Evaluation of a Computer-Based Educational Intervention to Improve Medical Teamwork and Performance During Simulated Patient Resuscitations

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Objectives: To determine the impact of a low-resource-demand, easily disseminated computer-based teamwork process training intervention on teamwork behaviors and patient care performance in code teams.

Design: A randomized comparison trial of computer-based teamwork training versus placebo training was conducted from August 2010 through March 2011.

Setting: This study was conducted at the simulation suite within the Kado Family Clinical Skills Center, Wayne State University School of Medicine.

Participants: Participants ($n = 231$) were fourth-year medical students and first-, second-, and third-year emergency medicine residents at Wayne State University. Each participant was assigned to a team of four to six members ($n_{teams} = 45$).

Interventions: Teams were randomly assigned to receive either a 25-minute computer-based training module targeting appropriate resuscitation teamwork behaviors or a placebo training module.

Measurements: Teamwork behaviors and patient care behaviors were video recorded during high-fidelity simulated patient resuscitations and coded by trained raters blinded to condition assignment and study hypotheses. Teamwork behavior items (e.g., "chest radiograph findings communicated to team" and "team member assists with intubation preparation") were standardized before combining to create overall teamwork scores. Similarly, patient care items ("chest radiograph correctly interpreted"; "time to start of compressions") were standardized before combining to create overall patient care scores. Subject matter expert reviews and pilot testing of scenario content, teamwork items, and patient care items provided evidence of content validity.

Main Results: When controlling for team members' medically relevant experience, teams in the training condition demonstrated better teamwork (F [1, 42] = 4.81, $p < 0.05$; $\eta^2_p = 10\%$) and patient care (F [1, 42] = 4.66, $p < 0.05$; $\eta^2_p = 10\%$) than did teams in the placebo condition.

Conclusions: Computer-based team training positively impacts teamwork and patient care during simulated patient resuscitations. This low-resource team training intervention may help to address the dissemination and sustainability issues associated with larger, more costly team training programs. (*Crit Care Med* 2013; 41:2551–2562)

Key Words: cardiopulmonary resuscitation; education measurement; healthcare team; medical education; medical errors; patient simulation

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Communication breakdown and teamwork failures have been directly linked with medical error and adverse patient events (1–3). As a result, multiple efforts have been made to improve the performance of interdisciplinary healthcare teams (4). Code teams function in complex, dynamic, and time-pressured working conditions (5–8). These conditions present challenges to teams, thus threatening their ability to effectively communicate, coordinate, and recognize threats to patient safety (9–11).

Recent educational efforts to improve healthcare team effectiveness have focused on team training (12). Although some of these efforts have demonstrated promising results, feasibility issues limit their implementation (13, 14). Team training programs such as Team Strategies and Tools to Enhance Performance and Patient Safety (TeamSTEPPS) and Anesthesia Crisis Resource Management are resource-intensive, requiring significant organizational investment to sustain (15, 16). An easily implemented, low-resource-demand team training program could be used by institutions unable to support more resource-intensive efforts. Furthermore, such training could be implemented as part of a refresher training program aimed toward minimizing skill decay.

A recent report in *Critical Care Medicine* comments on the importance of effective teamwork to patient safety (17). However, the same article notes a relative lack of high-quality research evaluating the efficacy of team training interventions. Similarly, the general healthcare literature has called for research demonstrating team training effectiveness using robust evaluation techniques (14, 18). Assessing the impact of team training on team performance requires precise and reliable measures for team processes (i.e., team interactions such as coordination and back-up behavior) and patient care (i.e., error reduction, evidence-based patient care, or adherence to standard treatment guidelines) (19). Using appropriate measurements is critical to understanding not only what happened in terms of patient care outcomes but also why and how in terms of teamwork process behaviors. However, accurately capturing both teamwork process and patient outcome data in a real-world environment can present significant challenges. Methodologically sound, high-fidelity human patient simulations provide an assessment platform that is both realistic and scientifically valid, i.e., systematic, reliable, and replicable (20, 21). The use of simulation offers the ability to diagnose performance and link ineffectual teamwork with specific team characteristics and skill deficiencies (22, 23). Simulation-based assessment therefore provides a necessary first step to determining the impact of an intervention on overall patient outcomes (24).

