the AHA released eight recommendations to transform CPR education with innovative, educationally sound training methods (Cheng et al., 2018). Included among these recommendations were spaced learning, deliberate practice, feedback, and debriefing. To bring all of these recommendations into one training program, the AHA and Laerdal Medical developed a novel, quarterly CPR training program that incorporates real-time audiovisual feedback while CPR providers are practicing adult/child and infant CPR skills (Resuscitation

Quality Improvement Partners, 2021). Following the completion of the skill activities, providers receive automated debriefings on their skill performance that provide recommendations for improving their CPR skill quality. To date, there have been few studies that have focused on outcomes from the novel quarterly CPR training program and whether CPR providers are able to obtain and maintain high-quality adult and infant CPR skills over time.

Theory Framework

Behaviorism is a classical learning theory that emphasizes a learner's observable response to a stimulus (Moore, 2011; Skinner, 1974). Behaviorists theorize that learning occurs when a learner is repeatedly exposed to a stimulus. Learning will not occur if there is no behavior repetition over time. Additionally, Skinner’s model of behaviorism includes the central tenant of feedback which serves to either reinforce a positive behavior or extinguish a negative behavior (Skinner, 1974).

Behaviorism is a viable theory to explain how the novel quarterly CPR training program improves CPR providers CPR skills over time. Learning the behaviors of performing high-quality CPR occurs over time and through repeated practice with feedback. Without repeated exposure to performing CPR skills, CPR skill quality declines rapidly. Additionally, without feedback on performance, poor technique in chest compressions and ventilation will continue and providers will not be able to perform high-quality CPR. Through the audio and visual feedback that the novel CPR training program provides, poor-quality CPR can be corrected rapidly.

One limitation of the theory is that there is very little research in regards to the spacing of education sessions for optimal learning. Skinner (1974) does note that there must be a balance between too much positive reinforcement and too little positive reinforcement. If learners are continuously exposed to positive reinforcement, it may extinguish the power of that reinforcement. Future studies are needed to determine the optimal spacing of skills sessions to achieve high-quality CPR skill performance as quickly as possible.

Manuscript #1

Since little was found in the literature regarding the novel quarterly CPR training program, there was a need to determine the effects of this type of training on CPR providers' ability to obtain and maintain high-quality CPR skill performance. Manuscript #1 focused on examining the effects of the training program on 109 BLS providers adult chest compression and bag-mask ventilation skill performance over four quarters of training at a single hospital in Texas. For this study, BLS providers were classified at baseline into two groups dependent on whether they met the adult CPR measure at baseline (quarter 1). Providers were followed over three additional quarters to determine if those providers who failed to meet the recommended measure at baseline improved their performance over time, and if those providers who met the recommended target at baseline maintained their performance over time.

Research Questions for Manuscript #1

1. For BLS providers who do not meet the recommended adult chest compression measure at baseline (quarter 1), does the training program help improve their performance over subsequent quarters?

2. For BLS providers who meet the recommended adult chest compression measure at baseline (quarter 1), does the training program help maintain their performance over subsequent quarters?

3. For BLS providers who do not meet the recommended adult bag-mask ventilation measure at baseline (quarter 1), does the training program help improve their performance over subsequent quarters?

4. For BLS providers who meet the recommended adult bag-mask ventilation measure at baseline (quarter 1), does the training program help maintain their performance over subsequent quarters?

Findings in Manuscript #1

BLS providers who did not meet the recommended adult chest compression and ventilation measures at baseline quickly improved their performance during quarter 2 and maintained that performance over subsequent quarters. BLS providers who met the recommended adult chest compression and ventilation measures at baseline maintained their performance over subsequent quarters. The training program may be a viable training option for BLS providers that will allow them to obtain and maintain high-quality adult chest compression and ventilation skill quality over time.

Limitations of Manuscript #1

1. This was a retrospective cohort study at a single hospital in Texas, therefore the results cannot be generalized to other hospitals.
2. As no one was watching the participants while they were completing the skills, the fidelity of the study results cannot be determined.

Author Contributions to Manuscript #1

Alex Klacman, the primary investigator on manuscript #1 collected de-identified data from the training program's analytics database on all providers who met the inclusion criteria for the study and was the primary author who wrote the manuscript. Dr. Jing Wang, the study statistician, assisted with all statistical calculations and provided editorial assistance with the results section of the manuscript. Dr. Donelle Barnes, provided oversight on all aspects of the study and assisted with editing the manuscript for publication.

Manuscript #2

After completion of manuscript #1, it was determined that there was little in the literature regarding the effects of the novel quarterly CPR training program on hospital BLS providers ability to obtain and maintain high-quality infant CPR skills over time. Manuscript #2 focused on examining the impact of the training program on hospital BLS providers' infant compression and ventilation skills with audiovisual feedback (unblinded) over three consecutive quarters as compared to a baseline skill test without audiovisual feedback (blinded). The study was conducted at a single hospital in Texas and included 116 BLS providers in the data analysis.

Research Questions for Manuscript #2

1. At baseline without audiovisual feedback, how do BLS providers perform on an infant chest compression and ventilation skill test.
2. Compared to the baseline skill test, how do BLS providers perform over three subsequent quarters on infant chest compressions and ventilations with audiovisual feedback.

Findings in Manuscript #2

At baseline, a cut-off value of 95% was utilized to determine whether providers met the recommended CPR metric. For this study, the only data that was available was the percentage of the time that providers were within the correct target for the recommended CPR metric. For all chest compression measures, at baseline without audiovisual feedback, the median of the percent of time within the correct target range was greater than the 95% cut-off value. However, for infant ventilation measures, providers significantly underperformed and the median of the percent of time within the correct target range did not meet the 95% cut-off value. During quarter 1, with audiovisual feedback all measures met the cut off value of 95%, suggesting that providers were able to improve their performance with audiovisual feedback. Performance gains for most measures slowed over quarter 2 and quarter 3, suggesting that audiovisual feedback helped providers maintain their performance over time. Additionally, the odds of meeting the target of 95% improved for all measures over time.

Limitations of Manuscript #2

1. This was a retrospective cohort study at a single hospital in Texas, therefore the results cannot be generalized to other hospitals.
2. As no one was watching the participants while they were completing the skills, the fidelity of the study results cannot be determined.

Author Contributions to Manuscript #2

Alex Klacman, the primary investigator on manuscript #1 collected de-identified data from the training program's analytics database on all providers who met the inclusion criteria for the study and was the primary author who wrote the manuscript. Dr. Jing Wang, the study statistician, assisted with all statistical calculations and provided editorial assistance with the results section of the manuscript. Dr. Donelle Barnes provided oversight on all aspects of the study and assisted with editing the manuscript for publication. Dr. Raymond provided expertise and guidance in the interpretation and discussion sections given her expertise in infant and pediatric CPR.

References

Abella, B. S., Alvarado, J. P., Myklebust, H., Edelson, D. P., Barry, A., O'hearn, N., Vanden Hoek, T. L., & Becker, L. B. (2005). Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. *JAMA, 293*(3), 305-310. https://doi.org/10.1001/jama.293.3.305

Abella, B. S., Sandbo, N., Vassilatos, P., Alvarado, J. P., O'hearn, N., Wigder, H. N., Hoffman, P., Tynus, K., Vanden Hoek, T. L., & Becker, L. B. (2005). Chest compression rates during cardiopulmonary resuscitation are suboptimal: A prospective study during in-hospital cardiac arrest. *Circulation, 111*(4), 428-434. https://doi.org/10.1161/01.CIR.0000153811.84257.59

Anderson, R., Sebaldt, A., Lin, Y., & Cheng, A. (2019). Optimal training frequency for acquisition and retention of high-quality CPR skills: A randomized trial. *Resuscitation, 135*, 153-161. https://doi.org/j.resuscitation.2018.10.033

Auerbach, M., Brown, L., Whitfill, T., Baird, J., Abulebda, K., Bhatnagar, A., Lutfi, R., Gawel, M., Walsh, B., Tay, K.-Y., Lavoie, M., Nadkarni, V., Dudas, R., Kessler, D., Katznelson, J., Ganghadaran, S., & Hamilton, M. F. (2018). Adherence to pediatric cardiac arrest guidelines across a spectrum of fifty emergency departments: A prospective, in situ, simulation-based study. *Academic Emergency Medicine, 25*(12), 1396-1408. https://doi.org/10.1111/acem.13564/full

Beesems, S. G., Wittebrood, K. M., De Haan, R. J., & Koster, R. W. (2014). Cognitive function and quality of life after successful resuscitation from cardiac arrest. *Resuscitation, 85*(9), 1269-1274. https://doi.org/j.resuscitation.2014.05.027

Benjamin, E. J., Virani, S. S., Callaway, C. W., Chamberlain, A. M., Chang, A. R., Cheng, S., Chiuve, S. E., Cushman, M., Delling, F. N., Deo, R., de Ferranti, S. D., Ferguson, J. F., Fornage, M., Gillespie, C., Isasi, C. R., Jimenez, M. C., Jordan, L. C., Judd, S. E., Lackland, D. ... Munter, P. (2018). Heart disease and stroke statistics-2018 update: A report from the American Heart Association. *Circulation, 137*(12), 67-492. https://doi.org/10.1161/CIR.0000000000000558

Bhanji, F., Donoghue, A. J., Wolff, M. S., Flores, G. E., Halamek, L. P., Berman, J. M., Sinz, E. H., & Cheng, A. (2015). 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care: Part 14: Education. *Circulation, 132*, S561-S573. https://doi.org/10.1161/CIR.0000000000000268

Cheng, A., Nadkarni, V. M., Mancini, M. B., Hunt, E. A., Sinz, E. H., Merchant, R. M., Donoghue, A., Duff, J. P., Eppich, W., Auerbach, M., Bigham, B. L., Blewer, A. L., Chan, P. S., & Bhanji, F. (2018). Resuscitation education science: Educational strategies to improve outcomes from cardiac arrest: A scientific statement from the American Heart Association. *Circulation, 138*(6), e82-e122. https://doi.org/10.1161/CIR.0000000000000583

Chew, H.-S. J., Cheng, H. Y., Cao, X., & Lopez, V. (2018). Cognitive assessment in adult cardiac arrest survivors: What is known and how shall we move forward? *Connect: The World of Critical Care Nursing, 12*(3), 56-69. https://doi.org/10.1891/1748-6254.12.3.56

Holmberg, M. J., Ross, C. E., Fitzmaurice, G. M., Chan, P. S., Duval-Arnould, J., Grossestreuer, A. V., Yankama, T., Donnino, M. W., & Anderson, L. W. (2019). Annual incidence of adult and pediatric in-hospital cardiac arrest in the United States. *Circulation: Cardiovascular Quality and Outcomes, 12*(7), 1-8. https://doi.org/10.1161/CIRCOUTCOMES.119.005580

Holmberg, M. J., Wiberg, S., Ross, C. E., Kleinman, M., Hoeyer-Nielsen, A. K., Donnino, M. W., & Anderson, L. W. (2019). Trends in survival after pediatric in-hospital cardiac arrest in the United States. *Circulation, 140*(17), 1398-1408. https://doi.org/10.1161/CIRCULATIONAHA.119.041667

Lin, Y., Cheng, A., Grant, V. J., Currie, G. R., & Hecker, K. G. (2018). Improving CPR quality with distributed practice and real-time feedback in pediatric healthcare providers- A randomized controlled trial. *Resuscitation, 130*, 6-12. https://doi.org/10.1016/j.resuscitation.2018.06.025

