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Original Research

Development and Pilot of an Online, Interactive Defibrillator Simulation for Advanced Cardiovascular Life Support Providers

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Introduction

Every year, more than 500,000 patients in the United States require resuscitation for cardiac arrest.[1] Given advances in care over the decades, cardiac arrest in the perioperative period is rare: about 5.6 per 10,000 cases.[1] Perioperative arrests are so uncommon that anesthesiology residents may not witness or manage one during their training.[2] Advanced cardiovascular life support (ACLS) was originally developed for out-of-hospital arrest and then adapted for in-hospital use.[1] Resuscitation in the perioperative period is unique given the environment, timing of recognition, unique causes and treatments, and available tests (transesophageal echocardiography, etc).[3,4] Anesthesia providers must be prepared to manage these complex situations and lead teams of physicians, nurses, and advanced care providers during such critical events.

To accomplish this, anesthesia providers should be trained to use manual external defibrillators (MEDs), an advanced medical device that anesthesia providers rarely use.[1,2] Without training, providers can mismanage the device and delay delivery of the desired therapy, and ultimately patient harm.[5-7] In-hospital ACLS providers use MEDs to perform defibrillation, synchronized cardioversion, and transcutaneous pacing.[1]

ACLS providers are trained and certified every 2 years via a structured resuscitation training course that includes hands-on training with a defibrillator.[8] Various factors including cost, increased clinical demand, and the trend toward virtual learning after the COVID-19 pandemic have made this type of learning more difficult to coordinate.[9] Many hospital systems have transitioned away from in-person ACLS recertification courses every 2 years and opted instead for quarterly booster sessions via online learning modules provided by the American Heart Association and American Red Cross[10]; however, these courses do not provide education on the use of a defibrillator.[11]

These online resuscitation courses are examples of e-learning, which is defined as learning by using electronic technology to access internet or intranet-based resources outside of a traditional classroom.[12-14] A review of e-learning for surgical training found that this learning modality was effective in teaching a broad range of surgical competencies.[15] A recent single-center, prospective, randomized trial comparing in-person training against a blended in-person and online simulation-based defibrillator training in pediatrics providers showed no difference in defibrillator management immediately after education and at 2 months; it also highlights the importance of refresher sessions in preventing errors.[16] E-learning offers flexibility in terms of time and accessibility, which can make it appealing to busy clinicians.[12-14]

Current e-learning resources dedicated to defibrillator management primarily include YouTube videos and online tests from product manufacturers, all of which are examples of passive learning.[17] It has been shown that active learning is a better-received teaching model compared with passive learning.[12] The videos and online tests provided by manufacturers are not specific to ACLS providers but rather are directed at all users of defibrillators.[17]

Given the potential knowledge gap and the lack of available interactive e-learning opportunities for the MED, our goal was to create an interactive simulation-based training for this device. Our primary outcome was the time to successfully complete each of the 4 tasks of the simulation—pad placement, defibrillation, cardioversion, and pacing—between the pre- and post-assessment within the simulation. Secondary outcomes assessed were attitudes regarding the defibrillator simulation.

Materials and Methods

Development of Defibrillator Simulation

We developed the education module according to the successive approximation model.[18] The preparation phase took place from January 2022 to March 2022. This included the needs assessment, investigation of current educational offerings for defibrillator education,

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identification of team members, and initial planning of the desired educational content. We created a simulation for the Zoll R Series defibrillator (Zoll Medical Corporation), which is the primary device used at Richmond Veterans Affairs Medical Center and Virginia Commonwealth University Health. The study was approved by the Richmond Veterans Affairs Medical Center Institutional Review Board and consent was waived.

