Marilyn H. Oermann*, Yolanda M. VanRiel, Debra E. Stieve, Carol A. Vermeesch, Patrick C. Crane, Amanda Kratovil, Manisa Baker, Donna S. Guerra, Joseph Chamness, Bushra Ahmad Saeed, Vonda Rogers, Joy M. Flicker and C. Marie Patterson

Developing competency of nursing students in cardiopulmonary resuscitation using Resuscitation Quality Improvement technology

https://doi.org/10.1515/ijnes-2023-0122
Received December 29, 2023; accepted April 12, 2024; published online April 30, 2024

Abstract

Objectives: This study examined the outcomes of training nursing students in CPR skills using the Resuscitation Quality Improvement (RQI) program.
Methods: Nursing students (n=2,193) in 12 schools across the United States participated in this study. Students performed compressions and bag-masked ventilation on adult and infant manikins using the RQI simulation station without and then with feedback on their performance.
Results: With real-time, objective feedback from the RQI simulation station, students' performance of CPR skills improved, and they retained their skills over time.
Conclusions: The RQI program and methodology of feedback is effective for training nursing students to be competent in CPR skills, essential for safe patient care. Nursing and other healthcare professions programs should consider adopting the RQI program for students to develop competency in CPR.

Keywords: cardiopulmonary resuscitation; deliberate practice; low-dose high-frequency model; real-time feedback; simulation station

Introduction

Cardiopulmonary resuscitation (CPR) is an evidence-based practice that improves the outcomes of patients suffering from sudden cardiac arrest inside and out of the hospital setting. Despite growing efforts to decrease sudden cardiac death, an estimated 6 to 9 million people die worldwide each year, making this a global health issue [1, 2]. In the United States, nearly 290,000 hospitalized patients suffer in-hospital cardiac arrest each year [3]. The incident of cardiac arrests occurs at disproportionately higher rates in the intensive care unit (ICU) and emergency department (ED) than in other hospital units. This affords the nurses working in the ICU and ED more experience performing CPR than nurses working on other units. Unfortunately, the infrequent use of CPR by

***Corresponding author: Marilyn H. Oermann**, Thelma M. Ingles Professor of Nursing, Duke University School of Nursing, DUMC 3322, 307 Trent Drive, 27710, Durham, NC, USA, Phone: 1 248 568 1848, E-mail: marilyn.oermann@duke.edu. https://orcid.org/0000-0002-4534-8962
Yolanda M. VanRiel, Department of Nursing, North Carolina Central University, Durham, NC, USA
Debra E. Stieve, Carol A. Vermeesch and Patrick C. Crane, College of Nursing, Michigan State University, East Lansing, MI, USA
Amanda Kratovil and Manisa Baker, College of Nursing, Purdue University Northwest, Hammond, IN, USA
Donna S. Guerra and Joseph Chamness, College of Nursing, University of Alabama Huntsville, Huntsville, AL, USA
Bushra Ahmad Saeed and Vonda Rogers, Division of Nursing, Allied Health, Life and Physical Sciences, University of the District of Columbia Community College, Washington DC, USA
Joy M. Flicker, John and Karen Arnold School of Nursing, Alvernia University, Reading, PA, USA
C. Marie Patterson, Physician Assistant Studies, Middle Tennessee State University, Murfreesboro, TN, USA

healthcare providers outside of those units contributes to the deterioration of reliable CPR performance even when initial training is high quality [4–6]. Therefore, knowledge retention and the ability to execute high quality CPR after initial training is as critical as the initial acquisition of CPR skills.

Traditionally, the focus of CPR training has been on direct care providers such as nurses and physicians. The role of nursing students in the delivery of CPR is largely underappreciated, likely due to the complexities associated with training and maintaining novice students' skills. Due to the rapid decline in CPR skills after initial training juxtaposed with limited practice of these skills, nursing students are at particular risk of sub-par CPR performance. As nursing shortages grow and staffing continues to be a critical concern throughout the world, ensuring that nursing students begin their practice with the ability to provide high quality CPR can advance life-saving efforts in settings across the world.