Meaney, P. A., Bobrow, B. J., Mancini, M. E., Christenson, J., de Caen, A. R., Bhanji, F., Abella, B. S., Kleinman, M. E., Edelson, D. P., Berg, R. A., Aufderheide, T. P., Menon, V., & Leary, M. (2013). Cardiopulmonary resuscitation quality: Improving cardiac resuscitation outcomes both inside and outside the hospital: A consensus statement from the American Heart Association. *Circulation, 128*(4), 417-435. https://doi.org/10.1161/CIR.0b013e31829d8654

Moore, J. (2011). Behaviorism. *The Psychological Record, 61*, 449-464. doi:10.1007/BF03395771

Oermann, M. H., Kardong-Edgren, S. E., & Odom-Maryon, T. (2011). Effects of monthly practice on nursing students' CPR psychomotor skill performance. *Resuscitation, 82*, 447-453. https://doi.org/10.1016/j.resuscitation.2010.11.022

Raina, K. D., Rittenberger, J. C., Holm, M. B., & Callaway, C. W. (2015). Functional outcomes: One year after a cardiac arrest. *BioMed Research International, 2015*, 1-8. https://doi.org/10.1155/2015/283608

Resuscitation Quality Improvement Partners. (2021). Why RQI? https://rqipartners.com/solutions/in-hospital-solutions/rqi-resuscitation-quality-improvement/

Sabedra, A. R., Kristan, J., Raina, K., Holm, M. B., Callaway, C. W., Guyette, F. X., Dezfulian, C., Doshi, A. A., & Rittenberger, J. C. (2015). Neurocognitive outcomes following successful resuscitation from cardiac arrest. *Resuscitation, 90*, 67-72. https://doi.org/10.1016/j.resuscitation.2015.02.023

Skinner, B. F. (1974). *About behaviorism* (1st ed.). Random House.

Sullivan, N. J., Duval-Arnould, J., Twilley, M., Smith, S. P., Askamit, D., Boone-guercio, P., Jeffries, P. R., & Hunt, E. A. (2015). Simulation exercise to improve retention of cardiopulmonary resuscitation priorities for in-hospital cardiac arrests: A randomized controlled trial. *Resuscitation, 86*, 6-13. https://doi.org/10.1016/j.resuscitation.2014.10.021

Sutton, R. M., Reeder, R. W., Landis, W., Meert, K. L., Yates, A. R., Berger, J. T., Newth, C. J., Carcillo, J. A., Mcquillen, P. S., Notterman, D. A., Holubkov, R., Dean, J. M., Nadkarni, V. M., & Berg, R. A. (2018). Chest compression rates and pediatric in-hospital cardiac arrest survival outcomes. *Resuscitation, 130*, 159-166. https://doi.org/10.1016/j.resuscitation.2018.07.015

Sutton, R. M., Reeder, R. W., Landis, W. P., Meert, K. L., Yates, A. R., Morgan, R. W., Berger, J. T., Newth, C. J., Carcillo, J. A., McQuillen, P. S., Harrison, R. E., Moler, F. W., Pollack, M. M., Carpenter, T. C., Notterman, D. A., Holubkov, R., Dean, J. M., Nadkarni, V. M., & Berg, R. A. (2019). Ventilation rates and pediatric in-hospital cardiac arrest survival outcomes. *Critical Care Medicine, 47*(11), 1627-1636. https://doi.org/10.1097/CCM.0000000000003898

Tiainen, M., Vaahersalo, J., Skrifvars, M., Hastbacka, J., Gronlund, J., & Pettila, V. (2018). Surviving out-of-hospital cardiac arrest: the neurological and functional outcome and health-related quality of life one year later. *Resuscitation, 129*, 19-23. https://doi.org/10.1016/j.resuscitation.2018.05.011

Virani, S. S., Alonso, A., Benjamin, E. J., Bittencourt, M. S., Callaway, C. W., Carson, A. P., Chamberlain, A. M., Chang, A. R., Cheng, S., Delling, F. N., Djousse, L., Elkind, M. S. V., Ferguson, J. F., Fornage, M., Khan, S. S., Kissela, B. M., Knutson, K. L., Kwan, T. W., Lackland, D. T. ... Tsao, C. W. (2020). AHA statistical update: Heart disease and stroke statistics-2020 update. *Circulation, 141*, e139-e596. https://doi.org/10.1161/CIR.0000000000000757

Wolfe, H. A., Sutton, R. M., Reeder, R. W., Meert, K. L., Pollack, M. M., Yates, A. R., Berger, J. T., Newth, C. J., Carpenter, T. C., Notterman, D. A., Holubkov, R., Dean, J. M., Nadkarni, V. M., & Berg, R. A. (2019). Functional outcomes among survivors of pediatric in-hospital cardiac arrest are associated with baseline neurologic and functional status, but not with diastolic blood pressure during CPR. *Resuscitation, 143*, 57-65. https://doi.org/10.1016/j.resuscitation.2019.08.006

The Effects of a Novel Quarterly CPR Training Program on Hospital Basic Life Support Providers' Adult and Infant CPR Skills

Chapter 2

The Effects of a Novel Quarterly Cardiopulmonary Resuscitation Training Program on Hospital Basic Life Support Providers' Cardiopulmonary Resuscitation Skill Performance[1]

Klacman, A., Barnes, D. M., Wang, J. (2021). The effects of a novel quarterly cardiopulmonary resuscitation training program on hospital basic life support providers' cardiopulmonary resuscitation skill performance. *Journal for Nurses in Professional Development.* Advance online publication. https://doi.10.1097/NND.0000000000000727

Abstract

This is a retrospective descriptive study of a novel CPR training program. Using quarterly, brief CPR training at a skills station, hospital BLS providers who failed to meet CPR performance measures during the first quarter quickly improved on the skills necessary to meet CPR measures. Those meeting CPR measures during the first quarter maintained that performance over time. Staff nurse educators should consider incorporating innovative CPR education strategies that focus on spaced learning with immediate feedback.

The Effects of a Novel Quarterly CPR Training Program on Hospital Basic Life Support Providers' CPR Skill Performance

Introduction

Each year in the United States, approximately 211,000 adult patients experience an in-hospital cardiac arrest (IHCA; Holmberg et al., 2019). Despite improvements in IHCA survival rates over time, only 25.6% of adult patients will survive to hospital discharge (Benjamin et al., 2018). Even with training in cardiopulmonary resuscitation (CPR), health care providers often fail to perform chest compressions and ventilation that are consistent with current resuscitation guidelines (Abella et al., 2015a; Abella et al., 2015b). The failure to perform CPR that is consistent with current guidelines raises the possibility that basic life support (BLS) education may not be adequate. Inadequate education that leads to poor-quality CPR may contribute to the low survival rates following an IHCA.

Multiple factors during classroom-based BLS training may contribute to the quality of CPR performed by BLS providers. Including non-essential information in the course may increase BLS providers' cognitive load and decrease their ability to focus on the critical psychomotor skills required to perform high-quality CPR. Shortened training sessions that focus on CPR skills may reduce BLS providers' cognitive load and improve CPR quality. Researchers have shown that brief, on-going refresher training improves BLS providers' CPR skill quality (Niles et al., 2017; Panchal et al., 2020). However, it is unclear if the improved CPR skill quality is due to the targeted brief education, the more frequent training, or a combination of both. Even ultra-short training sessions of one to two minutes improves the quality of compression-only CPR provided by laypersons (Benoit et al., 2017; Beskind et al., 2017).

Additionally, the visual assessment of CPR skill quality during teaching, practice, and testing is subjective. Classroom training that incorporates feedback devices that provide objective, real-time measurement of CPR skills improves the quality of CPR performed during simulated practice sessions (Martin et al., 2013; Wagner et al., 2019; Yeung et al., 2009). Without objective feedback, BLS providers may not be able to self-correct poor CPR skills, and instructors cannot provide quality feedback to BLS providers (Brennan et al., 2016; Hansen, Rasmussen, Nebsbjerg, Stærk, & Løfgren, 2016).

Finally, training in CPR once every two years may not be adequate for BLS providers to master the skills required to perform high-quality CPR. Researchers have shown that frequent skill refresher sessions result in improved CPR skill quality (Lin et al., 2018; Niles et al., 2017). The optimal spacing of these refresher training sessions to improve BLS providers CPR skill quality is not known but appears to be between two and three months (Sullivan et al., 2015). It is possible that the optimal spacing of refresher sessions to improve CPR skill quality varies based on the individual BLS provider. Those who struggle while performing CPR skills may need more frequent training than once every three months.

Improving CPR quality during an IHCA depends on adopting evidence-based training methods. The American Heart Association (AHA) recommends CPR training that incorporates brief, on-going skill refreshers using CPR feedback devices that measure CPR skill quality (Cheng et al., 2018). However, the personnel and financial resources required to implement and sustain on-going skill refreshers may exceed many healthcare organizations' resources.

The Use of a Novel Quarterly CPR Training Program

In 2014, one Texas hospital became the first globally to implement a novel quarterly CPR training program developed by the American Heart Association and Laerdal Medical. The training program consists of brief (<10 minutes), quarterly (every three months) CPR skills practice sessions at a CPR skills station located on the hospital units. The station contains an automated computer system and an adult and infant voice-advisory CPR manikin (VAM). The

VAMs are equipped with sensors that record BLS providers' compression and ventilation skill quality. The use of VAMs to train CPR providers is not a new concept. Historically, the use of these manikins was limited to AHA HeartCode® testing for BLS certification. Recently, there has been a growing interest in using these manikins to train BLS providers on an on-going basis on the hospital units. A significant advantage of the novel quarterly training program that incorporates the use of VAMs is its' sustainability at the unit level within the hospital, eliminating the need for classroom-based BLS training.

Every three months, BLS providers perform compressions and ventilation at the skills station. During the adult CPR skills session, BLS providers perform 60 continuous compressions followed by one-minute of bag-mas ventilation. As the provider performs the compression skill, the automated computer system provides real-time audio and visual feedback on the rate and depth of compressions, the adequacy of chest recoil, and whether the provider's hands are in the correct location on the manikin's chest. During the ventilation skill, the provider receives feedback on the rate and depth of ventilation. When providers perform adequate CPR, the computer provides brief, encouraging messages ("you are doing well," "good," "great"). If CPR is inadequate, the computer uses brief messages that coach the provider on how to improve ("compress deeper," "don't compress quite so fast," "don't ventilate quite so fast"). After completing the skill, the provider receives an automated debriefing on the quality of their skills. Providers must achieve a minimum score of 75% to pass the skill. If the provider does not achieve a passing score, the skill must be repeated.

The training program includes an analytics software package that contains data on BLS providers' CPR performance. Educators can review and trend BLS providers' CPR metrics to ensure that they obtain or maintain quality CPR skills. Data in the analytics program can also be aggregated at the unit- and hospital-wide levels to identify performance improvement opportunities.

Theoretical Framework

Behaviorism is a classical learning theory that emphasizes a learner's observable response to a stimulus (Moore, 2011). Behaviorists theorize that learning occurs when a learner is repeatedly exposed to a stimulus. Learning will not occur if there is no behavior repetition over time. Learning the behaviors of performing high-quality CPR occurs over time and through repeated practice. Without repetition, CPR skill decay occurs, and BLS providers will not be able to perform high-quality CPR.