The goal of this study was to evaluate the efficacy of a computer-based teamwork process training (cTPT) intervention on medical emergency teamwork and patient care performance during simulated patient resuscitations. Computer-based training is frequently used in healthcare education due to its ease of distribution, ability to track learner activity, low cost, and standardized content (25). Accordingly, it is a valuable solution when high-volume, easily disseminated training is required. We hypothesized that teams receiving cTPT would exhibit a greater number of appropriate teamwork and patient care behaviors as compared with teams receiving placebo training.

In a meta-analysis of teamwork training research across various industries, Salas et al (26) evidenced effect sizes of 12–19%. These percentages represent the amount of team performance attributable to training. Teamwork training initiatives in simulation-based studies have demonstrated similar, and sometimes even larger, effect sizes. For example, Jankouskas et al (27) evaluated a 3-hour simulation-based crisis resource management training and found that training accounted for 13–35% of team performance outcomes. The present research aims to determine if similar benefits for team performance can be achieved through a relatively low-resource training tool.

MATERIALS AND METHODS

Study Design

This study used a randomized comparison design to evaluate the efficacy of cTPT on medical resuscitation teamwork and patient care during simulated patient resuscitations (**Fig. 1**). Approval for this study was obtained from the Wayne State University (WSU) and Michigan State University institutional review boards.

Participants and Setting

Study participants (n = 231) were enrolled from a class of fourth-year medical students and first-, second-, and third-year emergency medicine residents at WSU from August 2010 to March 2011. Eligible participants provided written informed consent and signed an agreement to maintain confidentiality of all study-related activities. Individuals unable to attend the entire simulation were excluded from the study. Both training and simulated cases were conducted in the WSU-Kado Clinical Skills Center simulation suite. Coding of teamwork behaviors was conducted at Michigan State University. Coding of patient care behaviors was done independently at WSU.

Study Protocol

Participants were scheduled to participate during their emergency medicine clerkship rotation (students) or during their weekly education conference (residents). Consenting participants that met inclusion criteria were assigned to teams of four to six members based on schedule availability (n_{teams} = 45). Assignments were reviewed to ensure that no more than two members of each team had worked together in prior simulations (28). Participants completed a questionnaire that captured demographic information, clinical experience, and past simulation experience. Teams were randomized using computer software (http://www.randomizer.org) to receive either the cTPT intervention or placebo training. Both trainings were delivered via audio-narrated, automatic computer slide presentations lasting 25 minutes. Participants viewed the presentations individually at workstations equipped with headphones. Next, teams performed a single practice simulation that permitted exposure to the simulation environment. Each team then completed a second simulation that served as the training assessment. Instructor-led training and debriefing was withheld until the participants completed both scenarios. The content of the two simulation scenarios differed (cardiac arrest vs hemorrhagic shock); each one involved a

