Simulation-Based Training of Internal Medicine Residents in Advanced Cardiac Life Support Protocols: A Randomized Trial

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Background: *Internal medicine residents must be competent in Advanced Cardiac Life Support (ACLS) for board certification.*
Purpose: *The purpose was to use a medical simulator to assess baseline proficiency in ACLS and determine the impact of an intervention on skill development.*
Method: *This was a randomized trial with wait-list controls. After baseline evaluation in all residents, the intervention group received 4 education sessions using a medical simulator. All residents were then retested. After crossover, the wait-list group received the intervention, and residents were tested again. Performance was assessed by comparison to American Heart Association guidelines for treatment of ACLS conditions with interrater and internal consistency reliability estimates.*
Results: *Performance improved significantly after simulator training. No improvement was detected as a function of clinical experience alone. The educational program was rated highly.*

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Conclusion: *Training on a medical simulator dramatically increased the skills of residents in ACLS scenarios, compared to clinical experience.*

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The American Board of Internal Medicine requires candidates for certification to be judged competent by their residency program director in Advanced Cardiac Life Support (ACLS) procedures.[1] Residents usually fulfill this requirement by completing an American Heart Association (AHA) approved ACLS provider course. These courses typically include 1 day of reading, lecture, and practical instruction about the recognition and management of cardiac arrest events. However, ACLS course outcomes are not evaluated rigorously, and there is no follow-up. Despite recommended ACLS renewal on a 2-year cycle,[2] poor skill retention has been found among physicians, nurses, and laypersons in shorter time periods.[3–5] Several authors have argued that frequent refresher courses should be given to increase ACLS skill and knowledge retention.[6,7]

In-hospital cardiac arrest events that prompt "calling a code" occur rarely. A recent systematic review covering 207 academic and community hospitals showed that the average number of annual events requiring an ACLS response was 54.1 per facility.[8] Thus, internal medicine residents are expected to recognize and manage life-threatening events that occur infrequently and are not subject to audit or accountability assessment.

Medical education at all levels is placing increased reliance on simulation technology to boost the growth of learner knowledge, provide controlled and safe practice opportunities, and shape the acquisition of physicians' clinical skills.[9–11] Simulations vary in fidelity from inert task trainers used to practice endotracheal intubation to standardized patients to sophisticated mannequins linked to computer systems that can mimic complex medical problems, show interacting physiologic and pharmacologic parameters, and present problems in real time.[12] Combined with opportunities for controlled, deliberate practice with specific feedback,[13,14] simulations have demonstrated great effectiveness at promoting skill acquisition among medical learners[15,16] and generalizing simulation-based learning into patient care settings.[17,18] Gaining proficiency in clinical skills also gives rise to a sense of self-efficacy[19] among medical learners, an affective outcome that accompanies mastery experiences.

Our study had three purposes: first, to assess the baseline proficiency of 2nd-year internal medicine residents at managing simulated ACLS scenarios; second, to evaluate an educational intervention designed to strengthen residents' ACLS skills; and third, to address the feasibility and acceptance by internal medicine residents of a simulation-based educational program as a component of their postgraduate educational experience.

Methods

Study Design

Our study was a randomized, controlled trial of a simulation-based educational intervention designed to increase internal medicine residents' clinical skills in ACLS procedures. The trial featured a wait-list control group with crossover[20] (Figure 1). Primary measurements were obtained on three occasions: (a) baseline, (b) after the first intervention period, and (c) after group crossover and the second intervention period.

Participants

Study participants ($n = 38$) were all 2nd-year residents at Northwestern University's Chicago campus internal medicine residency program. The Northwestern University Feinberg School of Medicine Institutional Review Board approved the study. Participants provided informed consent prior to the baseline assessment.