The iterative design phase took place from April 2022 to October 2022. During this time, the educational content was determined by subject matter experts including anesthesiologists, cardiac anesthesiologists, critical care physicians, critical care nurses and cardiologists, and the mock code educator. The module content was based on recommendations provided by the American Heart Association and the device manufacturer (Zoll Medical Corporation).[17,19] Using a modified Delphi method, the content was collaboratively developed by team members from multiple institutions.[20]

The iterative development phase took place from November 2022 through November 2023. The University of Florida Department of Anesthesiology Center for Safety, Simulation, and Advanced Learning Technologies (CSSALT) produced this online simulation. Development occurred in Unity/C#, allowing users to adjust all settings via a pointing device, and the simulation was posted online using WebGL to ensure compatibility with HTML5 web browsers (Chrome browser recommended). The simulation is web-based and accessible from any computer free of charge at the following link: https://simulation.health.ufl.edu/education-training/online-simulations/defibrillator-simulator/.

The learning objectives for users of the module are to demonstrate the ability to correctly place defibrillator pads on a patient and perform a synchronized cardioversion, defibrillation, and transcutaneous pacing. The components of the module include a pre-assessment, video tutorial, interactive tutorial, and post-assessment. The pre-assessment determines whether learners are able to perform the desired functions of the defibrillator (ie, pad placement, cardioversion, defibrillation, and transcutaneous pacing) and the time it takes for them to perform these functions.

The second component of the module contains educational videos demonstrating how to place defibrillator pads and perform a synchronized cardioversion, defibrillation, and transcutaneous pacing. After watching the videos, learners move on to the interactive tutorial (Figure 1). For pad placement, learners are shown a human torso and use a mouse to drag the pads to the correct anatomical areas. A simulated Zoll R Series defibrillator is presented, and the correct steps to perform a defibrillation, cardioversion, and pacing are highlighted in correct order. Learners use the mouse to turn the dial and press the correct buttons.

The module concludes with a post-assessment in which learners are presented cases and must correctly perform all the procedures without guidance. The simulation logs the number times it takes the learner to successfully complete each task and time to correct interventions (Figure 2).

Pilot

We performed a pilot study at one institution with different perioperative ACLS providers including attending anesthesiologists, certified registered nurse anesthetists, physician assistants, nurse practitioners, registered nurses, and medical students from the Department of Anesthesiology and surgical intensive care unit. Anesthesiology residents were not asked to participate because of their activity in other defibrillator education didactics. Members of both departments were invited to participate in the simulation curriculum via a department-wide email (a total of 69 providers), and participation was voluntary. Providers who agreed to participate were sent the link to the simulation and asked to complete all parts on their own time in one sitting. They were instructed to send their post-assessment data, a screenshot of their results page, to the principal investigator once completed. In addition, participants were asked to complete a survey with questions on a Likert scale (1-5) and an area for free text regarding their attitudes toward the new curriculum (Supplemental Online Material, Appendix A). All data were sent in a non-anonymized fashion, but then the data were de-identified when analyzed.

Each participant's baseline and post-education abilities and time required (in seconds) to place defibrillator pads and perform a defibrillation, cardioversion, and transcutaneous pacing were then anonymized. Normality was assessed through visual inspection of Q-Q plots as well as Shapiro-Wilk tests. Descriptive statistics (eg, percentage of successful first attempts, median and interquartile range of time taken) were calculated. Wilcoxon signed-rank tests were used to assess the differences in time for each performance between baseline and post-education assessment, with a significance level set at alpha = 0.05. Data analysis was conducted using SAS 9.4 software (SAS Institute).

Results

Twenty-two providers completed both the simulation and survey. Feedback regarding the curriculum was positive (Table 1). After completing the simulation, the number of participants who could correctly place pads increased from 10% to 77% and cardioversion, defibrillation, and pacing were stable at 85%, 100%, and 100%, respectively. There was not a significant improvement in time to place defibrillator pads (median [interquartile range] = 26.18 [50.32] vs 22.64 [24.26] seconds; $P = .593$). However, there was a significant reduction in time to perform a cardioversion (31.31 [34.23] vs 20.10 [13.92] seconds; $P = .001$), defibrillation (19.79 [19.24] vs 15.54 [6.22] seconds; $P < .0001$), and pacing (39.51 [30.72] vs 20.07 [10.59] seconds; $P < .0001$).