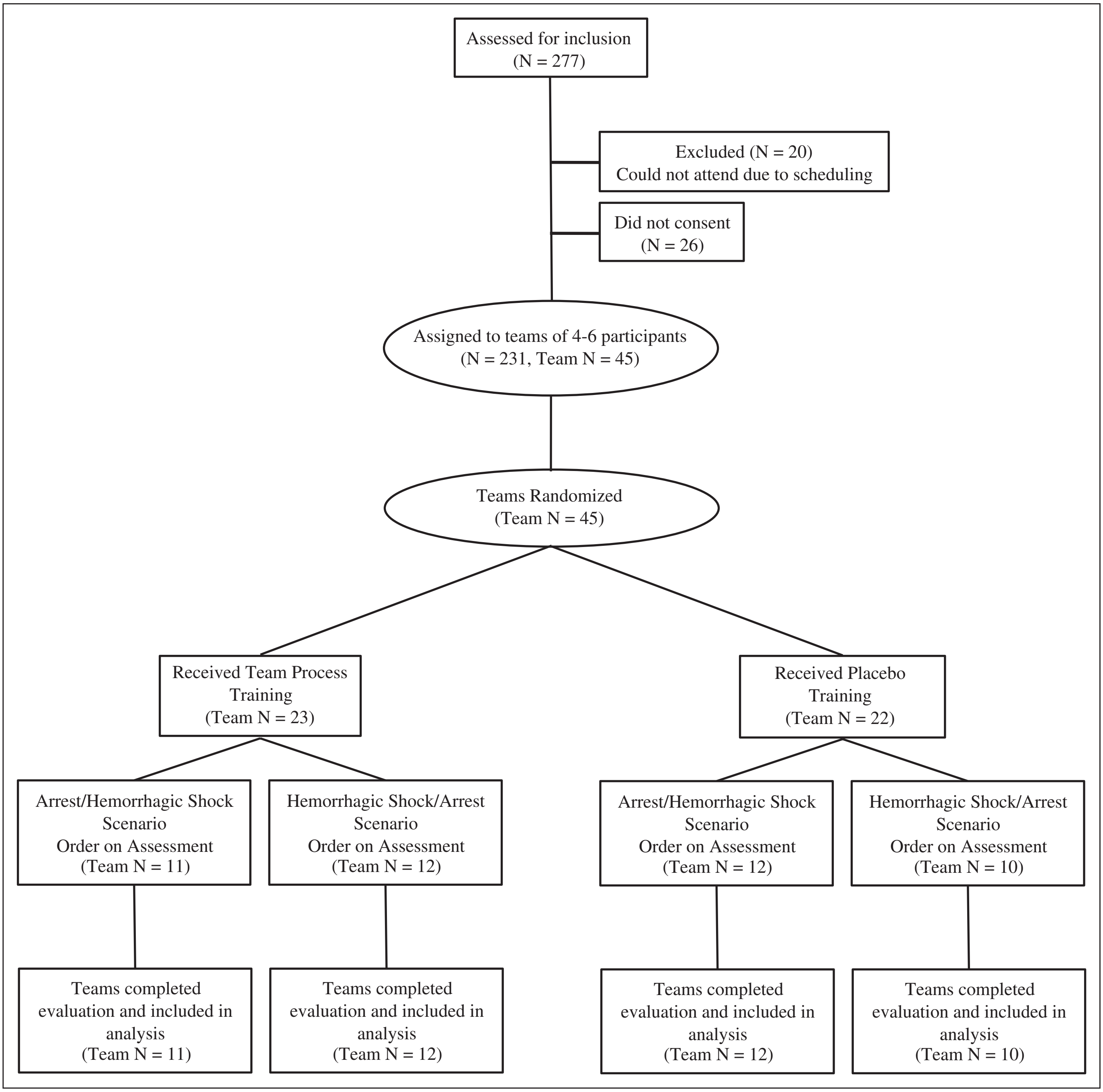

Figure 1. Participant and team flow. Arrest/hemorrhagic shock = cardiac arrest scenario performed first, followed by hemorrhagic shock scenario. Hemorrhagic shock/arrest = hemorrhagic shock scenario performed first, followed by cardiac arrest scenario.

patient with different symptoms and required different treatment protocols, but both necessitated resuscitation. Scenario order was counterbalanced across teams to ensure the effects of the cTPT would generalize across different clinical content (29). Both simulations employed a confederate nurse actor to execute nursing tasks and deliver scripted prompts built into the scenarios. The confederate was blind to condition assignment. Participants were proctored at all times to prevent team member interaction outside the simulations. Video recordings of the simulations were later coded for teamwork process and patient care behaviors as described below.

Teamwork Training

The objectives of the cTPT intervention were to improve 1) declarative knowledge of healthcare teams and critical teamwork behaviors, 2) understanding of why effective teamwork is important to patient safety, and 3) implementation of teamwork behaviors during code team events. A three-step instructional design process was employed to develop the training intervention (30). This approach is grounded in team training theory and uses principles of social learning theory to provide both declarative knowledge and implementation examples and teach the knowledge, skills, and attitudes necessary to support teamwork in medical resuscitation teams (31).

In Step 1, we analyzed code team structure, teamwork behaviors, and tasks to inform training content. Prior work by team science and medical experts provided a model of team effectiveness and a taxonomy of teamwork process behaviors for use in code teams (32, 33). From this taxonomy, teamwork domains critical to code team effectiveness were identified and incorporated into the team training session. Content and examples are outlined in **Table 1**.

In Step 2, we created content to deliver information about teamwork behaviors that could be disseminated using a low-resource training platform. A PowerPoint-based format was chosen as it could be easily disseminated, would not demand specialized equipment or personnel, and could be modified as needed. Training content included clinical examples specific to code teams that demonstrated effective implementation of teamwork behaviors. The examples did not provide participants with information regarding situations or tasks they would encounter during the simulation-based assessments.