Research Purpose

To date, we know of no other studies that have examined the effect of the novel quarterly CPR training program on BLS providers' ability to obtain or maintain high-quality CPR skill performance. The primary purpose of this retrospective one-group cohort study was to examine the outcomes of this type of training on hospital BLS providers' ability to obtain and maintain high-quality CPR skill performance. For chest compression skill quality, six outcome measures were studied: (1) the average depth of compressions (in mm), (2) the average rate of compressions (in compressions per minute), (3) the percent of compressions performed at the correct depth, (4) the percent of compressions performed at the correct rate, (5) the percent of compressions where full recoil of the manikin's chest was achieved, and (6) the percent of compressions where the provider's hands were in the correct location on the manikin's chest. For the ventilation activity, three outcome measures were studied: (1) the average volume of ventilation (in mL), (2) the average rate of ventilation (in breaths per minute), and (3) the percent of ventilation where correct volumes were achieved.

Methods

We performed a retrospective one-group cohort study using existing CPR skills data in the analytics software program. The study was exempted from Institutional Review Board (IRB) oversight as it was considered non-human subjects research. We conducted the study at a large 634-bed acute care hospital in a metropolitan city in Texas.

Participants

As of January 1, 2017, there were 1,976 active BLS providers at the study hospital who were enrolled in the training program. In 2014, we lost some BLS providers' data in the analytics program when the data were migrated to a corrupted server. Additionally, changes to the maximum depth of chest compressions in the 2015 AHA Guidelines for CPR caused an interruption in the program for two quarters for the updates. Therefore, we excluded all BLS providers enrolled in the program before January 1, 2017 (n=1,110). We further excluded BLS providers who had not completed four quarters of adult CPR skills during the study period (n=866). Finally, we excluded one provider that experienced a computer malfunction while performing the first quarter's skill activities. The final sample included 102 BLS providers who were either full- or part-time hospital employees that completed four quarters of adult chest compression and ventilation skill activities between January 1, 2017, and December 31, 2018 (see Figure 1).

Sample Characteristics

Most of the study participants were female (82.5%) and registered nurses (74.8%). The nurses in the study worked on medical-surgical (25.2%), telemetry (25.2%), critical care (19.4%), and emergency (9.7%) units. Of those participants who were not nurses, 10.7% were patient care technicians, 4.9% were rehabilitation therapists (speech, physical, and occupational), and 9.6% were allied health providers (scrub, emergency medical, exercise, or telemetry).

Data Analysis

Data were analyzed using the statistical software SAS (version 9.4; SAS; Cary, NC). For each of the six compression measures, we classified the cohort into two groups depending on whether they met the recommended measure during the first quarter, defined as follows: (1) average depth of compressions (at least 50 mm), (2) average rate of compressions (100-120 compressions per minute), (3) the percent of compressions performed at the correct depth (at least 80%), (4) the percent of compressions performed at the correct rate (at least 80%), (5) the percent of compressions with full recoil of the manikin's chest (at least 80%), and (6) the percent of compressions where the participants hands were in the correct location on the manikin's chest (at least 80%).

For each of the three ventilation measures, we classified the cohort into two groups depending on whether they met the recommended measure during the first quarter, defined as follows: (1) average rate of ventilation (8 to 12 per minute), (2) average volume of ventilation (400-700 mL), and (3) the percent of ventilation at the correct rate (at least 80%). Descriptive statistics (mean ± standard deviation (SD)) were calculated for each measure classified by group. We used linear mixed-effects modeling (LMM) to test for differences between the two groups for each of the six compression measures and three ventilation measures over time. We chose LMM over simple linear models to account for hierarchical groupings and repeated measures.

Results

At the beginning of the analysis, the cohort was divided into two groups depending upon whether they met the recommended measure during the first quarter. For the group that met the recommended measure in the first quarter, we were interested in determining whether they maintained that performance over time. For the group that did not meet the recommended measure, we were interested in determining if they improved their performance over subsequent quarters to meet the recommended measure.

The first quarter chest compression data for the entire cohort showed that 79.4% (81/102) of participants were able to compress the chest at a depth of at least 50 mm; however, only 60.7% (62/102) maintained compressions at the correct depth for at least 80% of the time. These results raise the possibility that the BLS providers initially compressed at the correct depth, but during the 60 compressions, they became fatigued and were no longer able to maintain adequate compression depth.

Similarly, 92.1% (94/102) of participants were able to compress the chest at the recommended rate, but only 63.7% (65/102) maintained the correct rate for at least 80% of the time. These results suggest that the BLS providers initially struggled to provide compressions at the correct rate and improved over time, or they became fatigued over time and were no longer able to maintain adequate rates towards the end of the activity.

During the second quarter, the group that did not meet the target for chest compression depth, average compression rate, percent of compressions with full chest recoil, and percent of compressions with correct hand placement were able to improve their performance to meet the target and maintained their performance during quarters three and four (See Table 1). For percent of compressions at the correct depth and percent of compressions at the correct rate, the group that did not meet the target in the first quarter met the target at quarter three and maintained their performance at quarter four.

For the ventilation measures, the entire cohort was able to ventilate the manikin at the correct rate. Only two participants were unable to ventilate at the correct volume during the first quarter. During the second quarter, these two participants met the volume target and maintained their performance during quarters three and four. Although 98% (100/102) of the participants were able to meet the ventilation volume target during the first quarter, only 85.2% (87/102) maintained correct volumes at least 80% of the time. Those participants who were unable to maintain ventilation volumes at least 80% of the time during the first quarter met the target in the second quarter and maintained their performance over quarters three and four.

The linear mixed-effects model (see Table 1) showed that the interaction effect of time and group was significant for all compression and ventilation measures during the first quarter. This suggests that there were significant differences between the two groups in terms of their performance for each measure; in particular, the group that did not meet the measure underperformed the group that met the measure. At the second quarter, these significant differences in performance diminished for the following measures: (1) chest compression depth, (2) percent of compressions at the correct rate, (3) percent of compressions with hands in the correct location on the manikin's chest, and (4) percent of ventilation with correct volumes. For the measures of average compression rate and percent of compressions with full chest recoil, significant differences in performance persisted during quarter two but diminished during quarters three and four. Finally, for the percent of compressions at the correct depth, although the group that did not meet the target at quarters one and two met the target at quarters three and four, their performance remained significantly different during each quarter from the group that met the target at the first quarter.

Discussion

To our knowledge, this is the first study analyzing the effects of a novel quarterly CPR training program using an automated computer system with adult and infant voice-advisory CPR manikins on BLS providers' CPR skill performance. The results of our study suggest that this program may be a practical way to train BLS providers. To support our hypothesis that this automated training program has better outcomes as compared to standard CPR training, a two-group prospective study is needed.

These results also support the recent AHA Scientific Statement on Resuscitation Education that recommends innovative education strategies that focus on spaced learning and immediate feedback with debriefing (Cheng et al., 2018). Although the novel training program uses quarterly, brief training, future studies are needed to determine whether quarterly training is sufficient for all BLS providers. It may be that a variable training schedule based on the individual BLS provider's performance is best. BLS providers who can perform adequate CPR may not need to train every three months, while those who struggle may need to train more often than every three months to improve their performance.

Limitations

There are multiple limitations to this study. First, the study's retrospective nature severely limits the ability to compare this training program to other types of CPR training programs. A prospective study with rigorous control is needed to determine how this novel quarterly training program compares to other CPR training types. We do not know about this program's fidelity as no proctor was present while the BLS providers performed their skills.

Additionally, the study participants were mainly female registered nurses, which limits generalizing these results to male health care providers and other health care occupations. Further, we conducted the study at one hospital in Texas, limiting the generalizability of the results to other hospitals and healthcare systems. Although our organization was the first globally to implement the novel training program, other hospitals near the study site implemented the program during the study period. It is possible that if a provider worked at the study hospital and another organization using the novel training program, that the provider may have completed the activities more than once each quarter. Multiple completions each quarter could have influenced their skill performance at the study hospital.

Finally, we are unsure of how skills practice in the novel training program translates into actual performance during an IHCA. The skills stations used in this study were located in quiet, private rooms where there were minimal distractions. During actual IHCA events where distractions are common, it is possible that CPR performance may not correlate well with CPR practice in quiet locations with minimal distractions. Additionally, the chest of CPR manikins may not accurately simulate the dynamic properties of the human chest. Standard-size CPR manikins are not realistic for all body types. Future studies are needed to determine how performance on the standard CPR manikin correlates with performance on an obese manikin.

References

Abella, B. S., Alvarado, J. P., Myklebust, H., Edelson, D. P., Barry, A., O'Hearn, N., & Becker, L. B. (2005a). Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. *JAMA, 293*, 305-310. doi:10.1001/jama.293.3.305

Abella, B. S., Sandbo, N., Vassilatos, P., Alvarado, J. P., O'Hearn, N., Wigder, H. N.,...Becker, L. B. (2005b). Chest compression rates during cardiopulmonary resuscitation are suboptimal: A prospective study during in-hospital cardiac arrest. *Circulation, 111*, 428-434. doi:10.1161/01.CIR.0000153811.84257.59

Benjamin, E. J., Virani, S. S., Callaway, C. W., Chamberlain, A. M., Chang, A. R., Cheng, S.,...Munter, P. (2018). Heart disease and stroke statistics- 2018 update: A report from the American Heart Association. *Circulation, 137*, e67-e492. doi://doi.org/10.1161/CIR.0000000000000558

Benoit, J. L., Vogele, J., Hart, K. W., Lindsell, C. J., & McMullan, J. T. (2017). Passive ultra-brief video training improves performance of compression-only cardiopulmonary resuscitation. *Resuscitation, 115*, 116-119. doi:10.1016/j.resuscitation.2017.04.008

Beskind, D. L., Solz, U., Thiede, R., Hoyer, R., Robertson, W., Brown, J.,...Panchal, A. R. (2017). Viewing an ultra-brief chest compression only video improves some measures of bystander CPR performance and responsiveness at a mass gathering event. *Resuscitation, 118*, 96-100. doi:10.1016/j.resuscitation.2017.07.011

Brennan, E. E., McGraw, R. C., & Brooks, S. C. (2016). Accuracy of instructor assessment of chest compression quality during simulated resuscitation. *Canadian Journal of Emergency Medicine, 18*, 276-282. doi:10.1017/cem.2015.104

Cheng, A., Nadkarni, V. M., Mancini, M. B., Hung, E. A., Sinz, E. H., Merchant, R. M.,...Bhanji, F. (2018). Resuscitation education science: Educational strategies to improve outcomes from cardiac arrest. *Circulation, 138*, 82-122. doi:10.1161/CIR.0000000000000583

Hansen, C., Rasmussen, S. E., Nebsbjerg, M. A., Stærk, M., & Løfgren, B. (2016). Certified basic life support instructors assess cardiopulmonary resuscitation skills poorly [Supplement]. *Circulation, 134*(1), . Retrieved from http://www.ahajournals.org/doi/abs/10.1161/circ.134.suppl_1.16131

Holmberg, M. J., Ross, C. E., Fitzmaurice, G. M., Chan, P. S., Duval-Arnould, J., Grossestreuer, A. V.,...Anderson, L. W. (2019). Annual incidence of adult and pediatric in-hospital cardiac arrest in the United States. *Circulation: Cardiovascular Quality and Outcomes, 12*(7), 1-8. doi:10.1161/CIRCOUTCOMES.119.005580

Lin, Y., Cheng, A., Grant, V. J., Currie, G. R., & Hecker, K. G. (2018). Improving CPR quality with distributed practice and real-time feedback in pediatric healthcare providers- A randomized controlled trial. *Resuscitation, 130*, 6-12. doi:10.1016/j.resuscitation.2018.06.025