Furthermore, high quality CPR training systems such as the Resuscitation Quality Improvement (RQI) program afford healthcare systems the ability for staff to develop CPR skills and maintain them independently through practice using this technology. The RQI program uses a low-dose, high-frequency model with quarterly skills assessments that measure and verify competence, allowing for mastery learning via continuous deliberate practice of CPR skills [7, 8]. Researchers have found the RQI training system is effective for improving the quality of CPR and retention of skills among healthcare workers [4, 6, 9]. Only a few studies, however, have focused on the use of the RQI program with nursing students and the impact of real-time feedback on skill performance [10–12].

Literature review

Research has consistently documented that healthcare providers need to practice CPR skills to retain them [5, 13]. The same is true for students. Completing CPR training and being certified in basic life support (BLS), without subsequent practice, are not sufficient to retain these skills. Kardong-Edgren et al. [14] evaluated the quality of CPR skills of 467 nursing students from 10 schools of nursing across the United States after they had their BLS certification. Only 59 % were able to perform compressions with adequate depth and only 42 % with an adequate rate. With only one brief refresher (10 min), there was an 81 % increase in quality of compression skills and similar improvements with ventilation. The benefits of refreshers and brief practice sessions on retention of CPR skills have been supported by other studies [5, 11, 13, 15, 16].

Practicing CPR on standalone audiovisual feedback (AVF) devices, which provide real-time audio and/or visual feedback on performance, improves skills and promotes retention [4, 5, 11–13, 17–20] including laypersons [21]. A systematic review and meta-analysis found that training using standalone AVF devices among laypersons enabled them to improve compression depth but not chest recoil and hand placement [22]. Training and practice using AVF devices are critical to preparing healthcare providers, students, and the public to perform and retain quality CPR skills.

The RQI program offers consistent and regular CPR training to maintain high quality skills [23, 24]. Li et al. [25] examined the quality of CPR skills performed on out-of-hospital patients among paramedics who were trained using the RQI program. Paramedics trained with RQI had a statistically significant improvement in chest compression rate compared with paramedics who did not have this type of training.

Purpose

The purposes of this study were to (1) examine the outcomes of training nursing students in the CPR skills of compression and ventilation after one session using the RQI simulation station and (2) measure retention of these CPR skills over time.

Methods

Design and sample

This was a descriptive study to examine the effects of one feedback session using the RQI simulation station on CPR skill performance. A total of 2,193 nursing students in 12 schools across the United States participated in the study. Students performed compressions and bag-masked ventilations on adult and infant manikins using the RQI simulation station without and then with feedback on their performance of these skills. Students who had a health condition or a physical health problem such as a fractured wrist and thus could not perform CPR were excluded from the study. The study was conducted between February 2022 and September 2023. The study was reviewed by the Institutional Review Board (IRB) of Mass General Brigham (United States) and was identified by the IRB as an exempt study.

CPR training procedures

Participants were enrolled in the RQI 2025 Student Healthcare Provider Program. On entry to the RQI program, students completed a preparation assignment that included both an eLearning course and skills activities. The eLearning course is delivered in an adaptive platform to build and validate students' knowledge of the core competencies of BLS including compressions, rescue breaths, ventilations, and automated external defibrillator (AED) usage. The skills activities included an initial assessment of their compression and ventilation skills without feedback (pretest) and then a session immediately after with real-time, objective feedback on their performance of these skills, with a required passing rate of 75 % proficiency. Students completed a pretest (no feedback) followed by performance of CPR (with feedback) every 3 months.

Schools used various ways of onboarding students to the RQI program. All students received detailed instructions via email. These instructions included setting up an RQI account, completing the eLearning course, information about quarterly skills practice, and information regarding the reciprocity of the RQI system at local healthcare facilities that used the RQI system. The RQI program itself includes a demonstration and tips for performing CPR videos at the simulation station. In some schools, students also had a detailed prebrief by an instructor (in the simulation or skills laboratory) who demonstrated the steps required to complete compressions and ventilation.