TABLE 1. Computer-Based Team Process Training Content Outline

Team Processes	Description	Exemplars Provided in Training
Planning or preparation		A single critical incident (sentinel event) was used to demonstrate appropriate team process behaviors and their impact on patient care
Mission analysis	Identification and interpretation of the team's tasks as well as environmental conditions, available resources, and potential challenges	1. Team members should not only interpret the team's mission but also discuss it with team members 2. Team members should adapt to changing circumstances 3. Team members should think about what information is needed to perform a thorough mission analysis
Goal specification	Identification and prioritization of team goals	1. Team members should ensure that all necessary roles and tasks are filled by team members in a timely manner 2. Team members should encourage team members with specific skills to carry out tasks that are aligned with those skills 3. Team members should be responsive to changing demands associated with current roles, as well as new roles that arise
Strategy formulation	Developing a course of action as well as contingency plans. Involves adjusting strategies in response to environmental and task changes	1. Team members should continuously gather relevant information that may enable the team to revise or reformulate the plans of action 2. Team members should engage in both *deliberate planning* and *reactive strategy adjustment* *Deliberate planning* requires the establishment and communication of a plan for mission accomplishment *Reactive strategy adjustment* involves altering initial plans in response to unanticipated changes in the environment
Action		A single critical incident (sentinel event) was used to demonstrate appropriate team process behaviors and their impact on patient care
Systems monitoring and adaptation	Tracking team resources and environmental conditions to ensure the team can accomplish its goals; monitoring environmental changes and adapting strategies as necessary	1. You should assess the discrepancies between your team's goals and its current situation in real time 2. You should frequently monitor the status of key environmental factors that influence team goals and actions
Team monitoring/ back-up behavior	Team members assist other team members with their tasks, help to balance workloads, and compensate for areas of deficiencies. Also called cooperation, workload sharing, and group level citizenship behavior	1. Team members should diligently monitor and ask whether other members need help and provide it when they do 2. Team members should always provide verbal feedback or behavioral assistance if they notice that a team member makes an error 3. If team members are uncertain about the appropriateness of something they are about to do, they should make other team members aware immediately

(Continued)

TABLE 1. (*Continued*). Computer-Based Team Process Training Content Outline

Team Processes	Description	Exemplars Provided in Training
Coordination	Organizing the sequencing and timing of team activities	1. Team members should coordinate activities for tasks that are interdependent or require more than one individual to complete 2. Team members should anticipate transitions between tasks and try to reduce the amount of time they require 3. Team members should be able to change the sequencing, pace, or number of people involved in activities if unexpected circumstances arise
Mechanisms		A single critical incident (sentinel event) was used to demonstrate appropriate team process behaviors and their impact on patient care
Leadership	Directs and coordinates activities, assesses overall team performance, assigns roles, monitors and develops team attitudes and behaviors, facilitates problem solving and error recognition, and facilitates feedback	1. Team members should be mindful of situations where your expertise and experience put you in a position to lead the team 2. Team leaders should share the rationale for important team decisions
Communication	Following-up with a team member to verify that a message was correctly received and clarifying with the sender of a message that the message was received as intended	1. Team members should maintain the integrity of information when providing or receiving requests by using closed-loop communication 2. You should share key information with the whole team 3. You should communicate openly and supportively with your team members

In Step 3, we constructed the training intervention and piloted it within a group of expert healthcare providers to ensure usability, clinical relevance, and accuracy of information. Specifically, board-certified emergency medicine and critical care physicians previewed the PowerPoint presentation. After viewing the presentation, experts were queried by the investigators (R.F., K.J.) with regard to the overall content, applicability of clinical examples, pace and clarity of presentation, and length of training. Minor adjustments were made based on responses prior to enrolling subjects. The overall architecture and content of the curriculum is described in detail in **Appendix 1** (Supplemental Digital Content 1, http://links.lww.com/CCM/A690).

Placebo Training

Placebo training provided general information about different types of teams in a healthcare context and the role of simulation in healthcare training. A clinical example illustrating the importance of teams to patient safety was incorporated to keep the design as similar as possible to the intervention training. Neither specific teamwork behaviors nor their implementation were discussed. The format and overall length of the placebo training was identical to the cTPT intervention.