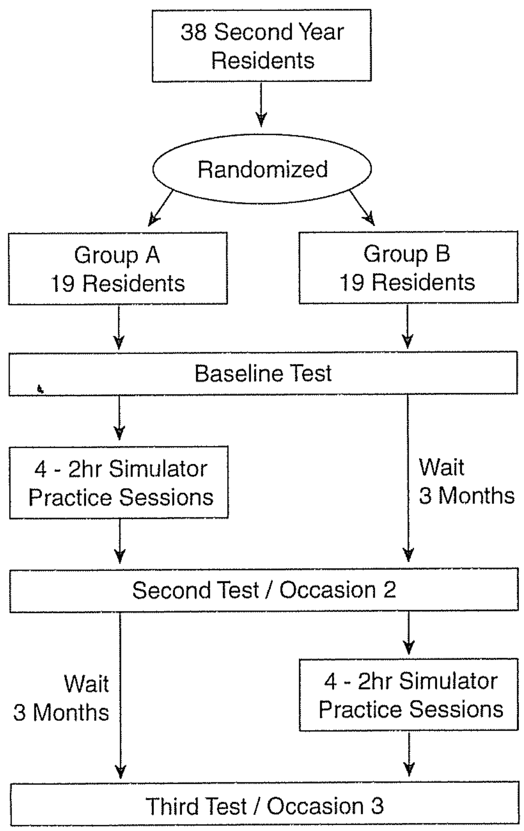

Figure 1. *Flow of participants through the study.*

The residency program is based at Northwestern Memorial Hospital and the Jesse Brown Veteran's Affairs Medical Center. Resident teams respond to all cardiac arrests at both hospitals. Teams are composed of two to three internal medicine residents and representatives from the anesthesia, surgery, and nursing services. All residents complete an AHA ACLS at the beginning of residency training. However, only 2nd- and 3rd-year residents are designated as the code leader. The 1st-year residents respond to cardiac arrests but do not serve as code leaders.

Procedure

As shown in Figure 1, 38 residents were randomly allocated to either receive the intervention (Group A) or serve as wait-list controls (Group B). Both groups underwent baseline testing after randomization. The intervention group then received four 2-hour simulator practice sessions while the wait-list control group received no intervention (i.e., performed normal clinical duties). After a second round of testing 3 months later, the control group crossed over and received the educational intervention while the intervention group returned to routine duties. A third round of standardized clinical skills testing was then conducted after 3 months for both groups. We could not conceal group assignments from the participants because half received the educational intervention early in the 2003 to 2004 academic year, whereas the second half received the same intervention later.

Intervention

The intervention was designed to help residents acquire, shape, and reinforce clinical skills needed to respond to ACLS scenarios. The intent was to engage the residents in deliberate practice[13] involving high-fidelity simulations of clinical events. Practice, feedback, and correction in a supportive environment were the operational rules of the educational intervention.

The study was conducted in Northwestern Memorial Hospital's Patient Safety Simulation Center using the life-size Human Patient Simulator (HPS®) developed by Medical Education Technologies, Inc., Sarasota, Florida. Using computer software, the mannequin displays multiple physiologic and pharmacologic responses observed in ACLS situations. Features of the mannequin include responses of the respiratory system, pupils, and eyelids as well as heart sounds and peripheral pulses. Monitoring of noninvasive blood pressure, arterial oxygen saturation, electrocardiogram, and arterial blood pressure is available. Simulator personnel can also give the mannequin voice through a speaker in the occipital area by talking into a microphone in an adjacent control room.

Six case scenarios were developed to assess resident proficiency in ACLS techniques. The scenarios were based on case studies described in the *ACLS Provider Manual*[21] used by the AHA as instructional materials for ACLS Provider courses. The six scenarios (asystole, ventricular fibrillation, supraventricular tachycardia, ventricular tachycardia, symptomatic bradycardia, and pulseless electrical activity) were selected because they were the ones most commonly encountered by residents in actual cardiac arrest situations during a 4-month preintervention monitoring period. Scenarios began with a brief clinical history also based on content found in the AHA text.

