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Journal

Teaching and learning in medicine, 26(3)

ISSN

1040-1334

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Publication Date

2014-07-01

DOI

10.1080/10401334.2014.910466

Peer reviewed

High-Fidelity Simulation Enhances ACLS Training

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Background: Medical student training and experience in cardia arrest situations is limited. Traditional Advanced Cardiac Life Support (ACLS) teaching methods are largely unrealistic with rare personal experience as team leader. Yet Postgraduate Year 1 residents may perform this role shortly after graduation. *Purposes:* We expanded our ACLS teaching to a "Resuscitation Boot Camp" where we taught 2010 ACLS to 19 pregraduation students in didactic (12 hours) and experiential (8 hours) format.

Methods: Immediately before the course, we recorded students per- forming an acute coronary syndrome/ventricular fibrillation (VF) scenario. As a final test, we recorded the same scenario for each student. Primary outcomes were time to cardiopulmonary resuscitation (CPR) and defibrillation (DF). Secondary measures were total scenario score, dangerous actions, proportion of students voicing "ventricular fibrillation," 12-lead ST-elevation myocardial infarction (STEMI) interpretation, and care necessary for return of spontaneous circulation (ROSC). Two expert ACLS instructors scored both performances on a 121-point scale, with each student serving as their own control. We used *t* tests and McNemar tests for paired data with statistical significance at $p < .05$.

Results: Before instruction, average time from arrest to CPR was 112 seconds and to first DF 3.01 minutes. Students scored 45 ± 9/121 points and 9/19 (49%) performed dangerous actions. After instruction, time to CPR was 12 seconds ($p = .004$) and to first DF 1.53 minutes (p .03). Time to DF was delayed as students showed mastery of bag-valve-mask ventilation before DF. After instruction, students scored 97 ± 4/121 points ($p < .0001$) with no dangerous actions. Before training, only 4 of 19 (21%) students performed both CPR and DF within 2 minutes, and 3 of these had ROSC. After training, 14 of 19 (74%) achieved CPR DF 2 minutes (p .002), and all had ROSC. Before training, 5 of 19 (26%) students said "VF" and 4 of 19 obtained an ECG, but none identified STEMI. After training, corresponding performance was 13 of 19 "VF" (68%, p .021) and 100% ECG and STEMI identification ($p < .05$).

Conclusions: This course significantly improved knowledge and psychomotor skills. Critical actions required for resuscitation were much more common after training. ACLS training including high-fidelity simulation decreases time to CPR and DF and improves performance during resuscitation.

BACKGROUND

The standard American Heart Association (AHA) Advanced Cardiac Life Support (ACLS) course uses low-fidelity simulators with limited realism and is designed for all levels of healthcare providers. Hayes[1] found that residents felt unprepared to lead cardiac arrest teams despite having completed a standard ACLS course and called for high-fidelity simulation training. Similarly, Lighthall[2] found that resuscitation performance by residents included a high frequency of errors: failure to start cardiopulmonary resuscitation (CPR), notice dysrhythmias, and inquire about do-not-resuscitate status. Another study by Promes[3] of entering residents from all specialties found that 64% had never performed Basic Life Support procedures (undefined), 36% had never specifically done CPR, and 16% had never performed bag-valve-mask (BVM) ventilations. Con- firming this, Wu[4] found that 72% of medical students at the end of their 3rd year had never performed CPR, and this number only decreased to 68% after their 4th year. He concluded that the 4th-year curriculum did not add significant procedural experience. Promes concluded that it is "imperative to incorporate a standardized procedures-training curriculum into undergraduate medical education" (p. S61).

Therefore we expanded the standard ACLS course for late 4th-year medical students, who would soon be expected to lead the resuscitation team, and therefore included additional pharmacology, physiology, rhythm and ECG interpretation, and advanced airway management as part of a "Resuscitation Boot Camp." The ACLS course was the cornerstone of this mandatory 5-day course, which also included basic resuscitation, team training, and high-fidelity simulation. We immersed the students in the resuscitation milieu with a 32-hour (vs. standard 13-hour AHA version) didactic and experiential course.