Martin, P., Theobald, P., Kemp, A., Maguire, S., Maconochie, I., & Jones, M. (2013). Real-time feedback can improve infant manikin cardiopulmonary resuscitation by up to 79%- A randomized controlled trial. *Resuscitation, 84*, 1125-1130. doi:10.1016/j.resuscitation.2013.03.029

Moore, J. (2011). Behaviorism. *The Psychological Record, 61*, 449-464. doi:10.1007/BF03395771

Niles, D. E., Nishisaki, A., Sutton, R. M., Elci, O. U., Meaney, P. A., O'Connor, K. A.,...Nadkarni, V. (2017). Improved retention of chest compression psychomotor skills with brief "rolling refresher" training. *Simulation in healthcare: Journal of the Society for Simulation in Healthcare, 12*, 213-219. doi:10.1097/SIH.0000000000000228

Oermann, M. H., Kardong-Edgren, S. E., & Odom-Maryon, T. (2011). Effects of monthly practice on nursing students' CPR psychomotor skill performance. *Resuscitation, 82*, 447-453. doi:10.1016/j.resuscitation.2010.11.022

Panchal, A. R., Norton, G., Gibbons, E., Buehler, J., & Kurz, M. C. (2020). Low dose- high frequency, case based psychomotor CPR training improves compression fraction for patients with in-hospital cardiac arrest. *Resuscitation, 146*, 26-31. doi:10.1016/j.resuscitation.2019.10.034

Sullivan, N. J., Duval-Arnould, J., Twilley, M., Smith, S. P., Aksamit, D., Boone-Guercio, P.,...Hunt, E. A. (2015). Simulation exercise to improve retention of cardiopulmonary resuscitation priorities for in-hospital cardiac arrests: A randomized controlled trial. *Resuscitation, 86*, 6-13. doi:10.1016/j.resuscitation.2014.10.021

Wagner, M., Bibl, K., Hrdliczka, E., Steinbauer, P., Stiller, M., Gropel, P.,...Olischar, M. (2019). Effects of feedback on chest compression quality: A randomized simulation study. *Pediatrics, 143*(2), 1-9. doi:10.1542/peds.2018-2441

Wik, L., Thowsen, J., & Steen, P. A. (2001). An automated voice advisory manikin system for training in basic life support without an instructor. A novel approach to CPR training. *Resuscitation, 50*, 167-172. doi:10.1016/S0300-9572(01)00331-8

Yeung, J., Meeks, R., Edelson, D., Gao, F., Soar, J., & Perkins, G. D. (2009). The use of CPR feedback/prompt devices during training and CPR performance: A systematic review. *Resuscitation, 80*, 743-751. doi:10.1016/j.resuscitation.2009.04.012

Yiqun, L., Cheng, A., Grant, V. J., Currie, G. R., & Hecker, K. G. (2018). Improving CPR quality with distributed practice and real-time feedback in pediatric healthcare providers-A randomized controlled trial. *Resuscitation, 130*, 6-12. doi:10.1016/j.resuscitation.2018.06.025

Figure 1.

Participant Enrollment

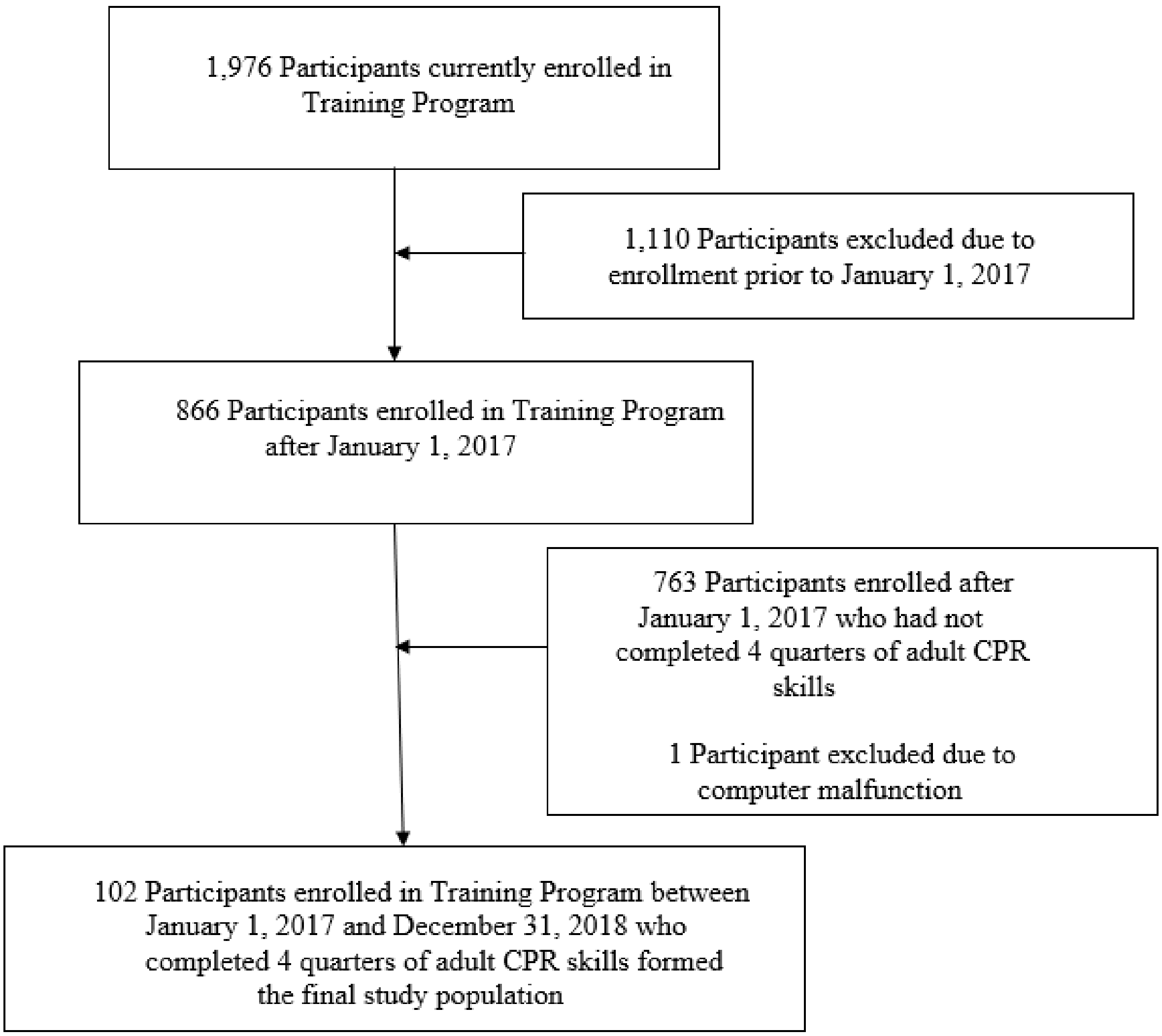

Table 1.

CPR Skill Measures by Group and Quarter

	Group Not Meeting Target			Group Meeting Target		LMM analysis
CPR Skill	Quarter	N	Mean (STD)	N	Mean (STD)	Effect
Chest Compression Depth (in mm)	1	21	47.3 (2.4)	81	53.3 (2.5)	6.0*
	2		53.0 (3.8)		53.2 (3.1)	.2
	3		53.1 (2.8)		54.1 (2.9)	1.0
	4		53.1 (2.9)		54.1 (2.8)	1.0
Percent of Compressions at Correct Depth	1	40	51.1 (21.3)	62	92.5 (6.2)	41.4*
	2		78.8 (17.8)		86.9 (16.3)	8.1*
	3		84.3 (18.4)		90.5 (14.9)	6.2*
	4		84.0 (18.7)		91.5 (14.2)	7.5*
Average Compression Rate	1	8	96.5 (3.8)	94	109.1 (6.1)	12.6*
	2		100.6 (6.1)		107.8 (6.7)	7.2*
	3		107.9 (7.5)		107.7 (7.0)	-.2
	4		108.2 (6.5)		108.0 (6.0)	-.2
Percent of Compressions at Correct Rate	1	37	58.4 (17.0)	65	92.9 (6.3)	34.5*
	2		77.0 (21.1)		81.8 (25.0)	4.8
	3		83.6 (20.8)		83.0 (26.2)	-.6
	4		84.5 (19.1)		87.2 (19.2)	2.7
Percent of Compressions with Full Chest Recoil	1	22	55.9 (23.6)	79	96.2 (5.2)	40.3*
	2		80.8 (19.4)		90.4 (16.7)	9.6*
	3		86.9 (20.5)		93.3 (14.7)	6.4
	4		88.8 (13.9)		94.8 (10.3)	6.0
Percent of Compressions with Correct Hand Placement	1	3	75.7 (2.5)	99	98.6 (3.6)	22.9*
	2		100.0 (0.0)		98.3 (5.2)	-1.7
	3		96.3 (6.4)		97.9 (5.7)	1.6
	4		89.3 (9.2)		98.0 (5.3)	8.7*
Average Ventilation Rate	1	-	-	102	10.7 (1.2)	-
	2	-	-	102	10.9 (1.4)	-
	3	-	-	102	11.3 (1.6)	-
	4	-	-	102	11.7 (1.2)	-
Average Ventilation Volume	1	2	372.5 (30.4)	100	524.7 (69.3)	152.2*
	2		415.0 (90.5)		513.2 (67.2)	98.2*
	3		510.0 (62.2)		526.3 (66.9)	16.3
	4		529.0 (113.1)		533.6 (66.7)	4.6
	1	15	68.0 (10.3)	87	95.2 (6.3)	27.2*

Percent of Ventilation with Correct Volume	2	85.0 (22.6)	88.7 (16.9)	3.7
	3	94.1 (6.3)	89.3 (14.8)	-4.8
	4	95.3 (9.1)	91.0 (12.1)	-4.3

*The p-value for the test is less than .001

Chapter 3

The Effects of a Novel Quarterly Cardiopulmonary Resuscitation Training Program on Hospital Basic Life Support Providers' Infant Cardiopulmonary Resuscitation Skill Performance

Abstract

The primary purpose of this retrospective cohort study was to examine the impact of a novel quarterly CPR training program on hospital BLS providers' infant CPR skills over three consecutive quarters with audiovisual feedback as compared to a baseline skill test with no feedback. One hundred and sixteen BLS providers at a single hospital in Texas were enrolled in the study. As compared to baseline, audiovisual feedback dramatically improved the quality of infant chest compressions and ventilation at quarter 1. During quarters 2 and 3, improvements continued for adherence to ventilation volumes, but other metrics showed little to no improvement compared to quarter 1. The novel CPR training program may be a practical option to assist BLS providers in obtaining and maintaining high-quality CPR skill performance over time.

The Effects of a Novel Quarter CPR Training Program on Hospital Basic Life Support Providers' Infant CPR Skills

Introduction

Approximately 15,200 pediatric in-hospital cardiac arrests (IHCAs) occur each year in the United States (Holmberg et al., 2019a). Among hospitals reporting infant cardiac arrest data in the Get with the Guidelines-Resuscitation registry, approximately 438 pulseless and 548 non-pulseless arrests occurred in infants between 2016 and 2018 (Holmberg et al., 2019b). Although pediatric IHCA survival rates have improved over time, only 38% who suffer a pulseless arrest and 66% who suffer a non-pulseless arrest will survive (Holmberg et al., 2019b).