Simulator sessions were standardized and labeled as teaching or testing sessions. Teaching sessions gave groups of two to four residents time to practice protocols and procedures and to receive structured education from simulator faculty. Debriefing allowed the residents to ask questions, review algorithms, and receive feedback. The four teaching sessions were presented in uniform order: (a) procedures—intubation, central line placement, pericardiocentesis, and needle decompression of tension pneumothorax; (b) pulseless arrhythmias—asystole, ventricular fibrillation, pulseless electrical activity; (c) tachycardias—supraventricular and ventricular; and (d) bradycardias—second- and third-degree atrioventricular block.

Two residents were present at each testing session (see Figure 2). While one resident directed resuscitation efforts, the other resident performed cardiopulmonary resuscitation or other tasks but did not

Figure 2. *Residents participate in ACLS scenarios. Photograph courtesy of Northwestern University.*

make management decisions or lead the arrest scenario. The presentation order of the six scenarios was randomized within each testing session. As described in the ACLS guidelines, residents were expected to obtain a history; perform a physical examination; request noninvasive and invasive monitoring; order medications, procedures, and tests; and direct resuscitative efforts of other participants. Residents did not review the scenarios before the session and were not permitted to use written materials while directing the simulations.

Measurements

A checklist was developed for each of the six conditions from the ACLS algorithms using rigorous step-by-step procedures.[22] Within the checklists, each patient assessment, clinical examination, medication, or other action was listed in the order recommended by the AHA and given equal weight. None of the checklist items was weighted differentially. A dichotomous scoring scale ranging from 0 (*not done/done incorrectly*) and 1 (*done correctly*) was imposed for each item. Checklists were reviewed for completeness and accuracy by three of us (D.B.W., J.B., and V.J.S.), all of whom are ACLS providers. One of us (V.J.S.) is an ACLS instructor.

Evaluations of each resident's adherence to ACLS protocols on a randomly selected set of three of the six simulated scenarios were recorded by one of the two faculty raters on the checklists during the testing sessions. A 50% random sample of the testing sessions was rescored by the other rater from videotapes to assess interrater reliability. The rescoring was blind to the results of the first checklist recording. Both raters were blind to the residents' group assignments.

Demographic data were obtained including age, gender, ethnicity, medical school, and scores on the United States Medical Licensing Examination (USMLE) Steps 1 and 2. Each resident's experience in managing patients with any of the six conditions was collected at each test occasion.

Primary outcome measures were checklist scores. A secondary outcome measure was a course assessment survey completed at the end of the 10-month study period.

Raw checklist scores ranged from 16 to 31 items for the six ACLS simulations. To achieve equal weighting of performance across all simulations, scores were computed as percent correct for each of the simulations and summed across the three simulations randomly assigned to each resident. The total scores thus ranged from 0 to 300.

Data Analysis

Checklist score reliability was estimated in two ways: (a) interrater reliability was calculated using the Kappa (κ) coefficient[23] adjusted using the formula of Brennan and Prediger[24] and (b) using Cronbach's Alpha (α) coefficient.[25] Pearson correlations were used to study the association of ACLS performance measured by checklists with USMLE scores Steps 1 and 2. Intervention versus wait-list control group differences at each testing interval were analyzed using independent samples *t* tests.

Results

All residents consented to participate and completed the entire training protocol. The simulator operated without error or breakdown.

Table 1 presents demographic data about the residents enrolled in the study. The two groups did not differ in terms of age, gender, ethnicity, percentage of U.S. medical school graduates, or scores on USMLE Steps 1 and 2 (not shown). A majority of the residents had little or no experience responding to actual ACLS situations during the first residency year.