For the pretest, each student performed 60 continuous compressions and 12 ventilations with a bag valve mask, providing one breath every 5–6 s on the Resusci Anne adult manikin at the RQI simulation station without feedback from the manikin. Next, they proceeded to the Resusci Baby and performed 60 compressions and 12 ventilations, providing one breath every 2–3 s, also without feedback.

Following the pretest, students performed compressions and ventilation on the manikins and received real-time, objective feedback from the RQI simulation station to correct their performance of these skills. In addition to audio feedback, students received visual feedback: they could view their performance on the monitor next to the simulation station (Photograph).

Photograph. RQI simulation station used in study.
Source: RQI Partners, LLC. [8]. *RQI Simulation Stations*. RQI Partners. https://rqipartners.com/resources/simulation-stations/. Reprinted by permission.

Measures

The RQI program measures the quality of compressions and ventilation. For compressions, participants were evaluated on hand placement, rate, depth, chest recoil, and chest compression fraction. For ventilation, they were evaluated on volume and rate. Performance is represented by scores using a scale of 0–100 %, with at least 75 % required in each skill (adult compressions, adult ventilation, infant compressions, and infant ventilation) to pass.

The RQI program was created by RQI Partners, a partnership between the AHA and Laerdal Medical. The scoring algorithm and passing score of 75 % are in alignment with AHA guidelines for CPR and are based on clinical evidence and the consensus of experts in resuscitation and education. The scoring limits are continuously reviewed based on the most recent evidence and guideline recommendations.

Procedures

At each school, students received their CPR training in the school's simulation or skills laboratory. Participants who were not able to pass compressions or ventilation with one feedback session from the RQI program continued to practice with feedback up to 3 times. During this time, RQI provided real-time, objective feedback and/or tip videos as needed. After the third attempt, the RQI program suggests that students take a break and try again at another time.

Data analysis

Data on participants' performance of CPR skills are collected automatically by the RQI simulation station. In addition, participants provided demographic data by completing questionnaires upon entry to RQI, as part of the program. The variances in the number of participants in the demographic survey data compared to the performance data were due to versioning of the RQI courseware, resulting in modifications to the questionnaires.

Frequencies, percentages, medians, and 25th and 75th percentiles were calculated. The data were analyzed in the cloud computing platform Databricks (Databricks Inc., San Francisco, CA) using a cluster with Apache Spark 3.4.1. Code was written in PySpark, which is the Python API for Spark. Timeouts, where a student was unable to complete the skills activity, were excluded from the analysis.

Results

Demographics

A total of 2,193 nursing students in 12 schools across the United States participated in the study; of this group, 1847 students completed the questionnaire collecting demographic information and their previous experience in performing CPR and with CPR training at each of the assessment points. The majority of participants (n=1,344, 72.8 %) were between 18 and 30 years old. Most participants had completed CPR training within the last two years (n=1,459, 79.0 %) and were certified in BLS prior to the start of the RQI program. Their CPR training was provided typically by an instructor (n=1,124, 60.9 %). However, some participants completed online CPR training with independent practice on a manikin (n=273, 14.8 %) or with an instructor (n=251, 13.6 %). Only 175 (9.5 %) participants had never completed CPR training before the RQI program.

Some participants had prior healthcare experience (for example, as a paramedic) before entering the nursing program. There was a wide range of experience, from less than 1 year (n=724, 39.2 %) through 21 and more years (n=37, 2.0 %). When asked to rate their confidence in performing high quality CPR on an adult or a child, most participants were neutral (n=610, 33.0 %) or agreed/strongly agreed (n=820, 44.4 %) that they were confident in their skills. Nearly a quarter of the participants (n=417, 22.6 %), however, were not confident in their skills. Compared with adult CPR skills, more participants reported a lack of confidence in their ability to perform CPR on an infant (n=590, 31.9 %). Consistent with their confidence ratings, most participants did not perceive a loss of CPR skills since they completed their CPR training before starting the program. Even though many of the participants had experience working in healthcare, most had never (n=1,243, 67.3 %) performed CPR in their job.

