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Simulation-Based Education Improves Quality of Care During Cardiac Arrest Team Responses at an Academic Teaching Hospital*

A Case-Control Study

Diane B. Wayne, MD; Aashish Didwania, MD; Joe Feinglass, PhD; Monica J. Fudala, BA; Jeffrey H. Barsuk, MD; and William C. McGaghie, PhD

Background: Simulation technology is widely used in medical education. Linking educational outcomes achieved in a controlled environment to patient care improvement is a constant challenge.

Methods: This was a retrospective case-control study of cardiac arrest team responses from January to June 2004 at a university-affiliated internal medicine residency program. Medical records of advanced cardiac life support (ACLS) events were reviewed to assess adherence to ACLS response quality indicators based on American Heart Association (AHA) guidelines. All residents received traditional ACLS education. Second-year residents (simulator-trained group) also attended an educational program featuring the deliberate practice of ACLS scenarios using a human patient simulator. Third-year residents (traditionally trained group) were not trained on the simulator. During the study period, both simulator-trained and traditionally trained residents responded to ACLS events. We evaluated the effects of simulation training on the quality of the ACLS care provided.

Results: Simulator-trained residents showed significantly higher adherence to AHA standards (mean correct responses, 68%; SD, 20%) vs traditionally trained residents (mean correct responses, 44%; SD, 20%; p = 0.001). The odds ratio for an adherent ACLS response was 7.1 (95% confidence interval, 1.8 to 28.6) for simulator-trained residents compared to traditionally trained residents after controlling for patient age, ventilator, and telemetry status.

Conclusions: A simulation-based educational program significantly improved the quality of care provided by residents during actual ACLS events. There is a growing body of evidence indicating that simulation can be a useful adjunct to traditional methods of procedural training.

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Key words: advanced cardiac life support; cardiopulmonary resuscitation; medical education; simulation technology

Abbreviations: ACLS = advanced cardiac life support; AHA = American Heart Association; NMH = Northwestern Memorial Hospital

The use of simulation technology has great potential to shape medical education, certification, licensure, and the quality of care. Simulation has demonstrated its effectiveness to achieve, measure, and maintain trainee skill in the performance of a variety of clinical procedures including laparoscopic surgery, endoscopy, advanced cardiac life support (ACLS), emergency airway management, trauma resuscitation, bronchoscopy, and carotid angiography. Although this technology has much promise, a key challenge is to link performance in the controlled simulation environment to the quality of the patient care delivered. Small studies have evaluated clinical performance after simulator training with encouraging results, but their scope is limited.
In July 2003, we initiated a simulation-based ACLS training program for internal medicine residents featuring 8 h of deliberate practice on a full-body patient simulator, immediate feedback, and rigorous outcome measures. We evaluated training outcomes using a randomized trial with a waiting list control group. Results showed that residents’ ACLS skills increased 38%,$^6$ were maintained over a period of 14 months,$^8$ and that the training was rated highly as an adjunct to traditional didactic and clinical experience. The present study evaluates whether simulation-based ACLS education affects the quality of care during actual ACLS events at our institution.

**Materials and Methods**

**Design**

This was a retrospective case-control study$^8$ of cardiac arrest team responses at Northwestern Memorial Hospital (NMH) from January to June 2004. An educational program had been started 6 months earlier for second-year internal medicine residents featuring simulation-based training in ACLS. A 6-month study period was selected because it provided an opportunity to compare two groups of ACLS team leaders as a natural quasi-experiment.$^3$ Cases and controls are team responses to ACLS events divided into those who were directed by simulator-trained leaders vs those who were managed by traditionally trained leaders. The Northwestern University institutional review board approved the study and waived informed consent.

**Setting**

NMH is a tertiary health-care facility located in urban Chicago and is the principal setting for graduate medical education under the auspices of Northwestern University. At NMH, cardiac arrest teams, led by an on-call second-year or third-year internal medicine resident, respond to all “code blue” calls. All residents completed an American Heart Association (AHA) ACLS provider course at the beginning of the first year of training and again at the start of the third year of training (Fig 1).

**Procedure**

Second-year internal medicine residents (ie, the simulator-trained group $[n = 38]$) received a 10-h simulation-based education allowed the residents to ask questions, review algorithms, and receive standardized 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 as follows: (1) procedures (intubation, central line placement, pericardiocentesis, and needle decompression of tension pneumothorax); (2) pulseless arrhythmias (asystole, ventricular fibrillation, and pulseless electrical activity); (3) tachycardias (supraventricular and ventricular); and (4) bradyarrhythmias (second-degree and third-degree atrioventricular block).

Third-year residents (ie, the traditionally trained group $[n = 40]$) had more postgraduate training and had recently renewed their ACLS provider status through an AHA ACLS course, as shown in Figure 1, but were not trained using the simulator. The study period provided a unique opportunity for a natural experiment$^3$ to compare these two groups.