Table 2 reports descriptive statistics about resident performance on each of the six ACLS scenarios at baseline, measurement Occasion 2, and measurement Occasion 3. Interrater reliability coefficients, expressed as the mean Kappa ($\overline{\kappa_n}$) and Cronbach's alpha internal consistency reliability coefficients (α) are also given. With one exception, pulseless electrical activity (α), the reliabilities indicated a high degree of

Table 1. *Baseline Demographic Data*

Characteristic	Group A	Group B
Age (years)		
M	27.53	27.00
SD	1.26	0.94
Gender		
Male	13 (68.4)	10 (52.6)
Female	6 (31.6)	9 (47.4)
Total	19 (100)	19 (100)
Ethnicity		
African American	0 (0)	0 (0)
Caucasian	9 (47.4)	6 (31.5)
Asian	10 (52.6)	11 (57.9)
Native Hawaiian or Pacific Islander	0 (0)	1 (5.3)
Hispanic	0 (0)	1 (5.3)
Total	19 (100)	19 (100)
Medical School		
U.S. Medical School Graduate	19 (100)	19 (100)
Actual ACLS situations participated in during first year of training		
0–5	13 (68.4)	16 (84.2)
5–10	5 (26.3)	3 (15.8)
10–15	1 (5.3)	0 (0)
> 15	0 (0)	0 (0)
Total	19 (100)	19 (100)

Note. Numbers in parentheses are percents. ACLS = Advanced Cardiac Life Support.

Table 2. *Checklist Descriptive Statistics and Reliabilities*[a]

		Baseline Performance				Occasion 2				Occasion 3			
		Group A		Group B		Group A Post-Training		Group B		Group A		Group B Post-Training	
Scenario	No. Items	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Asystole[b]	17	66.9	11.7	62.0	18.3	92.2	3.0	67.9	14.1	86.6	7.5	87.1	2.6
Ventricular Fibrillation[c]	31	65.3	24.0	58.9	23.4	94.1	4.7	64.8	20.2	82.5	17.1	92.9	2.7
Supraventricular Tachycardia[d]	30	60.4	20.0	57.9	14.1	83.9	4.9	58.7	12.1	84.5	6.6	89.3	6.0
Ventricular Tachycardia[e]	22	72.3	18.2	77.3	16.7	95.5	4.9	84.5	6.9	92.7	10.5	92.5	6.1
Symptomatic Bradycardia[f]	19	51.7	13.3	60.5	17.1	85.0	7.4	57.9	9.4	83.2	6.9	85.7	8.4
Pulseless Electrical Activity[g]	16	65.3	12.0	74.2	14.0	83.2	3.9	66.7	12.3	87.5	7.7	90.6	4.7

[a]Tabular entries = percentage correct. [b]$\kappa = .78$, $\alpha = .63$. [c]$\kappa = .70$, $\alpha = .91$. [d]$\kappa = .79$, $\alpha = .82$. [e]$\kappa = .93$, $\alpha = .81$. [f]$\kappa = .80$, $\alpha = .61$. [g]$\kappa = .80$, $\alpha = .50$.

interrater agreement about resident scenario performance and good internal consistency.

There was no association between ACLS scenario performance measured by checklists and USMLE Step1 and 2 scores (median correlation = –.05).

The primary research outcomes are reported in Figure 3. The figure shows that at baseline, the total ACLS checklist scores for Group A ($M = 192.8$, $SD = 42.4$) and Group B ($M = 190.7$, $SD = 24.9$) did not differ significantly, $t(36) = -.19$, *ns*. However, after the first educational intervention, the total ACLS checklist performance for Group A ($M = 265.6$, $SD = 9.5$) was 38% higher than the total score for the wait-list control Group B ($M = 192.5$, $SD = 35.9$), a highly significant difference, $t(36) = -8.58$, $p < .0001$. Following crossover, the second educational intervention, and the third round of simulation-based testing, the total ACLS checklist scores for Group A ($M = 256.15$, $SD = 20.28$) and Group B ($M = 268.98$, $SD = 12.63$) were very similar yet significantly different on statistical grounds, $t(36) = 2.34$, $p < .05$).