CPR skills

At pretest, although most students had completed CPR training and were certified in BLS, median scores for adult (67 %) and infant (46 %) compressions and adult (65 %) and infant ventilation (57 %) were all below the passing threshold of 75 %. With one practice session at the RQI station, where students received immediate feedback on their performance, their adult compression skills improved by 40 %, infant compression by 107 %, adult ventilation by 51 %, and infant ventilation by 68 %. Table 1 presents the scores for CPR skill performance without feedback and following one feedback session at the RQI simulation station. Students' improvement in compressions and ventilations can be seen in Figure 1.

With continued CPR practice using the RQI simulation station, participants retained their CPR skills: the percentage of participants who were able to perform compressions and ventilation on their first attempt continued to increase the longer they were in the nursing program and practiced CPR (Figure 2). Continued practice using the RQI simulation station prevented the loss of CPR skills and allowed participants to become more likely to pass their skills assessment on their first attempt (Figure 3).

Discussion

This study found that real-time feedback using the simulation station in the RQI program improved students' performance of CPR and enabled them to retain their skills. The results of this study are consistent with other

Table 1: Overall scores for CPR skills without and with feedback during the first session at the RQI station.

Activity	Median	25th percentile	75th percentile	n
Without feedback				
Adult compressions	67 %	23 %	92 %	2,033
Adult ventilation	65 %	10 %	94 %	1,674
Infant compressions	46 %	70 %	82 %	2,040
Infant ventilation	57 %	42 %	82 %	2,023
With feedback				
Adult compressions	94 %	87 %	98 %	2,177
Adult ventilation	98 %	90 %	99 %	2,177
Infant compressions	95 %	88 %	98 %	2,177
Infant ventilation	96 %	90 %	99 %	2,177

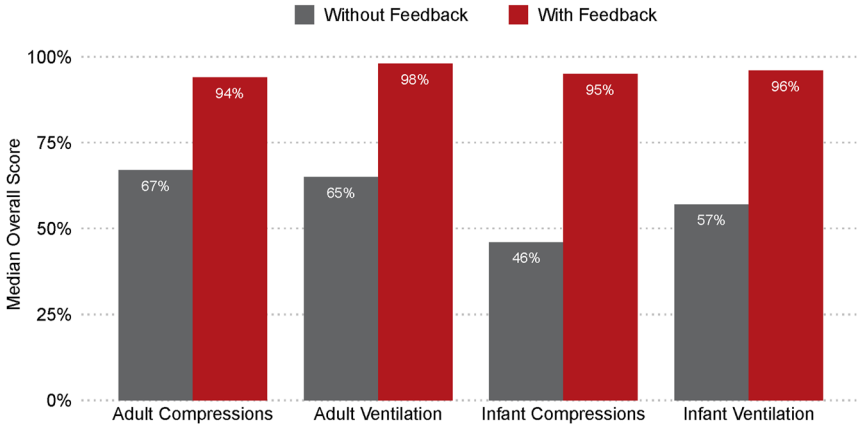

Figure 1: Improvement in CPR skills with one feedback session at RQI station.

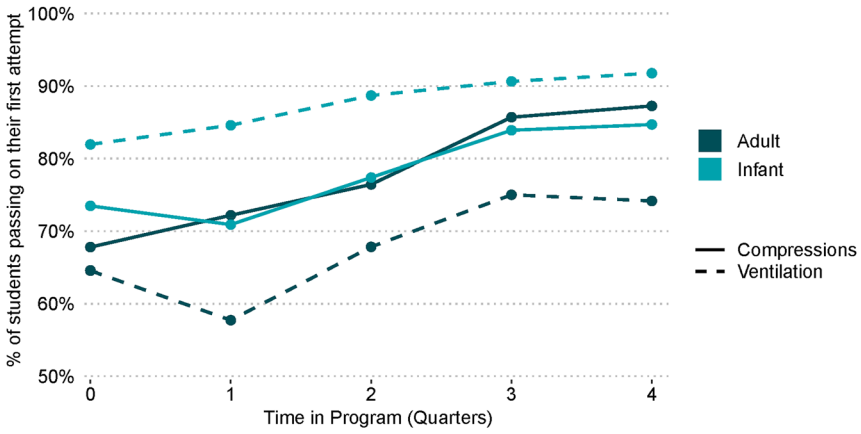

Figure 2: Change in the percentage of students passing each CPR skills assessment over time with feedback on their first attempt in the RQI program.