Discussion

We developed an online, interactive simulation for ACLS providers to learn how to properly place defibrillator pads and perform indicated cardioversion, defibrillation, and transcutaneous pacing on a simulated Zoll R Series MED. We completed a single-institution pilot study that revealed that initial perception toward the education was positive. This simulation improved the abilities of perioperative ACLS providers to use a simulated MED.

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Because we piloted this education with perioperative providers and included learners from multiple medical professions, we believe that the education is generalizable between specialties and levels of providers. Feedback was positive, and measured performance improved in all the different types of providers in our pilot study. This suggests that the simulation module could be useful to learners at various levels of training.

Although hands-on learning is still considered the "gold standard" for learning about this complex device, the trends in ACLS education toward online learning have left many providers without access to this type of education. The data from this pilot study show preliminary evidence that this simulation can help meet this knowledge gap. Providers that do not have access to a simulation center or content expert could use this simulation to practice and maintain their skills over time. Our hope is that providers who use the Zoll R Series could take this simulation alongside the American Heart Association Resuscitation Quality Improvement education to get a comprehensive ACLS refresher every 3 months.

However, there are limitations to this work. The foremost being that our education and outcomes all took place within the simulation and we are unsure whether this will translate to the clinical realm. Therefore, we are unable to determine if the learners actually learned how to use the defibrillator or just learned how to use the interface. This is an inherent limitation of a pilot study and further studies are needed to investigate the clinical application. Second, the pilot study recruited a small sample of participants from one institution. However, we incorporated learners from various disciplines and specialties, which suggests that it may benefit a broad learning group. Further pilots will include different institutions and anesthesiology residents. Third, this simulation is specific to one type of commercial defibrillator and some ACLS providers may not have that particular device or model at their institutions; however, we believe that the core concepts taught in our simulation will cross over to other devices. Fourth, the education module was completed on the learner's own time and the data from the post-assessments were self-reported and sent to the investigators in a non-anonymized fashion. Although they were encouraged to complete the module only once, there is no way to control for multiple attempts at the beta testing phase of the module's development when the pilot data were collected.

We plan to improve the simulation based on the feedback from the participants. First, they had difficulty with the pad placement portion. The first issue was the orientation of the pads. Users reported difficulty identifying which pad went where based on the location. Users also shared they thought there should be a larger margin of error for what was correct and incorrect pad placement. Second, learners wanted the ability to go back and forth between the different topics in the simulation. Third, there was feedback requesting an option to play the videos faster. We plan to make these changes in the next version of the simulation.

Future directions include making the requested edits within the simulation, expanding the simulation to include a "generic" defibrillator interface that would be applicable to all commercial devices, and dissemination at our local institution. We believe that all ACLS providers need some exposure to defibrillator training with an optimal approach likely consisting of a blended approach with hands-on and e-learning. We also hope to validate this educational resource against in-person training in a prospective, randomized trial.

In conclusion, this is the first step toward validating this novel simulation as an educational resource for ACLS providers to learn and refresh their knowledge about this complicated medical device. We hope that we can turn the simulation into a useful tool for providers to use alongside other online ACLS education.

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Abstract

Background: To decrease the risk of device mismanagement when using manual external defibrillators (MED), we created and piloted an online simulation to build and assess skills in using an MED.

Methods: Subject matter experts from anesthesiology, critical care, and nursing developed an online, interactive simulation-based curriculum for the MED device used at the VA Health System (R Series, Zoll) following the successive approximation method. Content was from the 2020 American Heart Association advanced cardiac life support (ACLS) guidelines and product manufacturer recommendations. Instructions for ACLS providers on how to correctly place defibrillator pads and perform synchronized cardioversion, defibrillation, and transcutaneous pacing were included. During the pilot study, 22 users from one institution completed a pre-assessment (baseline ability to place pads, perform the 3 defibrillator tasks), watched instructional videos and engaged with an interactive tutorial, and, in the post-assessment, must have correctly completed each task independently. The assessments tracked "pass/fail," number of attempts, and the time to complete each task.