Even with evidence-based guidelines that direct cardiopulmonary resuscitation (CPR) providers on how to perform high-quality CPR, researchers have shown that pediatric healthcare providers often perform poor-quality CPR during simulated and actual pediatric cardiac arrests (Donoghue et al., 2020; Garcia-Jordan et al., 2019; Niles et al., 2017). Significant variability exists in the quality of CPR performed across pediatric hospitals, suggesting that poor quality CPR is a widespread problem (Auerbach et al., 2018; Sutton et al., 2018; Sutton et al., 2019) and may be a contributing factor to the low survival rates following a pediatric IHCA.

Poor-quality CPR, along with the variability in CPR performance across pediatric hospitals, raises the possibility that the current recommendations for CPR training may not be adequate for basic life support (BLS) providers to achieve optimal CPR skill quality. To improve BLS providers' CPR skill quality, the American Heart Association (AHA) has shifted its' focus from CPR training once every two years (massed learning) to spaced learning where BLS providers practice CPR skills during short refresher sessions on an on-going basis (Cheng et al., 2018; Cheng et al., 2020). The use of short refresher training has been shown to improve pediatric CPR skill quality (Anderson et al., 2019; Lin et al., 2018; Niles et al., 2017). Although monthly refresher training has been shown to have the greatest effect on improving pediatric CPR skill quality (Anderson et al., 2019), the resources needed to sustain such a training program would likely overwhelm most healthcare organizations' resources. Refresher training once every two to three months has been shown to improve pediatric CPR skill quality (Anderson et al., 2019; Lin et al., 2018; Niles et al., 2017), and may provide the balance between improved skill quality and the organizational resources needed to sustain refresher CPR training programs.

The AHA has also recognized the importance of audiovisual feedback devices to aid CPR providers in performing high-quality CPR skills, and recommends that these devices be used during training, when possible (Cheng et al., 2018; Cheng et. al., 2020). The benefit of these devices during adult and pediatric simulated CPR is clear (Katipoglu et al., 2019; Zhou et al., 2020), but the benefit during simulated infant CPR is less clear, with some studies showing benefit (Garcia-Jordan et al., 2019; Lin et al., 2018; Wagner et al., 2019), and others showing little to no benefit (Austin et al., 2019). It is likely that a combination of spaced learning with audiovisual feedback leads to improved CPR skill quality over time.

In 2014, the AHA in partnership with Laerdal Medical developed a novel quarterly CPR training program designed to improve hospital BLS providers' CPR skill quality and prevent skill decay (Resuscitation Quality Improvement Partners, 2021). The novel training program uses brief, once a quarter training at a CPR skills station located on the hospital units. A computer system attached to the manikin records providers' compression and ventilation performance metrics. An analytics software packing is available that contains the performance metrics for all providers enrolled in the training program and is available for hospital personnel to review.

Research Purpose

To date, we know of no other studies that have examined the impact of the novel quarterly CPR training program on hospital BLS providers' ability to obtain and maintain high quality infant compression and ventilation skills over time. The primary purpose of this retrospective cohort study was to examine the impact of the training program on hospital BLS providers' infant compression and ventilation skills with audiovisual feedback (unblinded) over three consecutive quarters of the training program as compared to a baseline skill test without audiovisual feedback (blinded).

Methods

Study Overview

This was a retrospective cohort study of 116 BLS providers enrolled in the training program at one large teaching hospital in Texas. The hospital primarily serves adult patients with few, if any, infant and pediatric patients admitted to the hospital each year. The study hospital's emergency department may receive infant and pediatric patients, but critically ill patients are stabilized and transferred to local pediatric hospitals. For this study, we utilized the analytics database that contained individual CPR providers' infant compression and ventilation scores. As the study utilized an existing database, it was exempted from Institutional Review Board oversight as non-human subjects research.

Participants

As of February 2021, there were 1,906 BLS providers enrolled in the training program at the study hospital. During the second quarter of 2020, an updated version of the training program was released that included the baseline CPR skill test along with quarterly adult and infant CPR skill activities. As the primary purpose of this study was to examine the performance over three quarters as compared to baseline, we excluded providers who had participated in the previous version of the program (n=1,590). Providers were further excluded if they had not completed a baseline assessment and three consecutive quarters of infant CPR skills (n=200). Our final sample included 116 BLS providers who completed a baseline infant CPR skill test and three quarters of infant CPR skill activities at the study hospital between April 2020 and February 2021 (Figure 1).

Equipment

The CPR skills station contains an infant ResusciBaby (Laerdal Medical, Stavanger, Norway) manikin designed to simulate an infant less than one year of age. The manikin weighs less than 5 kg and contains sensors that record chest compression and ventilation skill quality. A computer system attached to the manikin provides real-time audiovisual feedback to BLS providers as they perform their CPR skills. A separate analytics software package contains performance metrics for individual BLS providers enrolled in the program that can be reviewed by hospital personnel.

Before completing the infant chest compression activity, providers are given a choice to review a short video on how to complete the skill. Following the video, providers complete 60 continuous compressions and receive audiovisual feedback on four compression metrics: (1) rate of compressions (in compressions per minute), (2) depth of compressions (in millimeters), (3) adequate chest recoil, and (4) correct finger location for performing compressions on the manikin's chest. During the skill, the computer generates a compression waveform that represents compression rate, depth, and recoil. If the provider meets the recommended metric, a green waveform is displayed on the screen. The waveform turns red when the metric is not met. A hand symbol is displayed on the waveform if the provider's fingers are not in the correct location for chest compressions. An accelerometer provides feedback on the rate of compressions. During the activity, providers receive positive audio messages if the compression skill is performed correctly ("good," "great," "you are doing well"). If the skill is performed incorrectly, an audio message coaches the provider on how to correct their performance ("don't compress quite so fast," "compress faster," "compress deeper"). An overall score of 75% is required to pass the compression activity.

Before completing the infant bag-mask ventilation activity, providers are given a choice to review a short video on how to complete the skill. During the bag-mask ventilation activity, providers perform one-minute of bag-mask ventilation and receive audiovisual feedback on two ventilation metrics: (1) ventilation rate (in breaths per minute) and (2) ventilation volume (in milliliters). As providers perform ventilation, a vertical bar displays the volume of ventilation. An accelerometer provides feedback on the rate of ventilation. During the activity, providers receive positive audio messages if the ventilation skill is performed correctly. If the skill is performed incorrectly, audio messages coach the provider on how to correct their performance ("don't ventilate quite so fast," "don't ventilate quite so much"). An overall score of 75% is required to pass the ventilation activity.

Procedure

At enrollment, BLS providers completed a baseline infant compression and ventilation skill test without audiovisual feedback (blinded). Immediately following the baseline skill test, providers were directed to complete their first quarter infant skill activities with audiovisual feedback (unblinded). The computer attached to the manikin captured the providers' CPR skill quality for each infant chest compressions and ventilation component. The data was available for review in the analytics software package. Data available for review at the time of this study included the percentage of time during the activity that the provider met the recommended metric for each component of infant compressions and ventilation.

Outcome Measures

The primary outcome measures for this study were based on the 2015 AHA Guidelines for pediatric BLS (Atkins et al., 2015) and included the percentage of time that BLS providers were within the target range for the rate of compressions (100-120 compressions per minute) and depth of compressions (at least 40 mm). We also included the percentage of time during the compression activity that the provider allowed the manikin's chest to fully recoil to the resting position and the percentage of time that the provider's fingers were in the correct location on the manikin's chest (center of the chest just below the nipple line). For ventilation measures, the primary outcome was the percentage of time during the activity that the provider was within the target range for ventilation rate (1 breath every 3-5 seconds) and ventilation volume (20-40 mL per breath). For this study, we set a score of 95% as the passing score for each compression and ventilation measure.

Statistical Analysis

Data were analyzed using the statistical software SAS (version 9.4, SAS; Cary, NC). Compression and ventilation measures at baseline and during each quarter exhibited a negative skew and did not meet the assumption of normality as assessed by the Shapiro-Wilk test. Median and interquartile ranges were used to summarize the data. For each of the compression and ventilation measures, the number and percentage of providers who met the passing score of 95% were calculated at baseline and for each quarter. To examine performance over time as compared to baseline, each of the six outcome measures was dichotomized based on whether the provider met the recommended pass score of 95% or did not meet the recommended pass score. For each dichotomized measure, the generalized linear mixed-effects model (GLMM) was used to compare the odds of meeting the passing score at baseline and during each of the three quarters, after adjusting for the provider's gender.

Results

116 BLS providers were included in the analysis. The characteristics of the participants are summarized in Table 1. Overall, 77% (n=89) of the participants were female. Given the variability in the participants' job role and unit worked, participants were classified as either registered nurses, allied healthcare providers, or patient care technicians. Registered nurses made up 57.1% (n=60) of the participants. Allied healthcare providers included job roles with a technician or therapist classification (certified surgical scrub tech, exercise physiologist, paramedic, physical therapist, radiographer, respiratory therapist, behavioral health therapist). Participants were further classified by the unit on which they spent the majority of their time working. The majority of participants (31.9%, n=37) worked in procedural areas (surgery, invasive cardiac services, exercise research lab, radiology). Allied health units included participants who worked in respiratory therapy, rehabilitation services, or behavioral health.

Although the training program was done quarterly, the median number of days between completion of quarter 1 and quarter 2 activities was 96 days (IQR 85, 108), with the majority of participants (48.3%, n=56) completing the activities between 91 and 120 days. Sixteen providers (13.8%) had over 120 days elapse between trainings (Table 2). Between quarter 2 and quarter 3, the median number of days between completion of the activities was 93 days (IQR 82, 102), with the majority of participants (48.3%, n=56) completing the activities between 91 and 120 days. Twelve (10.3%) of those participants had over 120 days elapse between trainings (Table 2).

Infant Compression and Ventilation Skill Quality at Baseline with No Feedback

At baseline with no audiovisual feedback, the medians of the percentages of all chest compression metrics met the recommended passing score of 95% (Table 3). Overall, 86.2% (n=100) of the participants achieved adequate chest recoil at least 95% of the time. Only 59%

(n=68) of the participants performed chest compressions in the correct location on the manikin's chest at least 95% of the time. Significant variability was observed in the data for all compression metrics except for adequate chest recoil.

For ventilation measures at baseline with no feedback, the medians of the percentages for both ventilation rate and volume did not meet the recommended passing score of 95% (Table 3). Only 44% (n=51) of the participants met the recommended ventilation rate at least 95% of the time. Only 10.3% (n=12) of the participants met the recommended ventilation volume at least 95% of the time during the activity, with the median score of 70% being well below the target of 95%. The most significant variability was observed for ventilation rate.

Infant Compression and Ventilation Skill Performance Over Time

During quarter 1 with audiovisual feedback, the medians of the percentages of all chest compression and ventilation metrics met the recommended passing score of 95% (Table 3). Significant improvements in the number of participants who met the passing score of 95% were noted for chest compression depth, correct finger location for performing compressions, and ventilation rate and volume. Less variability was observed in the data for all metrics, with ventilation rate remaining with significant variability.

As compared to baseline with no feedback, during quarter 1, participants were 36 times more likely to perform adequate chest recoil for at least 95% of the time and almost five times more likely to perform chest compressions at the adequate depth of at least 40 mm at least 95% of the time (Table 4). For ventilation rate, participants were two times more likely to meet the recommended rate and 14 times more likely to meet the recommended ventilation volume at least 95% of the time during the activity.