**Outcome Measure**

Mirroring the simulation training evaluations,$^6$ medical abstraction was based on the 2003–2004 AHA guidelines, which list...
four key steps across six common ACLS events (i.e., asystole, ventricular fibrillation, supraventricular tachycardia, ventricular tachycardia, symptomatic bradycardia, and pulseless electrical activity) to compute the total correct performance score as a percentage. The four measures were selected because they were common across ACLS scenarios, did not depend on physician judgment, could be scored objectively, and were based on algorithms from the AHA ACLS textbook.22 The four key steps are as follows:

1. Provision of basic life support as a first response;
2. Selection and dosage of the first drug administered;
3. Sequence and dose of subsequent drugs administered; and
4. Use of defibrillation, synchronized cardioversion, and/or pacing at the correct strength/rate.

For the most common condition, refractory ventricular fibrillation (n = 16), a more detailed assessment was possible due to the AHA algorithm for this scenario.22 The algorithm consisted of the following: (1) use of defibrillation immediately after administering basic life support; (2) administration of three shocks without interruption; (3) use of a drug-shock-drug sequence; and (4) administration of an antiarrhythmic drug at the appropriate point in the algorithm. Abstracted data also included patient age and pre-cardiac arrest ventilator and telemetry status.

Adherent responses to each ACLS event were defined as compliance with AHA guidelines of ≥ 75%, based on adding all possible correctly performed performance measures. This cutoff was used because it is identical to the mean of the passing performance standards set by an expert panel in an earlier ACLS standard-setting study.21

![Figure 1. Timeline of AHA ACLS training, clinical training, and simulator training by resident year.](image)

Statistical Analysis

Interrater reliability was assessed using the κ coefficient24 adjusted using the formula of Brennan and Prediger.25 Group differences between simulator-trained and traditionally trained residents were evaluated using the t test and the χ² test. Logistic regression was computed to determine the odds ratio of an adherent ACLS response, testing the difference between groups controlling for patient age, and preevent ventilator and telemetry status (each coded “Y”/“N”). Logistic regression variables were selected because they were documented in the medical record and had been used in prior studies of survival from in-hospital cardiac arrest events.

**RESULTS**

The mean interrater reliability for the 20 randomly selected ACLS events across the eight performance measures was high (κ = 0.87). This indicates that there was very little disagreement about abstraction of ACLS performance data.

Twenty ACLS events were led by simulator-trained second-year residents and 28 were led by traditionally trained third-year residents. As shown in Table 1, no difference between patients in either group was shown by age, ventilator, or telemetry status.

Simulator-trained residents showed a significantly

<table>
<thead>
<tr>
<th>Variables</th>
<th>Simulator-Trained Residents</th>
<th>Traditionally Trained Residents</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean patient age, yr</td>
<td>67.1 (SD, 12.8)</td>
<td>66.9 (SD, 13.9)</td>
<td>0.97</td>
</tr>
<tr>
<td>Receiving ventilation</td>
<td>2 (10)</td>
<td>7 (25)</td>
<td>0.45</td>
</tr>
<tr>
<td>Receiving telemetry</td>
<td>9 (45)</td>
<td>11 (39.3)</td>
<td>0.69</td>
</tr>
<tr>
<td>Adherent to resuscitation (≥ 75% correct)</td>
<td>13 (65.0)</td>
<td>6 (21.4)</td>
<td>0.002</td>
</tr>
<tr>
<td>Survived event</td>
<td>9 (45.0)</td>
<td>13 (46.4)</td>
<td>0.92</td>
</tr>
<tr>
<td>Mean postevent survival to death or hospital discharge, h</td>
<td>194.7 (SD, 141.2)</td>
<td>107.1 (SD, 105.8)</td>
<td>0.11</td>
</tr>
<tr>
<td>Survived to hospital discharge</td>
<td>2 (10)</td>
<td>1 (3.6)</td>
<td>0.36</td>
</tr>
</tbody>
</table>

*Data are presented as No. (%) unless otherwise indicated.
higher adherence to AHA standards (mean correct responses, 68%; SD, 20%) vs traditionally trained residents (mean correct responses, 44%; SD, 20%; \( t_{(46)} = -3.7; p \leq 0.001 \) [Fig 2].

Using the \( \geq 75\% \) cut point for an adherent performance, 13 of 20 ACLS responses (65%) led by simulator-trained residents achieved this standard vs 6 of 28 (21.4%) responses led by traditionally trained residents (\( \chi^2_{(1)} = 7.7; p \leq 0.01 \)). Simulator-trained residents were over seven times more likely to lead an adherent ACLS response than traditionally trained residents (odds ratio, 7.1; 95% confidence interval, 1.8 to 28.6) after controlling for patient age, ventilator, and telemetry status in logistic regression.