Discussion

With regard to the first 2 study objectives, our results demonstrate that baseline resident performance on ACLS scenarios improved significantly with repetitive practice using a medical simulator compared

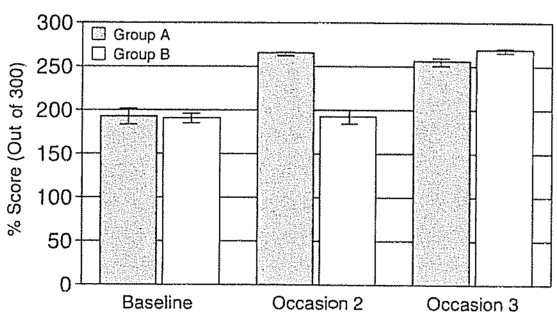

Figure 3. *Randomized trial Advanced Cardiac Life Support skill outcomes. Group mean ± 95% confidence interval.*

to clinical experience alone. Use of the computer-enhanced mannequin in a structured educational program with opportunities for deliberate practice yielded large, consistent, and sustained improvements in residents' skills with little decay over time. This educational approach incorporates features of the mastery[26] and competency-based[27] models of education that are now being introduced into clinical medical education.[16]

Medical education based on models that feature objective outcome measurements dovetail with a recent policy statement about needed improvements in postgraduate medical education. Goroll and colleagues[28] argued on behalf of the Residency Review Committee for Internal Medicine of the Accreditation Council for Graduate Medical Education for "a new outcomes-based accreditation strategy for residency training programs in internal medicine. It shifts residency program accreditation from external audit of educational process to continuous assessment and improvement of trainee clinical competence" (p. 902). Our study is an objective, data-based demonstration of the proposed accreditation model.

The study design we employed, a randomized trial with a wait-list control group, is well suited to intervention studies in clinical medical education. The design permits a rigorous evaluation of the effects of an educational intervention under circumstances in which a large group of learners cannot be trained simultaneously. All learners ultimately benefit from the new educational experience yet in a way that allows for systematic educational research and complete informed consent as argued by Lurie.[29]

Two unexpected findings derived from the study. First, there was no correlation between clinical competence measured by the ACLS skills checklists and academic competence measured by USMLE Step 1 and 2 scores. This supports the difference between professional and academic achievement described in earlier research.[30,31] Second, regarding our third study objective, we were delighted with the high level of enjoyment the residents received from simulator training.

Postcourse questionnaire responses were uniformly high and positive endorsing (1–5 Likert scale *M* and *SD*) such statements as "Practice with the medical simulator boosts my clinical skill" (4.82, 0.69); "Repetitive practice using the medical simulator is a valuable educational experience" (4.55, 0.76); and "The medical simulator has helped prepare me to be a code leader better than the ACLS course I took" (4.79, 0.70). Residents also felt strongly that this educational program should be a required part of residency training.

This study has several limitations. It was conducted within one residency program at a single academic medical center. The computer-enhanced simulator mannequin was used for both education and testing, potentially confounding the events. The results of the study cannot be generalized directly to clinical practice, as endorsed by Miller[32] and Kirkpatrick,[33] due to the infrequency of actual events. Whether these findings could be replicated using a lower fidelity simulator cannot be determined from this study. This does not, however, diminish the pronounced impact the simulation-based training produced among the medical residents.

This is the first report of a randomized trial on simulator-based ACLS training. Subsequent simulation-based studies will involve replications of this research model addressing different clinical skills with larger participant samples. Our education and research group plans to investigate such issues as variation among learners in the number of practice trials needed to achieve preestablished mastery performance standards and the rate of clinical skills decay without refresher training. In conclusion, our study demonstrated the ability of deliberate practice in a medical simulator to increase resident adherence to published guidelines in managing ACLS scenarios. This project was successfully implemented in a complex residency schedule, received high ratings from learners, and complies with new residency program accreditation requirements because it provides reliable assessments of residents' ACLS competence.

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