The 2010 versions of both standard AHA instructor and provider courses[5] have eliminated advanced airway management, focusing instead on the importance of high-quality CPR and emphasizing minimal if any delays in chest compressions. However, the AHA course is designed for all members of the resuscitation team, many of whom do not perform advanced airway management in the course of the resuscitation. Because our course was focused on physicians who will likely respond to in-hospital cardiac arrests, we felt that this was an essential psychomotor skill. Therefore, we modified both our teaching and testing scenarios to incorporate both basic and advanced airway management.

We performed a before-and-after study to evaluate the effectiveness of an expanded ACLS course using high-fidelity simulation on a cohort of late 4th-year medical students. Our primary outcome measures were time to first CPR and to first de- fibrillation (DF) after cardiac arrest. Secondary measures were change in total "scenario score" (maximum 121 points), frequency of performance of "dangerous actions," achievement of return of spontaneous circulation (ROSC), proportion of students voicing "ventricular fibrillation" (VF), and identifying ST elevation myocardial infarction (STEMI) or myocardial infarction.

METHODS

We obtained International Review Board approval to record simulation sessions and collect patient management data from 19 student volunteers (11 female), most interested in a career in emergency medicine, anesthesiology, or surgery. The course was held over a 4-day period in 1 school week. Pretest scenarios were recorded just prior to start of the course and tested again upon completion of the course. The 32-hour course consisted of 12 hours of didactics, 8 hours of simulation training, 8 hours of self-study time, and 4 hours of practical and written testing.

To assess ACLS skills, students directed a high-fidelity simulation scenario of a patient with STEMI, VF cardiac arrest, DF, basic and advanced airway management, return of spontaneous circulation, third-degree heart block, hypotension, acidosis, and activation of the cardiac catheterization team. Each student was tested in both phases of the study without additional team members to which they would normally delegate tasks.

We judged resuscitation successful and awarded ROSC if the student began near-continuous CPR, performed effective BVM and/or endotracheal intubation, defibrillated with appropriate joules, and administered two correct doses of epinephrine (or one of vasopressin) and either lidocaine or amiodarone in appropriate doses. We calculated the Kappa statistic for interrater reliability. Disagreements in scoring were resolved by jointly reviewing the videos.

Students performed their simulations in a well-equipped simulation center approximating a resuscitation room in a modern emergency department. Equipment included a SimMan 3G© (Laerdal, Wappinger Falls, NY), live defibrillator and crash cart, cardiac monitor, and basic and advanced airway equipment. We used B-line Medical Simbridge software© (B-line Medical, Washington, DC) for video capture, storage, and review.

A technical skills checklist of critical actions for the scenarios was created by clinical and simulation faculty using a modified-Delphi technique. Prior to participation in the ACLS course, subjects were recorded performing as team leader in the standard scenario. The students then completed the Resuscitation Boot Camp with imbedded ACLS course and, as a final test, each student was recorded repeating the same Acute Coro- nary Syndrome (ACS)/VF scenario (12–15 minutes). Two ex- pert ACLS instructors (one a Regional Faculty Member) scored the before and after performances on a 121-point scale (See Appendix), and the mean of their assessments was used for analysis. One postinstruction video performance was lost due to a malfunction with the server after coding by one instructor, so that the postinstruction score for this student was the score of one instructor.

We used *t* tests for paired data with each student serving as his or her own control. A mixed-model analysis of variance, with students treated as a random effect, was used to obtain an overall *p* value for change in the three phases of the scenario. Statistical significance was set at $p < .05$. We used the concordance correlation coefficient[6] to measure agreement between times and scores as coded by the two instructors. This statistic has a range of –1 to 1 and measures the extent to which two set of values are identical. For positive correlations, it is less than or equal to the more familiar Pearson correlation coefficient, which measures the extent to which two sets of values are linearly related.