Twenty-two of the 48 patients survived the ACLS event, and 3 patients survived to hospital discharge. Nine of the 20 patients (45%) managed by simulator-trained residents survived the event and 13 of the 28 patients (46.4%) managed by traditionally trained residents survived the event (\( p = 0.92 \)). Although postevent survival was not different between groups, the mean survival time to death or hospital discharge among the nine surviving patients managed by simulator-trained residents was 194.7 h compared to 107.1 h for the 13 surviving patients managed by traditionally trained residents (\( p = 0.11 \)). Two of the patients surviving to hospital discharge were in the simulator-trained group (discharge rate, 10%), and one patient was in the traditionally trained group (eventual discharge rate, 3.6%; \( p = 0.36 \)).

**Discussion**

This study amplifies the outcomes of past research on simulation-based ACLS medical education by extending those research findings to the quality of care provided during real ACLS events. Our prior work documented the ability of simulation-based training to significantly increase residents’ ACLS skills,\(^6\) to allow for the setting of mastery standards,\(^7\) and to demonstrate the retention of skill over a 14-month study period.\(^8\) The research situation described in this article presented a unique opportunity to assess clinical responses of simulator-trained vs traditionally trained residents in an actual patient care environment. Our study effectively demonstrates the ability of a simulation-based education program to improve adherence to AHA ACLS guidelines in a group of residents, even though they had less clinical experience and less traditional ACLS training (one vs two provider courses) than the comparison group (Fig 1).

While supporting a role for simulation training grounded in deliberate practice, our results highlight an unanswered question, “Can competence be evaluated independent of outcomes?”\(^2,28\) The clinical process was fulfilled by the ACLS training and evaluation program, but differences in clinical outcome were not achieved because most patients died regardless of the treatment they received. Our survival to hospital discharge rate of 3 of 48 patients is within the range of other published studies\(^29\) and reflects the high prearrest morbidity of this patient population. Many factors may also contribute to survival from in-hospital cardiopulmonary arrest including patient characteristics, initial cardiac rhythm, and circadian variation.\(^29,30\) Given these confounders and our small sample size, it is not surprising that our results did not conclusively show improved survival as a result of simulator training. Whether this would be seen in a larger patient sample is unknown, although a trend toward longer postevent survival and an improved survival to hospital discharge rate were seen.

Many of the ACLS events led by our residents did not meet the minimum standard for resuscitation despite prior conventional training and experience. This finding is consistent with those of other studies that show clinical experience alone is often insufficient to ensure the acquisition of such basic clinical skills as chest radiograph interpretation,\(^31\) hypertension diagnosis and management,\(^32\) cardiac auscultation,\(^33\) and emergency airway management.\(^34\) Poor adherence to AHA guidelines by well-trained hospital staff during in-hospital ACLS events\(^35,36\) and a rapid decline of skill after traditional ACLS education\(^37\) have also been well documented. Our results show a dramatic improvement in adherence to accepted guidelines in the clinical setting among residents who had an opportunity for focused, deliberate practice in a controlled simulation environment. Our prior observations\(^8\) of long-term retention of these skills following simulator training are encouraging and warrant further study.

![Figure 2](https://www.chestjournal.org/2008/133/1/january/59/figure2.jpg)

**Figure 2.** Adherence to AHA guidelines for 48 ACLS events (\( p = 0.001 \)).
Our study has several limitations. It represents a small sample of events at a single institution over a short time period. It used a case-control retrospective design rather than a prospective randomized design. The possibility of omissions or errors in chart documentation cannot be excluded. Clinical factors other than the training status of team leaders, such as input or cuing from other members of the resuscitation team, may influence adherence to ACLS guidelines. The existence of other confounding or uncontrolled factors cannot be definitively ruled out. However, the magnitude and consistency of the statistical results lead us to believe that the skill improvements gained in the simulated environment can be generalized to the clinical setting and are not an artifact of chance or other variables.

In conclusion, the use of a simulation-based training program improved the quality of resuscitation efforts by internal medicine residents in actual ACLS events at our institution. We believe traditional bedside and clinical teaching in medical education should be amplified to include simulation-based training. This may be especially useful in high-acuity skills such as ACLS, which are required for board training. This may be especially useful in high-acuity events at our institution. We believe traditional bedside and clinical teaching in medical education should be amplified to include simulation-based training. This may be especially useful in high-acuity skills such as ACLS, which are required for board certification yet occur infrequently. In patients with critical illness, teams of physicians need to respond effectively to provide high-quality patient care. This study adds to the growing body of knowledge that simulation-based education improves the procedural skills of physicians and may enhance the quality of their patient care. In this study, deliberate practice is shown to be a powerful tool to boost the competence of physicians and the quality of their patient care in actual ACLS events.

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