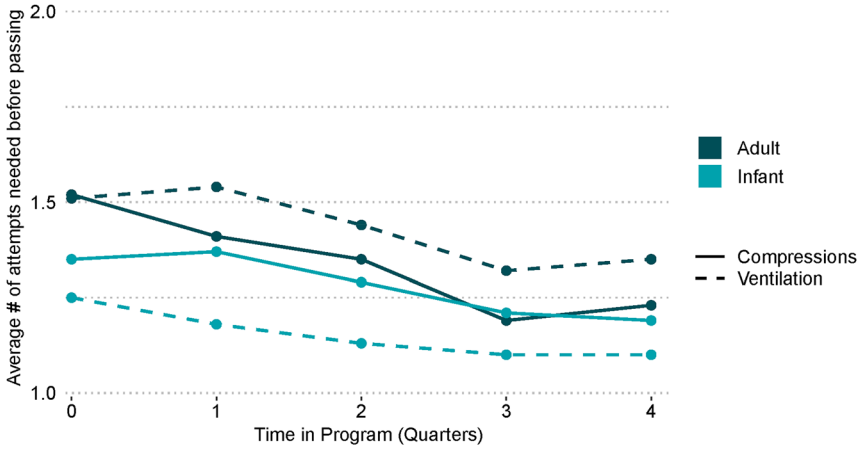

Figure 3: Change in the average number of attempts students needed before passing each CPR skills assessment over time in the RQI program.

research that has linked improved competency in the delivery of CPR with practice [5, 11, 12, 18]. In the current study, students had short guided practice of CPR skills every three months. Prior research and evidence-based guidelines support the use of frequent, spaced CPR training sessions to prevent skill deterioration and improve skill performance [4, 5, 11, 13, 26].

This study demonstrated that students who completed the RQI sessions with feedback were able to successfully deliver high-quality compressions and ventilation following as little as one session. While there was a decline of adult ventilation skills when reassessed at approximately 13 weeks post training, once refreshed with RQI, these skills improved with no further decline. This finding is consistent with other studies in which nursing students had difficulty ventilating with adequate volume and rate [12, 14]. Given that high quality CPR remains one of the cornerstones to cardiac arrest management [27], students in nursing and other healthcare programs need to master these skills and retain them throughout their education and as they transition into practice. The mastery of CPR ultimately will contribute to increased survivability of patients. Given our results, nursing and other healthcare professions programs should consider adopting the RQI program for students to remain competent in CPR.

Feedback is not only critical in the classroom and simulation settings, but also during actual resuscitation events to ensure that CPR is being delivered effectively. While not investigated in this study, it is reasonable to think that exposure to feedback in the learning and performance of CPR skills may help to foster positive communication and team dynamics during resuscitation events.

We agree with prior authors [18] that further study exploring long-term retention of knowledge and the ability for nurses to apply these skills in real-world resuscitation episodes needs to be conducted. The link between feedback, early defibrillation, and other skills necessary in a code are potential areas for further study.

Limitations

There were fewer demographic questionnaires than the total number of participants. We only reported demographic data for questionnaires that were complete at each assessment point. Modifications of the questionnaire due to versioning of the RQI courseware also contributed to the loss of some demographic data. There were variations when students had their CPR practice during each quarter of the study. Students had varying class and clinical schedules that impacted the timing of their practice. Most but not all students completed CPR training and were certified in BLS before starting the study. The length of time between this CPR training and when students began the study may have affected their performance of skills at the first pretest. Some participants had prior work experience as paramedics and in similar roles, which might have influenced their performance of CPR. For the majority of participants, however, their BLS certification was the only prior training in CPR they had, and few performed CPR in their jobs before beginning the nursing program. Students were typically between 18 and 30 years old. All of these factors may influence students' performance of CPR skills. Given the volume of participants (n=2,193 nursing students) in different 12 schools of nursing across the US, the findings are generalizable to other nursing students in prelicensure nursing programs.