During quarter 2, performance improvements slowed with only slight increases noted to compression rate and ventilation volume (Table 4). During quarter 3, performance improvements increased for compression depth and ventilation volume. Participants during quarter 3 were six times more likely to meet the recommended compression depth at least 95% of the time as compared to baseline, and 29 times more likely to meet the recommended ventilation volume as compared to baseline. During quarter 3, 100% (n=116) of the participants achieved adequate chest recoil at least 95% of the time.

Discussion

To our knowledge, this retrospective cohort study is the first to describe the impact of the novel CPR training program on hospital BLS providers' ability to obtain high-quality infant CPR skill performance over time. Although we did not have access to mean compression and ventilation scores, we feel that describing the percentage of time during the activity that the provider met the recommended target is descriptive, as over time the results showed that variability in performance decreased, which suggests that BLS providers were better able to adhere to the individual compression and ventilation metrics during the skill activities.

Performing high-quality infant chest compressions is critical to an infant's survival following a cardiac arrest. Similar to previous studies on infant chest compressions (Garcia-Jordan et al., 2019; Lin et al., 2019; Niles et al., 2019), our results showed that at baseline without audiovisual feedback, BLS providers struggled to perform high-quality infant CPR. In this study, BLS providers struggled with performing chest compressions in the correct location on the manikin's chest, which may have led to poor compression depth. Recent studies have suggested that single rescuers may achieve better adherence to chest compression depths with less fatigue using the two-thumb-encircling-hands technique as compared to the two-fingers technique (Lee et al., 2019; Millin et al., 2020; Tsou et al., 2020). Although the short training video available before completing the infant compression skill demonstrates the two-finger technique, we could not determine which technique for performing compressions that providers used due to the retrospective nature of this study.

The results of the baseline ventilation volume and rate skill test are concerning, given that respiratory arrest is a frequent cause of infant non-pulseless arrests. During the baseline skill test, less than one-half of BLS providers in this study achieved adequate ventilation rates and volumes at least 95% of the time. Previous studies have shown that hyperventilation is common during simulated and actual pediatric CPR (Donoghue et al., 2020; Niebauer et al., 2011; Sutton et al., 2019), but these studies have not described adherence to ventilation volumes. The results of this study suggest that serious errors exist in providing adequate ventilation volumes, with this metric showing the poorest adherence to recommended guidelines during the baseline skill test. There are three possible explanations for the poor adherence to ventilation volume: (1) providers administered too large of volumes (greater than 40 mL), (2) providers hyperextended the neck leading to an obstructed airway with failure to administer volume, or (3) mask leak leading to inadequate volumes. The retrospective nature of this study did not allow us to be able to determine the cause. However, given that the providers in this study rarely respond to infant cardiac and respiratory arrests, and given the slightly better adherence to ventilation rates at baseline, it is likely that providers either administered excessive volumes or had mask leak with too little volume delivered.

The results of this study demonstrate that the use of audiovisual feedback leads to significant improvements in infant compression and ventilation skills during quarter 1 as compared to the baseline skill test. Given the dramatic improvements in performance during quarter 1, and the slowing of improvements during quarters 2 and 3, the audiovisual feedback could be directly responsible for these improvements. These findings are similar to others who have found that audiovisual feedback improves the quality of chest compressions performed during simulated infant CPR (Garcia-Jordan et al., 2019; Martin et al., 2013; Niles et al., 2017; Wagner et al., 2019). It is unclear whether providers responded more to the audio or the visual feedback provided by the computer program.

Finally the results of this study suggest that the program has a positive effect on improving BLS providers infant CPR skill quality over time. Although performance improvements were noted during quarters 2 and 3 for compression depth and ventilation volumes, other metrics showed little to no improvement in performance as compared to quarter 1. These results must be interpreted within the context of the days elapsed between training. The majority of providers in this study completed their skills between 91 and greater than 120 days from their previous training. This suggests that providers in this study may have had better skill performance if less time had elapsed between trainings. In the future, more studies are needed to determine the impact of different training intervals on BLS providers ability to obtain and maintain high-quality infant CPR skills. It is possible that providers may respond best to a variable training schedule based on their skill performance. Those who struggle may need more frequent training until they are able to adequately perform CPR skills, whereas those who meet performance metrics may need less frequent training.

There are several limitations in this study. First, the retrospective nature of this study is a threat to the validity and generalizability of the results, and thus the novel training program cannot be compared to other current CPR training programs. Future prospective studies with adequate control are needed to determine how the novel training program compares to other types of CPR training. As no proctor was watching providers as they were completing their CPR skills, the fidelity of the study results cannot be verified.

Second, as this study was conducted at one hospital in Texas that primarily compares for adult patients, the results of this study cannot be generalized to hospitals in other areas or hospitals that treat infant and pediatric patients. Although we excluded participants who were enrolled in the training program prior to April 2020, most of the participants in this study were new to the study hospital after April 2020. It is possible that participants were enrolled in the training program at a previous place of employement. It is also possible that participants were enrolled in the training program at a second place of employment that utilized the novel training program and could have completed the infant CPR skills more than once during each quarter.

Finally, the CPR skills stations utilized in this study were located in quiet locations throughout the hospital where providers had minimal interruptions and distractions. We are unsure if the program improves infant CPR quality during an actual infant cardiac or respiratory arrest where distractions are common. Future studies are needed to examine whether the training program has a positive effect on CPR performance during an actual in-hospital infant cardiac or respiratory arrest.

Conclusion

At baseline without feedback, adherence to infant CPR guidelines was poor with significant variability in performance. Over three successive quarters of the training program, providers improved their CPR skill performance with audiovisual feedback. The novel CPR training program may be a viable option for BLS providers to obtain and maintain adequate infant CPR skill performance over time.

References

Anderson, R., Sebaldt, A., Lin, Y., & Cheng, A. (2019). Optimal training frequency for acquisition and retention of high-quality CPR skills: A randomized trial. *Resuscitation, 135*, 153-161. https://doi.org/j.resuscitation.2018.10.033

Auerbach, M., Brown, L., Whitfill, T., Baird, J., Abulebda, K., Bhatnagar, A., Lutfi, R., Gawel, M., Walsh, B., Tay, K.-Y., Lavoie, M., Nadkarni, V., Dudas, R., Kessler, D., Katznelson, J., Ganghadaran, S., & Hamilton, M. F. (2018). Adherence to pediatric cardiac arrest guidelines across a spectrum of fifty emergency departments: A prospective, in situ, simulation-based study. *Academic Emergency Medicine, 25*(12), 1396-1408. https://doi.org/10.1111/acem.13564/full

Austin, A. L., Spalding, C. N., Landa, K. N., Myer, B. R., Donald, C., Smith, J. E., Platt, G., & King, H. C. (2020). A randomized control trial of cardiopulmonary feedback devices and their impact on infant chest compression quality: A simulation study. *Pediatric Emergency Care.* Advance online publication. https://doi.org/10.1097/PEC.0000000000001312

Atkins, D. L., Berger, S., Duff, J. P., Gonzales, J. C., Hunt, E. A., Joyner, B. L., Meaney, P. A., Niles, D. E., Samson, R. A., & Schexnayder, S. M. (2015). 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation, 132*(18), 519-525. https://doi.org/10.1161/CIR.0000000000000265

Cheng, A., Magid, D. J., Auerbach, M., Bhanji, F., Bigham, B. L., Blewer, A. L., Dainty, K. N., Diederich, E., Lin, Y., Leary, M., Mahgoub, M., Mancini, M. E., Navarro, K., & Donoghue, A. (2020). 2020 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care: Part 6: Resuscitation education science. *Circulation, 142*(16), S551-S579. https://doi.org/10.1161/CIR.0000000000000903

Cheng, A., Nadkarni, V. M., Mancini, M. B., Hunt, E. A., Sinz, E. H., Merchant, R. M., Donoghue, A., Duff, J. P., Eppich, W., Auerbach, M., Bigham, B. L., Blewer, A. L., Chan, P. S., & Bhanji, F. (2018). Resuscitation education science: Educational strategies to improve outcomes from cardiac arrest: A scientific statement from the American Heart Association. *Circulation, 138*(6), e82-e122. https://doi.org/10.1161/CIR.0000000000000583

Donoghue, A. J., Myers, S., Kerrey, B., Sandler, A., Keane, R., Watanabe, I., Hanna, R., Abbadessa, M. K., Frey, M., & O'Connell, K. (2020). Analysis of CPR quality by individual providers in the pediatric emergency department. *Resuscitation, 153*, 37-44. https://doi.org/10.1016/j.resuscitation.2020.05.026

Garcia-Jordan, D., Walker, A., Camphuag, J., Bissett, W., Spence, T., Martin, D.-A., Lin, Y., Cheng, A., Mahoney, M., & Gilfoyle, E. (2019). Bedside chest compression skills: Performance and skills retention in in-hospital trained pediatric providers. A simulation study. *Journal of Critical Care, 50*, 132-137. https://doi.org/10.1016/j.jcrc.2018.11.033

Holmberg, M. J., Ross, C. E., Fitzmaurice, G. M., Chan, P. S., Duval-Arnould, J., Grossestreuer, A. V., Yankama, T., Donnino, M. W., & Anderson, L. W. (2019). Annual incidence of adult and pediatric in-hospital cardiac arrest in the United States. *Circulation:*

Cardiovascular Quality and Outcomes, 12(7), 1-8. https://doi.org/10.1161/CIRCOUTCOMES.119.005580

Holmberg, M. J., Wiberg, S., Ross, C. E., Kleinman, M., Hoeyer-Nielsen, A. K., Donnino, M. W., & Anderson, L. W. (2019). Trends in survival after pediatric in-hospital cardiac arrest in the United States. *Circulation, 140*(17), 1398-1408. https://doi.org/10.1161/CIRCULATIONAHA.119.041667

Katipoglu, B., Madziala, M. A., Evrin, T., Gawlowski, P., Szarpak, A., Dabrowska, A., Bialka, S., Ladny, J. R., Szarpak, L., Konert, A., & Smereka, J. (2019). How should we teach cardiopulmonary resuscitation? Randomized multi-center study. *Cardiology Journal.* Advance online publication. https://doi.org/10.5603/CJ.a2019.0092

Lee, J. E., Lee, J., Oh, J., Park, C. H., Kang, H., Lim, T. H., & Yoo, K. H. (2019). Comparison of two-thumbs encircling and two-finger technique during infant cardiopulmonary resuscitation with single rescuer in simulation studies: A systematic review and meta-analysis. *Medicine, 98*(45), 1-7. https://doi.org/MD.0000000000017853

Lin, Y., Cheng, A., Grant, V. J., Currie, G. R., & Hecker, K. G. (2018). Improving CPR quality with distributed practice and real-time feedback in pediatric healthcare providers- A randomized controlled trial. *Resuscitation, 130*, 6-12. https://doi.org/10.1016/j.resuscitation.2018.06.025

Martin, P., Theobald, P., Kemp, A., Maguire, S., Maconochie, I., & Jones, M. (2013). Real-time feedback can improve infant manikin cardiopulmonary resuscitation by up to 79%- A randomised controlled trial. *Resuscitation, 84*, 1125-1130. https://doi.org/10.1016/j.resuscitation.2013.03.029

Millin, M. G., Bogumil, D., Fishe, J. N., & Burke, R. V. (2020). Comparing the two-finger versus two-thumb technique for single person infant CPR: A systematic review and meta-analysis. *Resuscitation, 148*, 161-172. https://doi.org/j.resuscitation.2019.12.039