Results: Feedback from users was positive. Completing the simulation-based curriculum resulted in improved device management on a simulated device. Wilcoxon signed-rank tests showed no significant change in time to place defibrillator pads, but there was a significant reduction in time to perform a cardioversion (median [interquartile range] = 31.31 [34.23] vs 20.10 [13.92] seconds; $P = .001$), defibrillation (19.79 [19.24] vs 15.54 [6.22] seconds; $P < .0001$), and pacing (39.51 [30.72] vs 20.07 [10.59] seconds; $P < .0001$).

Conclusions: The online simulation-based curriculum was well received and should be particularly useful for those who do not have ready access to in-person MED training.

Keywords: Simulation, advanced cardiovascular life support, resuscitation, critical care medicine

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Figures

Figure 1. *Interactive, online simulation for the Zoll R Series manual external defibrillator. Screenshots taken from final simulation showing the 4 main educational portions: pad placement, synchronized cardioversion, defibrillation, and transcutaneous pacing. The simulation was developed in Unity/C#, allowing users to adjust all settings via a pointing device and then posted online using WebGL to ensure compatibility with HTML5 web browsers. Please use Google Chrome when accessing the course.*

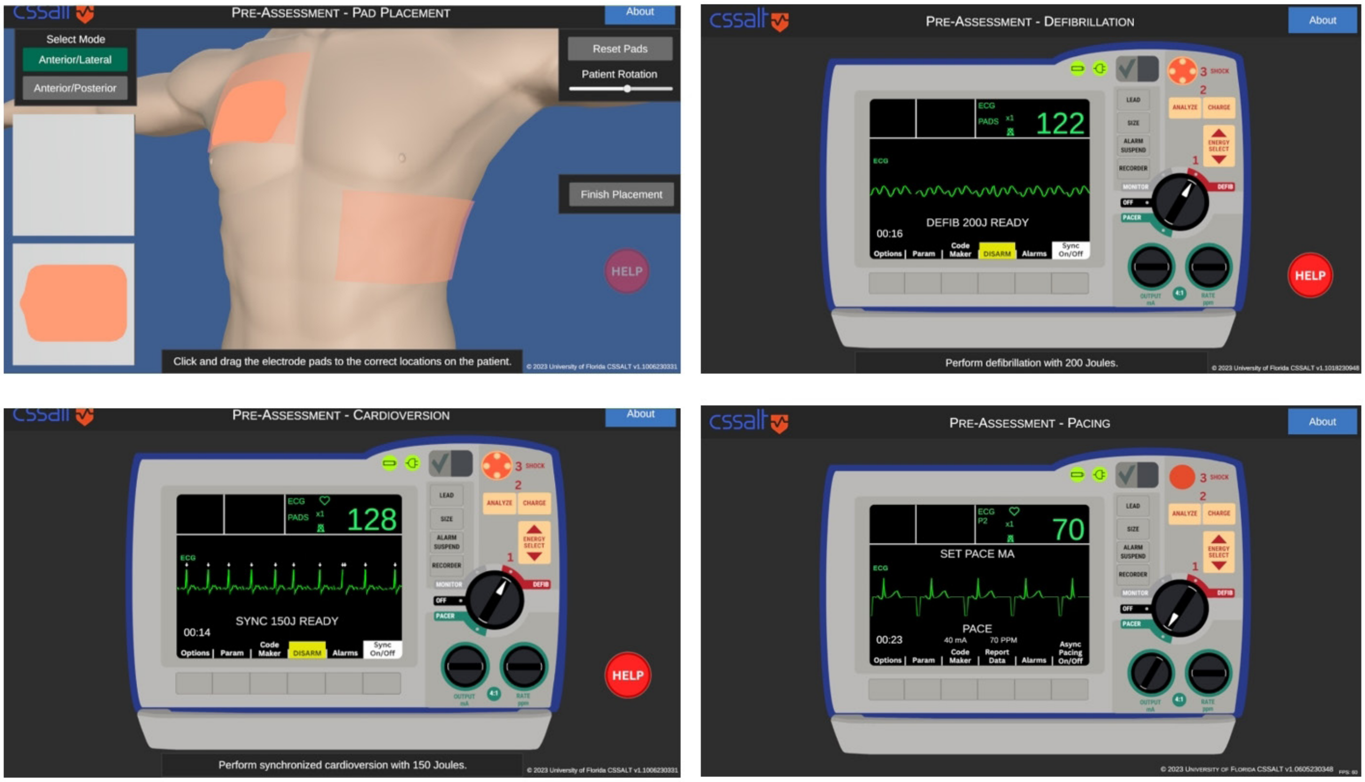

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Figure 2. *Example results screen from simulation. Screenshot taken from "Results" section of the simulation. There are pass/fail and time metrics for the pre- and post-education assessments. There are 4 parts to each assessment for the 4 main learning objectives of the curriculum: pad placement, synchronized cardioversion, defibrillation, and transcutaneous pacing. For pre-assessment, a "TRUE" means pass and "FALSE" means fail. The learner was only given 1 attempt to complete each task on the pre-assessment. After 1 attempt, the program moved on to the next task. The "HELP USED" button tracked if the learner pressed the "help button" in the simulation, which provided them a hint to the next correct step in the task. Time to complete was measured in seconds. For post-assessment, learners had to repeat the task until it was correctly completed. "Attempts" was the number of times taken to achieve this. The module tracked if they needed the "help button" in the post-assessment as well. If the learner used this feature, they had to repeat the task. Time to complete each task was measured in seconds.*