Conclusions

This study examined the outcomes of training nursing students in the CPR skills of compressions and ventilation using the RQI program and the retention of those skills. Students' skills improved with only one feedback session using the simulation station and were retained over time. The RQI program and methodology of feedback is a valid and an effective method for training nursing students.

Acknowledgments: The authors thank Carla Vanderbilt, PhD, Senior Data Impact Analyst, RQI PARTNERS, for analyzing the data, and Lauren Sanderson, Vice President, Research & Design, RQI PARTNERS, for reading a draft of the manuscript and providing feedback.
Research ethics: The Institutional Review Board of Mass General Brigham (United States) reviewed the study and indicated it was exempt.
Informed consent: Not applicable.
Author contributions: All authors have accepted responsibility for the entire content of this manuscript and approved its submission.
Competing interests: The schools were early adopters of the Resuscitation Quality Improvement® (RQI) program as part of a partnership of the National League for Nursing, Laerdal Medical, the American Heart Association, and RQI Partners to advance transformation of the standard of resuscitation care for cardiac arrest by preparing nursing students with high-quality CPR skills. The authors had sole responsibility for implementing the project in their schools and for writing and submitting the manuscript. Data on participants' performance of CPR skills were collected through the RQI simulation station and provided to the authors. Carla Vanderbilt, PhD, Senior Data Impact Analyst, RQI PARTNERS, provided an analysis of the data for the authors but was not involved in writing the manuscript. Lauren Sanderson, Vice President, Research & Design, RQI PARTNERS, read a draft of the manuscript at the authors' request. The Authors state no competing interests.
Research funding: No funding was provided for this study.
Data availabilty: The data can be obtained on request from RQI Partners. Contact Lauren.Sanderson@RQIPartners.com.