Niebauer, J. M., White, M. L., Zinkan, J. L., Youngblood, A. Q., & Tofil, N. M. (2011). Hyperventilation in pediatric resuscitation: Performance in simulated pediatric medical emergencies. *Pediatrics, 128*(5), 1195-1200. https://doi.org/10.1542/peds.2010-3696

Niles, D. E., Nishisaki, A., Sutton, R. M., Elci, O. U., Meaney, P. A., O'Connor, K. A., Leffelman, J., Kramer-Johansen, J., Berg, R. A., & Nadkarni, V. (2017). Improved retention of chest compression psychomotor skills with brief "rolling refresher" training. *Simulation in Healthcare, 12*(4), 213-219. https://doi.org/10.1097/SIH.0000000000000228

Oermann, M. H., Kardong-Edgren, S. E., & Odom-Maryon, T. (2011). Effects of monthly practice on nursing students' CPR psychomotor skill performance. *Resuscitation, 82*, 447-453. https://doi.org/10.1016/j.resuscitation.2010.11.022

Resuscitation Quality Improvement Partners (2021). Why RQI? https://rqipartners.com/solutions/in-hospital-solutions/rqi-resuscitation-quality-improvement/

Sutton, R. M., Reeder, R. W., Landis, W., Meert, K. L., Yates, A. R., Berger, J. T., Newth, C. J., Carcillo, J. A., McQuillen, P. S., Notterman, D. A., Holubkov, R., Dean, J. M., Nadkarni, V. M., & Berg, R. A. (2018). Chest compression rates and pediatric in-hospital cardiac arrest survival outcomes. *Resuscitation, 130*, 159-166. https://doi.org/10.1016/j.resuscitation.2018.07.015

Sutton, R. M., Reeder, R. W., Landis, W. P., Meert, K. L., Yates, A. R., Morgan, R. W., Berger, J. T., Newth, C. J., Carcillo, J. A., McQuillen, P. S., Harrison, R. E., Moler, F. W., Pollack, M. M., Carpenter, T. C., Notterman, D. A., Holubkov, R., Dean, J. M., Nadkarni, V. M., & Berg, R. A. (2019). Ventilation rates and pediatric in-hospital cardiac arrest survival outcomes. *Critical Care Medicine, 47*(11), 1627-1636. https://doi.org/10.1097/CCM.0000000000003898

Tsou, J.-Y., Kao, C.-L., Chang, C.-J., Tu, Y.-F., Su, F.-C., & Chi, C.-H. (2020). Biomechanics of two-thumb versus two-finger chest compression for cardiopulmonary resuscitation in an infant manikin model. *European Journal of Emergency Medicine, 27*(2), 132-136. https://doi.org/10.1097/MEJ.0000000000000631

Wagner, M., Bibl, K., Hrdliczka, E., Steinbauer, P., Stiller, M., Gropel, P., Goeral, K., Salzer-Muhar, U., Berger, A., Schmolzer, G. M., & Olischar, M. (2019). Effects of feedback on chest compression quality: A randomized simulation study. *Pediatrics, 143*(2), 1-9. https://doi.org/10.1542/peds2018-2441

Zhou, X.-L., Wang, J., Jin, X.-Q., Zhao, Y., Liu, R.-L., & Jiang, C. (2020). Quality retention of chest compression after repetitive practices with or without feedback devices: A randomized manikin study. *American Journal of Emergency Medicine, 38*(1), 73-78. https://doi.org/10.1016/j.ajem.2019.04.025

Figure 1. Enrollment Procedure

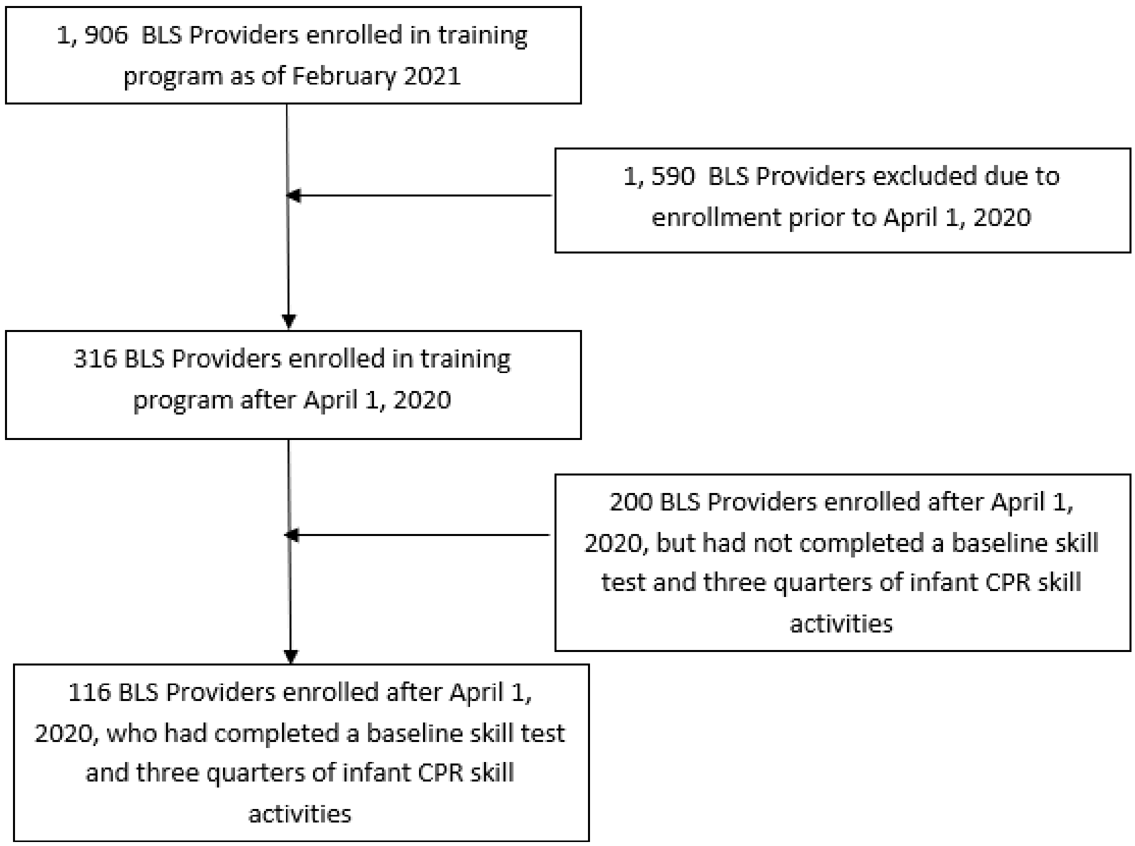

Table 1. Participant Characteristics

Characteristics	n (%)
Gender	
Female	89 (76.7)
Male	27 (23.3)
Profession	
Registered Nurse	60 (51.7)
Allied Healthcare	46 (39.6)
Patient Care Technician	10 (8.6)
Primary Unit Worked	
Procedural	37 (31.9)
Medical-Surgical	28 (24.1)
Allied Health	15 (12.9)
Telemetry	14 (12.1)
Emergency Department	9 (7.8)
Intensive Care Unit	8 (6.9)
Labor and Delivery	5 (4.3)

Table 2. Time Elapsed between the Completion of Quarter 1 and Quarter 2 Activities and Quarter 2 and Quarter 3 Activities

	Less than 30 days n (%)	30-60 days n (%)	61-90 days n (%)	91-120 days n (%)	Greater than 120 days n (%)
Q1 toQ2	1 (0.9)	10 (8.6)	33 (28.4)	56 (48.3)	16 (13.8)
Q2 to Q3	2 (1.7)	3 (2.6)	43 (37.1)	56 (48.3)	12 (10.3)

Table 3. Overall Infant Compression and Ventilation Skill Quality During Each Measurement and the Percent of Providers Meeting the Passing Score of 95% at Each Measurement

CPR Component	Baseline Median (IQR; P25, P75) n (%)	Quarter 1 Median (IQR; P25, P75) n (%)	Quarter 2 Median (IQR; P25, P75) n (%)	Quarter 3 Median (IQR; P25, P75) n (%)
Compression Depth (mm)	99 (12.5; 87.5, 100) 78 (67.2)	99.5 (2; 98, 100) 104 (89.7)	99 (2.8; 97.2, 100) 102 (87.9)	99 (2; 98, 100) 106 (91.4)
Compression Rate (compressions per minute)	97 (14; 85,99) 72 (62.1)	98 (5; 94,99) 86 (74.1)	98 (3; 96, 99) 93 (80.2)	98 (4; 95, 99) 90 (77.6)
Correct Finger Location	100 (56; 44, 100) 68 (58.6)	100 (4; 96, 100) 95 (81.9)	100 (2; 98, 100) 98 (84.5)	100 (2; 98, 100) 100 (86.2)
Adequate Chest Recoil	100 (1; 99, 100) 100 (86.2)	100 (1; 99, 100) 112 (96.6)	100 (1; 99, 100) 112 (96.6)	100 (1; 99, 100) 116 (100)
Ventilation Rate (breaths per minute)	90.5 (62; 38, 100) 51 (44)	99 (14.5; 85.5, 100) 77 (66.4)	99 (14.8; 85.2, 100) 80 (69)	99 (10.8; 89.2, 100) 81 (70)
Ventilation Volume (mL)	69.5 (33.8; 56, 89.8) 12 (10.3)	96 (7; 92, 99) 72 (62.1)	96 (6; 93, 99) 76 (65.5)	97 (5; 95, 100) 89 (76.7)

Table 4. Results of the GLMM at Baseline and During Each Quarter with Adjusted Odds Ratio (AORs) and 95 Confidence Intervals (CI)

CPR Component	Adjusted Odds Ratio and 95% CI
Compression Depth	
Baseline	1 (reference)
Quarter 1	4.89 (2.30, 10.41)
Quarter 2	4.05 (1.97, 8.34)
Quarter 3	6.08 (2.74, 13.51)
Compression Rate	
Baseline	1 (reference)
Quarter 1	1.73 (0.98, 3.05)
Quarter 2	2.45 (1.34, 4.46)
Quarter 3	2.09 (1.17, 3.75)
Correct Finger Location	
Baseline	1 (reference)
Quarter 1	2.41 (1.28, 4.56)
Quarter 2	2.91 (1.51, 5.63)
Quarter 3	3.35 (1.70, 6.61)
Adequate Chest Recoil	
Baseline	1 (reference)
Quarter 1	36.05 (3.97, 327.05)
Quarter 2	36.05 (3.97, 327.05)
Quarter 3	NA
Ventilation Rate	
Baseline	1 (reference)
Quarter 1	2.23 (1.29, 3.87)
Quarter 2	2.60 (1.48, 4.55)
Quarter 3	2.56 (1.47, 4.47)
Ventilation Volume	
Baseline	1 (reference)
Quarter 1	14.19 (6.99, 28.82)
Quarter 2	16.48 (8.09, 33.60)
Quarter 3	28.60 (13.68, 59.90)

Chapter 4: Conclusions

Summary of Results

The results of the studies included in this document support the use of this novel CPR training program to assists BLS providers in obtaining and maintaining high-quality adult and infant CPR skills. For adult CPR skills, the results of Manuscript #1 revealed that for BLS providers who did not meet the recommended chest compression and ventilation measures at baseline, providers were quickly able to improve their performance during quarter 2 to meet the recommended targets and maintained that performance over subsequent quarters. Providers who met the recommended chest compression and ventilation measures at baseline maintained their performance over subsequent quarters.