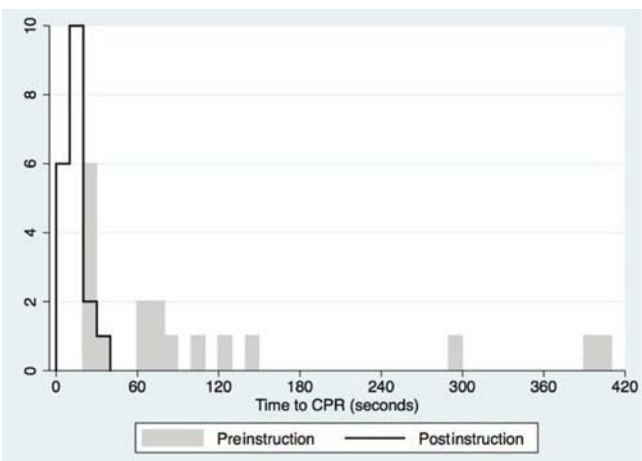

FIG. 1. Time from cardiac arrest to start of cardiopulmonary resuscitation (CPR) for students before (gray bars) and after (black outlines) resuscitation boot camp/Advanced Cardiac Life Support instruction. (Color figure available online).

RESULTS

We found marked deficiencies in performance among the cohort prior to receiving ACLS instruction. For primary out- comes, average time to CPR after cardiac arrest was 113 (± 126) seconds and to first DF was 3.02 (± 2.60) minutes. Students showed deficiencies in all three phases of the scenario. An average score of 13/22, 27/54, and 4/45 was achieved for the assessment phase, cardiac arrest phase, and postresuscitation phase, respectively. For secondary outcomes, students scored a total of 45 ± 9/121 points with nine of 19 students (49%) performing dangerous actions such as administering atropine during VF (six students), failing to start CPR (one student), or administering incorrect energy level (joules) during DF (two students). Only four of 19 students (21%) performed both CPR and DF within 2 minutes, with three of these achieving ROSC. Also, five of 19 students (26%) were able to correctly recognize VF, and four of 19 obtained an ECG, but none identified STEMI. In comparison, there were significant improvements in all measured areas after receiving ACLS instruction. For primary outcomes, the average time to CPR after arrest was 13 seconds (7, p .004; Figure 1) and to first DF was 1.53 minutes (0.56, p .03; Figure 2). The time to DF was artificially delayed, as students showed mastery of BVM prior to DF. Postinstruction performance on the assessment phase, cardiac arrest phase, and postresuscitation phase of the scenario improved significantly with an average score of 15/22, 44/54, and 40/45 respectively ($p < .0005$). For secondary outcomes, students scored a total 98 ± 4/121 points on the scenario ($p < .0001$) with no dangerous actions performed (Figure 3). A total of 14 of 19 students (74%) achieved CPR + DF within 2 minutes ($p = .002$), and all of these achieved ROSC ($p = .001$). Also, 13 of 19 students (68%) correctly verbalized recognition of VF ($p =.021$) with 100% obtaining a post-ROSC electrocardiogram and identifying STEMI ($p < .05$).

Interrater reliability for scoring the participants in pre- and posttraining scenarios was good. The median kappa for the 75 test items was 0.68 (interquartile range 0.36–0.94). Forty-six items (61%) had kappa > 0.60. The two times (arrest to CPR and to DF) had concordance correlation coefficients of 0.999. The performance scores had concordance correlation coefficients of 0.68 for the assessment phase, 0.82 for the cardiac arrest phase, 0.99 for the postresuscitation phase, and 0.96 for the total score.