References

1. Empana JP, Lerner I, Valentin E, Folke F, Bottiger B, Gislason G, et al. Incidence of sudden cardiac death in the European Union. J Am Coll Cardiol 2022;79:1818–27.
2. Tfelt-Hansen J, Garcia R, Albert C, Merino J, Krahn A, Marijon E, et al. Risk stratification of sudden cardiac death: a review. Europace 2023; 25:1–9.
3. Rasmussen TP, Riley DJ, Sarazin MV, Chan PS, Girotra S. Variation across hospitals in in-hospital cardiac arrest incidence among Medicare beneficiaries. JAMA Netw Open 2022;5:e2148485.
4. Anderson R, Sebaldt A, Lin Y, Cheng A. Optimal training frequency for acquisition and retention of high quality CPR skills: a randomized trial. Resuscitation 2019;135:153–61.
5. Cheng A, Nadkarni VM, Mancini MB, Hunt EA, Sinz EH, Merchant RM, et al. Resuscitation education science: educational strategies to improve outcomes from cardiac arrest: a scientific statement from the American Heart Association. Circulation 2018;138:e82–122. https://doi-org.pnw.idm.oclc.org/10.1161/CIR.0000000000000583.
6. Dudzik LR, Heard DG, Griffin RE, Vercellino M, Hunt A, Cates A, et al. Implementation of a low-dose, high-frequency cardiac resuscitation quality improvement program in a community hospital. Joint Comm J Qual Patient Saf 2019;45:789–97. https://doi-org.pnw.idm.oclc.org/10.1016/j.jcjq.2019.08.010.
7. American Heart Association. Resuscitation quality improvement program; 2023. https://cpr.heart.org/en/cpr-courses-and-kits/rqi#:~:text=The%20Resuscitation%20Quality%20Improvement%20(RQI,with%20life%2Dsaving%20patient%20care [Accessed 19 Dec 2023].
8. RQI Partners. Home page; 2023. https://rqipartners.com/ [Accessed 19 Dec 2023].
9. Mota S. Resuscitation quality improvement: improving clinicians' performance. AACN Adv Crit Care 2023;34:182–8. https://doi-org.pnw.idm.oclc.org/10.4037/aacnacc2023833.
10. Oermann MH, Krusmark MA, Kardong-Edgren S, Jastrzembski TS, Gluck KA. Training interval in cardiopulmonary resuscitation. PLoS One 2020;15:e0226786.
11. Oermann MH, Krusmark MA, Kardong-Edgren S, Jastrzembski TS, Gluck KA. Personalized training schedules for retention and sustainment of CPR skills. Simulat Healthc J Soc Simulat Healthc 2022;17:e59–67.
12. Oermann MH, Krusmark MA, Kardong-Edgren S, Gluck KA, Jastrzembski TS. Retention in spaced practice of CPR skills in nursing students. MEDSURG Nurs 2022;31:285–94.
13. Lin Y, Cheng A, Grant VJ, Currie GR, Hecker KG. Improving CPR quality with distributed practice and real-time feedback in pediatric healthcare providers – a randomized controlled trial. Resuscitation 2018;130:6–12.
14. Kardong-Edgren S, Oermann MH, Jastrzembski TS, Krusmark M, Gluck KA, Molloy MA, et al. Baseline cardiopulmonary resuscitation skill performance of nursing students is improved after one resuscitation quality improvement skill refresher. J Nurses Prof Dev 2020;36:57–62.
15. Merabti A, Elachqar A, Houssaïni TS, Kaddari F. Study of the relationship between simulation and clinical internships for nursing and technical health professions students. Int J Emerg Technol Learn 2022;17:108–22.
16. Misztal-Okońska P, Goniewicz K, Goniewicz M, Ranse J, Hertelendy A, Gray L, et al. Importance of immediate electronic-based feedback to enhance feedback for first-time CPR trainees. Int J Environ Res Publ Health 2021;18:3885.
17. Demırtaş A, Güvenç G, Aslan Ö, Ünver V, Başak T, Kaya C. Effectiveness of simulation-based cardiopulmonary resuscitation training programs on fourth-year nursing students. Australas Emerg Care 2021;24:4–10.
18. Gugelmin-Almeida D, Jones MD, Clark C, Rolfe U, Williams JM. A novel retraining strategy of chest compression skills for infant CPR results in high skill retention for longer. Eur J Pediatr 2022;181:4101–9.
19. Kuchaki Z, Taheri M, Esfahani H, Erfanifam T. The effect of CPR educational package on knowledge and performance of nurses working in intensive care units: a review study. J Fam Med Prim Care 2022;11:1677.
20. Marks SA, Shaffer L, Zehnder D, Aeh D, Prall DM. Under pressure: what individual characteristics lead to performance of high-quality chest compressions during CPR practice sessions? Resuscitation 2023;14:100380.
21. Chang Y, Wu K, Yang H, Lin C, Huang T, Yu Y, et al. Effects of different cardiopulmonary resuscitation education interventions among university students: a randomized controlled trial. PLoS One 2023;18:e0283099.
22. Kahsay DT, Peltonen L, Mieronkoski R, Tommila M, Salanterä S. The effect of standalone audio-visual feedback devices on the quality of chest compressions during laypersons' cardiopulmonary resuscitation training: a systematic review and meta-analysis. Eur J Cardiovasc Nurs 2024;23:11–20.
23. Jones-Schenk J. Resuscitation quality improvement (RQI®). J Cont Educ Nurs 2022;53:393–4.
24. Lee PH, Lai HY, Hsieh TC, Wu WR. Using real-time device-based visual feedback in CPR recertification programs: a prospective randomised controlled study. Nurse Educ Today 2023;124:105755.
25. Li T, Essex K, Ebert D, Levinsky B, Gilley C, Luo D, et al. Resuscitation Quality Improvement® (RQI®) HeartCode Complete® program improves chest compression rate in real world out-of hospital cardiac arrest patients. Resuscitation 2023;188:109833.
26. Toft LEB, Bottinor W, Cobourn A, Blount C, Tripathi A, Mehta I, et al. A simulation-enhanced, spaced learning, interprofessional "code blue" curriculum improves ACLS algorithm adherence and trainee resuscitation skill confidence. J Interprof Care 2023;37:623–8.
27. Merchant RM, Topjian AA, Panchal AR, Cheng A, Aziz K, Berg KM, et al. Part 1: executive summary: 2020 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation 2020;142:S337–357.