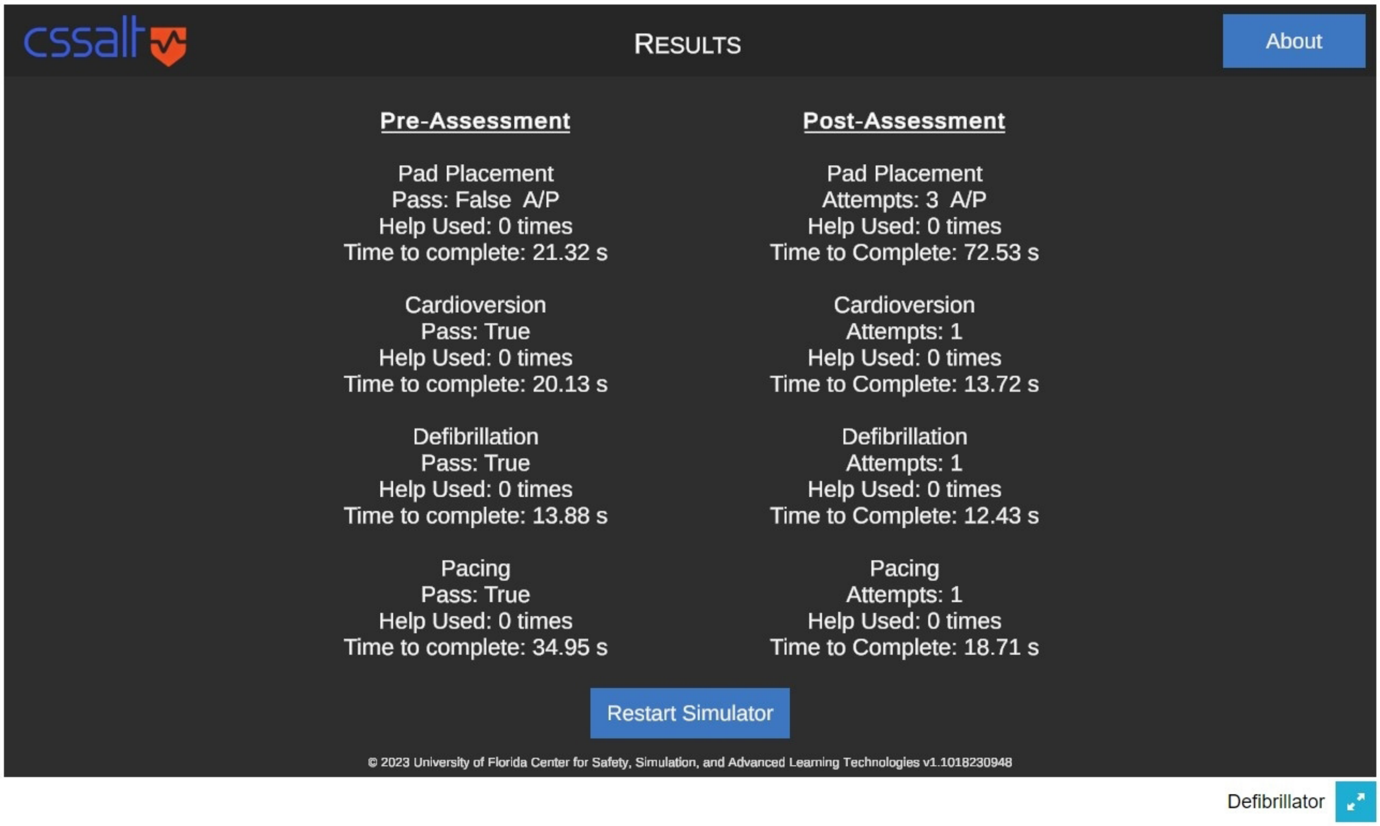

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Table

Table 1. *Assessment of Defibrillator Simulation*

Provider Type[a]	Overall (N)	Numerical Assessment[b]	Examples of Positive Feedback	Examples of Negative Feedback
Medical Student	6	4.6	I think it is a good tool because it will allow learners to complete the training effectively and remotely so they don't have to go in for training in-person.	It would be nice to have a feature to increase the playback time on the video.
Nursing	4	3.75	Simple and feels 100% close to real life.	I felt the pad placement portion in testing mode didn't allow for minor variability in placement. I couldn't proceed until the placement was "just right."
APP	4	5	Good simulation; feels like you are using the actual machine.	Had difficulty with the videos playing correctly and AP pad placement zones.
CRNA	4	3.75	It is to the point and maintains your attention. Simulated to being as close to real.	Allow the user to toggle back and forth for pad placement so you can change your selections if you want to.
Physician	4	5	I liked the fact that it actually forces you to use the buttons to perform the function.	I would start with defibrillation and then do synchronized cardioversion since it adds a step.
Overall	22			

[a] Provider types: Medical student (third year medical students), Nursing (critical care registered nurse), APP (advanced practice provider: nurse practitioner or physician assistant), CRNA (certified registered nurse anesthetist), Physician (anesthesiologist). N = number of participants.

[b] Assessment of educational tool via online survey based on 5-point Likert scale: "I think this educational tool would be helpful for teaching providers how to use a defibrillator" (1 = completely disagree, 2 = slightly disagree, 3 = neutral, 4 = slightly agree, 5 = strongly agree).

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Supplemental Online Material

Appendix A. Manual External Defibrillator Simulation Survey

1.) My role in the hospital is:
   a. Attending physician
   b. Resident physician
   c. NP, PA
   d. Nursing (RN)
   e. CRNA
   f. Medical Student

2.) I think this educational tool would be helpful for teaching providers how to use a defibrillator
   a. Completely agree
   b. Slightly agree
   c. Neutral
   d. Slightly disagree
   e. Completely disagree

3.) What do you like about this proposed educational tool for defibrillators? (free text)

4.) What do you not like about this proposed educational tool for defibrillators? What can be improved? (free text)