DISCUSSION

High-fidelity simulation is emotionally intense, preferred by students,[7,8] and arguably enhances retention.[9,10] Historically, mannequin simulation for ACLS has been rudimentary Resusci Anne© (Laerdal, Wappinger Falls, NY). These have not allowed instructors or students to assess presence and adequacy of ventilation through auscultation or observation of chest rise, judge CPR quality, start and stop pulses realistically, and recognize ROSC. Furthermore, more advanced resuscitation training as in our course requires realistic BVM use and endotracheal tube placement, previously not possible on low-fidelity simulators.

Adding to the emotional component of the experience, the mannequin was able to "speak" to the student, which enabled us to test history-taking skills as well as observe the therapeutic relationship between the student and a patient in crisis. Cahill and McGaugh[11] have written that human studies confirm that emotionally arousing events enhance memory retention. Wayne[12] showed that retention of ACLS skills with simulation training overcame the normal slope of decay. A previous needs assessment done for our medical students revealed significant gaps in their training and experience in resuscitation skills. In fact, there is no current requirement in the Liaison Committee on Medical Education curriculum for

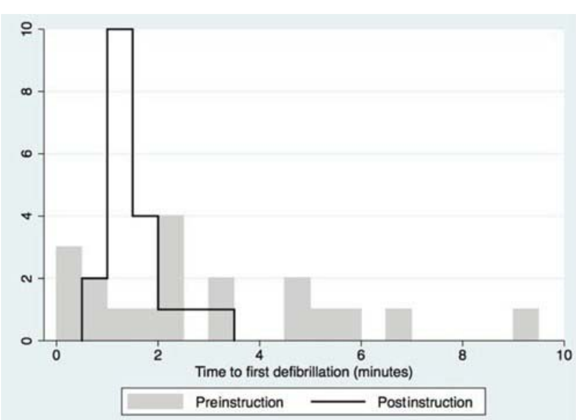

FIG. 2. Time from cardiac arrest to first defibrillation for students before (gray bars) and after (black outlines) resuscitation boot camp/Advanced Cardiac Life Support instruction. (Color figure available online).

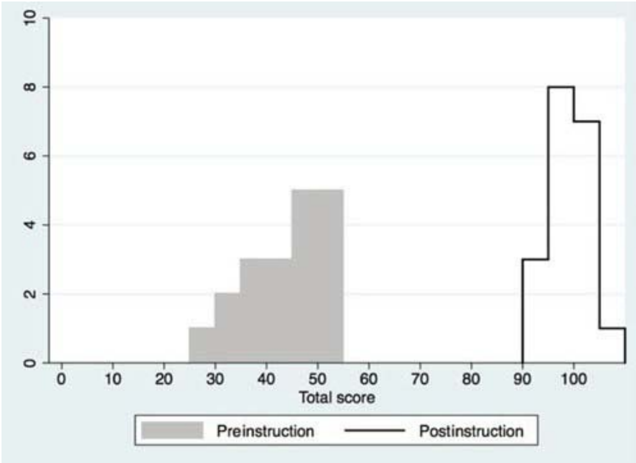

FIG. 3. Sum of scores for all three components of pre-arrest, arrest and post- arrest management for acute coronary syndrome/ventricular fibrillation scenario before (gray bars) and after (black outlines) resuscitation boot camp/Advanced Cardiac Life Support instruction. *Note:* Maximum possible score 121. (Color figure available online).

resuscitation training for medical students. In standard ED-13 of the Liaison Committee on Medical Education document, "Functions and Structure of a Medical School,"[13] medical schools are required to provide "important aspects of preventive, acute, chronic, continuing, rehabilitative, and end-of-life care," but there is no specific mention of resuscitation skills in the document.

Several schools have realized the need for additional preparation prior to starting the intern year.[13] They have tried to address this need by developing capstone or boot camp courses for graduating 4th-year medical students. Courses offer such items as management of acute emergencies, ECG and CXR interpretation, ACLS, handoffs, nursing pages, and legal/ethic issues.[14–16] These courses have been well received by students and were described by our students in their course evaluations and others[15] as being more helpful than 4th-year subinternships. These courses also improved performance in many areas where students lacked confidence.[15,16] The courses use learning tools such as didactics, web-based, and high-fidelity simulation. The high-fidelity portion has been found to be particularly helpful due to realism and a nonthreatening environment.[17] Our course focused on these skills and incorporated critical care pharmacology as well, to better prepare students to act independently in a few months.