For infant CPR skills, the results of Manuscript #2 revealed that BLS providers struggled with performing high-quality infant CPR at baseline without audiovisual feedback. Using a cut value of 95%, meaning that providers needed to meet the infant chest compression or ventilation measure at least 95% of the time during the activity, the most difficulty was noted with achieving correct ventilation volume and ventilation rate, with a median value of 90.5% and 69.5%. All chest compression measures met the 95% cut value. During quarter 1 with audiovisual feedback providers were able to meet the 95% cut value for all ventilation measures, suggesting that feedback helps providers perform better quality CPR. During quarters 2 and 3, providers continued to either make improvements in their skills or maintain their skill quality, suggesting that audiovisual feedback has the most significant impact during quarter 1, and over subsequent quarters the feedback helped providers maintain their infant CPR skill quality.

Implications for Nursing Practice

Although survival rates from both adult and infant cardiac arrest are improving, healthcare providers and healthcare organizations need to do more to continue to improve these survival rates. Although many healthcare systems across the United States have adopted the novel quarterly training program, many systems still utilize the two-year classroom-based training model. Realizing the potential for the novel training program to improve providers' CPR skills, the AHA has shifted its' efforts to improving adoption of the quarterly training program with plans to stop all classroom-based training. Sadly, because of this shifting paradigm, many healthcare organizations have switched to other CPR providers such as the American Red Cross for training providers in CPR. Even worse, and given the worries surrounding classroom-based training with the recent coronavirus pandemic, many hospitals may have adopted policies allowing providers to take CPR courses online that may not be regulated by either the AHA or the American Red Cross. This is concerning as the quality of these programs may not meet the rigorous standards set forth by the AHA or the American Red Cross.

Multiple high-quality research studies have demonstrated that CPR quality during hospital cardiac arrests is poor (Abella, Alvarado, et al., 2005; Abella, Sandbo, et al., 2005; Auerbach et al., 2018; Donoghue et al., 2015; Donoghue et al., 2020), and instructor feedback during classroom-based CPR training has also been demonstrated to be sub-optimal (Brennan et al., 2016; Hansen et al., 2016). Additionally, numerous high-quality research studies have demonstrated clear benefit to on-going refresher training, especially with audiovisual feedback as the provider is completing his/her CPR skills (Garcia-Jordan et al., 2019; Lin et al., 2018; Martin et al., 2013; Oermann et al., 2011). Given that one of the primary functions of professional nursing is advocating for safe practices (American Nurses Association, 2015), nurses and nurse educators need to advocate for implementing educationally sound and innovative CPR training methods.

In December 2020, in response to increasing evidence that supports the need for more frequent CPR training, The Joint Commission (2020) proposed several changes surrounding resuscitation services for accredited hospitals. Although the commentary period for the proposed change is still open, The Joint Commission (2020) has stated that hospitals must have a plan that determines the format and frequency of training that "increases and maintains staff's skills in resuscitation," and importantly, that "completing a basic life support (BLS) course does not meet this recommendation" (p. 1). It is likely that, if these proposed changes are implemented, accredited hospitals will be required to show that staff have frequent and on-going CPR training. The novel quarterly training program has been proposed as an option to meet this new recommendation.

There are implications for this type of training for patients, as well. Given that patients and insurance companies are focused on "health" care, safe care, and better care, all while decreasing costs, hospitals are now advertising the fact that staff are competent in CPR. Although not yet mainstream, patients should inquire about whether hospitals have training programs in place that help staff maintain competence in critical skills such as CPR, and hospitals should make their participation in these programs visible to the public.

One missing component to the program that needs to be included in the training is how to prevent an in-hospital cardiac arrest from occurring in the first place. Emphasis should be placed on how to respond to patients with early sepsis and other conditions that can lead to cardiac arrest. Given that training on a more frequent basis has been shown to improve skill quality, future iterations of the program need to include other skills, such as operating the defibrillator, starting intravenous lines, and for advanced practice providers, how to perform endotracheal intubation.

Implications for Future Research

There are many possibilities for future research on the novel CPR training program. More prospective studies are needed that include rigorous control to determine whether the new training program is better than the current two-year classroom-based training method. Although researchers have demonstrated improved skill quality with more frequent training, the novel CPR training has not yet been studied in a prospective, controlled study. Additionally, the studies included in this document did not focus on the acquisition and retention of the knowledge required to successfully resuscitate victims of cardiac arrest. The novel training program does include a baseline cognitive test for both basic life support and advanced cardiac life support (ACLS), with a second cognitive test at the end of the first year on the program. Participants are asked to rate their confidence in each answer on the exam at baseline and at the second-year test. A retrospective descriptive study of baseline gaps in CPR knowledge as well as whether the training program improves knowledge at the end of the first year is needed. CPR providers should be able to demonstrate knowledge in chest compression and ventilation measures, as well as knowledge in arrhythmia identification, pharmacology of ACLS drugs, and how to stabilize deteriorating patients.

There is also a need to determine if a "one-size-fits all" training schedule is appropriate, or whether a variable training schedule would be more effective. For example, those who meet CPR metrics may need less frequent training, and those who do not meet CPR metrics may need more frequent training. Similarly, healthcare providers who are less likely to respond to a cardiac arrest may need more frequent training than those who work in areas that respond to cardiac arrest frequently.

At the study hospital, staff frequently commented on how the program improved their confidence and competence in responding to a cardiac arrest. Program coordinators frequently receive e-mails from staff stating how they were able to respond to an emergency and instinctively knew what to do given the frequent training. The theme of confidence is interesting and lends itself to a qualitative study on the experiences of staff who complete the training program and their perceptions of being able to respond to a cardiac arrest. Further, it would give staff the opportunity to provide insight into changes needed to improve the program, and challenges in completing the program on a quarterly basis, and using the technology associated with the program.

Studies are needed that measure skill retention with this form of CPR training. The studies included in this manuscript are limited in that there was no determination of skill retention. Only skill maintenance and acquisition over time were studied. Therefore, studies are needed to determine if skills are retained over time as compared to a baseline skill test.

There is an important need to determine if the program translates into better performance of CPR during an actual in-hospital cardiac arrest. Staff currently practice their CPR skills alone in sterile training environments that are behind closed doors and free of noise and distractions. Given that cardiac arrest is a high-stakes event where providers must work in teams and distractions are common, there is a need for a correlation study to determine if performance on the novel training program truly results in better performance during an actual cardiac arrest.

Finally, to date, the training program has only been used to train hospital CPR providers. Future attention should be given to whether this type of training can be used in nursing schools to prepare nursing students in cardiac arrest management. To date, new graduate nurses have a gap in knowledge and skill in how to manage a patient in cardiac arrest. It is possible, that the program could be implemented during nursing school to better prepare students to resuscitate patients. Additionally, the question remains as to whether the program could be used to train family members on how to perform chest compressions, especially for patients that leave the hospital with high-risk conditions that can lead to cardiac arrest such as a myocardial infarction. The program could also be utilized to train new parents in infant CPR prior to leaving the hospital.

References

Abella, B. S., Alvarado, J. P., Myklebust, H., Edelson, D. P., Barry, A., O'hearn, N., Vanden Hoek, T. L., & Becker, L. B. (2005). Quality of cardiopulmonary resuscitation during in-hospital cardiac arrest. *JAMA, 293*(3), 305-310. https://doi.org/10.1001/jama.293.3.305

Abella, B. S., Sandbo, N., Vassilatos, P., Alvarado, J. P., O'hearn, N., Wigder, H. N., Hoffman, P., Tynus, K., Vanden Hoek, T. L., & Becker, L. B. (2005). Chest compression rates during cardiopulmonary resuscitation are suboptimal: A prospective study during in-hospital cardiac arrest. *Circulation, 111*(4), 428-434. https://doi.org/10.1161/01.CIR.0000153811.84257.59

American Nurses Association. (2015). *Code of ethics for nurses with interpretive statements* (1st ed.). American Nurses Association. https://www.nursingworld.org/practice-policy/nursing-excellence/ethics/code-of-ethics-for-nurses/coe-view-only/

Auerbach, M., Brown, L., Whitfill, T., Baird, J., Abulebda, K., Bhatnagar, A., Lutfi, R., Gawel, M., Walsh, B., Tay, K.-Y., Lavoie, M., Nadkarni, V., Dudas, R., Kessler, D., Katznelson, J., Ganghadaran, S., & Hamilton, M. F. (2018). Adherence to pediatric cardiac arrest guidelines across a spectrum of fifty emergency departments: A prospective, in situ, simulation-based study. *Academic Emergency Medicine, 25*(12), 1396-1408. https://doi.org/10.1111/acem.13564/full

Brennan, E. E., McGraw, R. C., & Brooks, S. C. (2016). Accuracy of instructor assessment of chest compression quality during simulated resuscitation. *Canadian Journal of Emergency Medicine, 18*(4), 276-282. https://doi.org/10.1017/cem.2015.104

Donoghue, A., Hsieh, T.-C., Myers, S., Mak, A., Sutton, R., & Nadkarni, V. (2015). Videographic assessment of cardiopulmonary resuscitation quality in the pediatric emergency department. *Resuscitation, 91*, 19-25. https://doi.org/10.1016/j.resuscitation.2015.03.007

Donoghue, A. J., Myers, S., Kerrey, B., Sandler, A., Keane, R., Watanabe, I., Hanna, R., Abbadessa, M. K., Frey, M., & O'connel, K. (2020). Analysis of CPR quality by individual providers in the pediatric emergency department. *Resuscitation, 153*, 37-44. https://doi.org/10.1016/j.resuscitation.2020.05.026

Garcia-Jordan, D., Walker, A., Camphuag, J., Bissett, W., Spence, T., Martin, D.-A., Lin, Y., Cheng, A., Mahoney, M., & Gilfoyle, E. (2019). Bedside chest compression skills: Performance and skills retention in in-hospital trained pediatric providers. A simulation study. *Journal of Critical Care, 50*, 132-137. https://doi.org/10.1016/j.jcrc.2018.11.033

Hansen, C., Rasmussen, S. E., Nebsbjerg, M. A., Staerk, M., & Lofgren, B. (2016). Certified basic life support instructors assess cardiopulmonary resuscitation skills poorly. *Circulation, 134*(1), . https://www.ahajournals.org/doi/abs/10.1161/circ.134.suppl_1.16131

The Joint Commission. (2020, December). *Proposed revisions for resuscitation hospital accreditation program*. https://www.courtemanche-assocs.com/wp-content/uploads/2021/02/2021-Proposed-Resuscitation-Standards-TJC.pdf

Lin, Y., Cheng, A., Grant, V. J., Currie, G. R., & Hecker, K. G. (2018). Improving CPR quality with distributed practice and real-time feedback in pediatric healthcare providers- A randomized controlled trial. *Resuscitation, 130*, 6-12. https://doi.org/10.1016/j.resuscitation.2018.06.025

Martin, P., Theobald, P., Kemp, A., Maguire, S., Maconochie, I., & Jones, M. (2013). Real-time feedback can improve infant manikin cardiopulmonary resuscitation by up to 79%- A randomised controlled trial. *Resuscitation, 84*, 1125-1130. https://doi.org/10.1016/j.resuscitation.2013.03.029

Oermann, M. H., Kardong-Edgren, S. E., & Odom-Maryon, T. (2011). Effects of monthly practice on nursing students' CPR psychomotor skill performance. *Resuscitation, 82*, 447-453. https://doi.org/10.1016/j.resuscitation.2010.11.022