In designing curriculum it is important to consider the Dreyfus model of knowledge development, which states competency is acquired in five progressive stages of learning, beginning with novice and moving to advanced beginner, competent, proficient, and expert. As it applies to medicine, Hicks suggested that these levels correlate with the 1st-year medical student (novice), resident physician (competent), and midcareer specialist (expert).[18] Hicks surveyed residents to determine frequency of and com- fort level with procedural experience and found that the comfort threshold was not reached until participation in least six ACLS procedures.[18] Our course, expanded from the typical 13-hour AHA/ACLS courses offered more opportunity for individual participation, and came closer to this six procedures suggested for comfort by Hicks. Each student served as team leader in four or five, and team member in 10 to 12, cardiac arrest and peri-arrest scenarios. If we expect our new graduate physicians to be the "Code Leader," they should clearly have more than novice level experience.

CONCLUSIONS

With a 32-hour cardiac resuscitation course expanded from traditional AHA/ACLS training, and using high-fidelity simulation, critical actions (time to CPR and DF) required for successful resuscitation were significantly more common after training and done more rapidly. ACLS training including high-fidelity simulation decreases time to CPR and defibrillation and improves performance during resuscitation. High-fidelity simulation, despite increased cost, is a useful and effective adjunct to traditional ACLS training.

LIMITATIONS

Our study had obvious limitations, including enrolling a small sample of self-selected, highly motivated students. We did not have any baseline data on the subject about prior ACLS train- ing or experience and this is a confounding variable. We used a nonvalidated evaluation scale with arbitrary weighting of points for critical actions (derived from two expert ACLS instructors), though the action items had been used for grading in the course for 15 years. Our course was nontraditional and expanded from ACLS and included advanced airway management. This course was an expanded version of the standard ACLS course including simulation and additional didactics. Therefore we were not able to specifically attribute the improved performance to the simulation component alone.

To provide maximal experience with the simulation and to reinforce specific and detailed proper ACS/cardiac arrest management, we used the same teaching and testing scenario and informed the students that the pre- and posttests would be identical. This may have artificially improved posttest performance through studying specifically for the known test, as well as ad- ditional familiarity with the simulation technology. We did not control for progressive experience and therefore comfort with the mannequin or simulation experience, nor was there a traditional ACLS course student control group. Also, the raters were blinded to the participants but not to whether they were pre- or postintervention.

Although the mannequins were capable of recording rate and depth of compressions, and tidal volumes, we did not assess these. The point at which a student achieved ROSC was subjective but consistent across subjects. We recognize there may have been a bias toward ROSC in the posttraining assessment. We planned a delay in defibrillation for the student to demonstrate basic and advanced airway management. The post- training assessment was done without a resuscitation team present, so we did not assess leadership skills.

Future studies should incorporate a control group of traditional ACLS training, use students destined for all specialty residencies, and assess the rate of long-term retention of psychomotor skills.

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APPENDIX

Critical Actions for Ventricular Fibrillation/Cardiac Arrest/Acute Coronary Syndrome Case UC Irvine Resuscitation Boot Camp Simulation Study, 2011

Subject # ———— Student name: ————

Evaluator ————Pre/Post ————

Exam Date ———— Review Date ————

Time of arrest: ——— Time to CPR: ——— Time to defibrillation: ———

Critical action:	Points possible	Points earned
Assessment Phase		
D Physical Exam	1	
D Obtain history of chest pain (within 1 minute)	1	
o Duration	1	
o Associated symptoms	1	
o Character (including location)	1	
o Radiation pattern	1	
o Previous treatment	1	
D Identify acute coronary syndrome by virtue of implementing treatment below	3	
D Initial treatment		
o Oxygen	1	
o Nitroglycerine	1	
o Aspirin	1	
D Obtain complete vital signs (HR, BP, RR, Temp) (1 pt partial)	2	
D Place pulse oximeter	1	
D Start peripheral IV	2	
D Place patient on cardiac monitor	2	
D Evaluate rhythm (ST or NSR)	2	
Total points this page:	22	

Cardiac Arrest Phase		
D Recognize syncope within 15 seconds	2	
D Call for help (code blue) within 15 seconds of syncope	2	
D Start chest compressions (2 pts) (states at least 100/min- 1pt) within 15 seconds of syncope	3	
D Start bag-valve-mask ventilations when help arrives	1	
D 100% O_2 for ventilations (1pt for additional O_2,)	2	
D Assess rhythm after loss of consciousness	3	
D Recognize ventricular fibrillation	3	
D Defibrillate within 10 seconds of recognizing Vfib	3	
o Say: "I'm clear, you're clear, everyone's clear" or similar	1	
o 200 joules biphasic defibrillation (2 pts defib, 1 pt correct dose)	3	
D CPR for 2 minutes	3	
D IV epinephrine 1 mg or Vasopressin 40 units IV	2	
D Intubate patient with ETT	1	
o Check tube placement by listening over epigastrium and lungs	1	
o Place end tidal CO2 detector	1	
D Run normal saline wide open during resuscitation	1	
D Pulse check after 2 minutes of CPR	1	
D Recheck rhythm (Vfib)	1	

Critical action:	Points possible	Points earned
o "I'm clear"	1	
o Defibrillate 200 joules	1	
D Resume CPR	1	
D Give Amiodarone (300 mg) or Lidocaine (100 mg) IVP	2	
D Pulse check after 2 minutes of CPR	1	
D Recheck rhythm (Vfib)	1	
o "I'm clear"	1	
o Defibrillate 200 joules	1	
D Resume CPR	1	
D Repeat epinephrine 1 mg IVP	2	
D Repeat Amiodarone (150 mg) or lidocaine (100 mg) second bolus IVP	1	
D Pulse check after 2 minutes of CPR	1	
D Recheck rhythm (Vfib)	1	
o "I'm clear"	1	
o Defibrillate 200 joules	1	
D Resume CPR	1	
D Repeat 3rd dose of epinephrine	2	
Total Points this page	54	
Clearly Not Indicated or Dangerous Actions: (circle)		
*No CPR *Incorrect Joules *Atropine *Other (list)		

Postresuscitation Phase

D Recognize presence of a pulse	2	
D Appreciate rhythm change	2	
D Diagonose bradycardia with 3rd degree AV Block rate 40	2	
D Stop CPR	1	
D Call for transcutaneous pacemaker (not available)	1	
D Give atropine 0.5 mg IVP	2	
o Recheck rate	1	
o Give atropine 0.5 mg IVP	2	
o Recheck rate (comes up to 60/minute)	1	
D Check BP (70/40)	2	
D Give fluid bolus of normal saline	2	
D Recheck BP (74/40)	1	
D Start pressor drug (dopamine or norephinephrine)	2	
D Recheck BP (110/70)	1	
D Obtain ancillary tests		
o 12 lead ECG (STEMI)	3	
o ABG	2	
o CXR	2	
o Cardiac markers (1 pt) and electrolytes (1pt)	2	
D Begin drip of antiarrhythmic (amiodarone or lidocaine)	2	
D Interpret ABG (metabolic acidosis with respiratory compensation)	2	

Postresuscitation Phase	
o Give sodium bicarbonate IVP	1
D Interpret CXR (no CHF, no PTX, essentially normal)	1
D Interpret ECG as STEMI	3
D Activate cath lab	3
Total points this page	45
Total points first page	22
Total points second page	54
Total points for 3 pages (entire scenario)	121