Outcome Measures

Two resuscitation simulations (cardiac arrest and hemorrhagic shock) were constructed using event-based scenario development techniques (34–36). Final scenarios (clinical content, behavioral triggers, timing, and expected responses) were content-validated by resuscitation experts ($n = 11$) and piloted using code teams consisting of emergency medicine attending physicians, critical care fellows, residents, and students ($n = 10$). Independent teamwork process and patient care behavioral checklist measures were developed for each scenario using evidence-based guidelines (24, 37) (**Table 2**). Time to completion, presence or absence of a behavior, and the number of behaviors occurring simultaneously are examples of outcome measure formats. These measures were content-validated by teamwork ($n = 17$) and clinical ($n = 10$) subject matter experts external to the research team and primary institution (38). Because the coding format of some measures differed from others (e.g., whether or not a behavior occurred vs the time to completion of an activity), data for each item were first standardized (i.e., converted to z-scores) before combining across all items to create overall teamwork and patient care scores. A team's overall teamwork score was the average of all teamwork behavior items, each item equally weighted. A team's overall patient care score was the weighted average of all patient care behavior items. Weighting was recommended by subject matter experts during the content-validation process (**Table 3**). Weights reflect the relative importance of each patient care behavior and were formally solicited from subject matter experts outside the research team.

Data Coding

This study used a data coding strategy following evidence-based practices as previously described (39, 40). Coders were blinded to condition assignments and study hypotheses. Two psychology

TABLE 2. Characteristics and Examples of Teamwork and Patient Care Measures

Scenario	Total Teamwork Items	Type of Measurement Item	Sample Teamwork Behaviors	Total Patient Care Items	Type of Measurement Item	Sample Patient Care Measures
Hemorrhagic shock resuscitation	81	Quality of teamwork action multitasking (BARS)	When possible, team members worked on multiple tasks, rather than having everyone focus on one task	63	Nature of patient care behavior (numerical value)	Rate of ventilations postintubation
		Presence of teamwork behavior (binary item)	Chest radiograph findings communicated to team		Presence of patient care behavior (binary item)	Chest radiograph correctly interpreted
		Proper sequencing/coordination of events (binary item)	Sequencing of actions during intubation appropriate		Time to critical patient care action (time)	Cause of patient's shock correctly identified
Cardiac arrest resuscitation	96	Quality of teamwork action (BARS)	Patient allergies communicated to all/few/no team members	91	Quality of patient care action (BARS)	Compressions during cardiopulmonary resuscitation done at appropriate depth
		Presence of teamwork behavior (binary item)	Change in cardiac rhythm communicated to team		Presence of patient care behavior (binary item)	Cardiac rhythm interpretation correct
		Proper sequencing/coordination of events (numerical value)	Percentage of times rhythm verbally communicated after defibrillation		Time to critical patient care action (time)	Time to successful intubation

BARS = behaviorally anchored rating scale.

research assistants coded videos for teamwork behaviors; two emergency medicine physicians coded videos for patient care behaviors. Inter-rater reliability for raters coding each class of behaviors met research standards (41). For teamwork behaviors, the average Cohen's $\kappa = 0.66$ (SD = 0.09) for categorical items and the average correlation = 0.95 (SD = 0.12) for continuous items. For patient care behaviors, the average Cohen's $\kappa = 0.97$ (SD = 0.04) for categorical items and the average correlation = 0.94 (SD = 0.09) for continuous items. This demonstrates substantial agreement for teamwork behavior coding and excellent agreement for patient care behavior coding (41).

Data Analysis

An experience composite variable was created for each participant using five indicators of medical skill level of education; age; and the number of resuscitations witnessed, participated in, or led. Since randomization occurred at the team, not the participant, level, it was necessary to control for member experience, as it is an established predictor of effectiveness (42). We first standardized each variable and conducted a principal components analysis to determine whether the five indicators loaded on the same underlying factor (i.e., experience). A one-factor solution was found, accounting for 79.27% of the variance with all indicators loading above 0.81. These results support the use of an averaged composite variable composed of these five indicators to represent experience.

Analyses of covariance (ANCOVA) were used to 1) establish that the particular scenario used for assessment did not have an influence on training outcomes (i.e., a precondition for assessing training effects) and 2) assess the effect of the training intervention on teamwork behaviors and patient care performance (primary analyses). In the first analysis, the independent variable was the scenario used for assessment (cardiac arrest vs hemorrhagic shock). In the second analysis, the independent variable was intervention condition (cTPT vs placebo training). The experience composite was included as a covariate to control for the effects of experience on teamwork processes and training outcomes. Statistical analyses were performed using IBM SPSS Statistics version 19 (SPSS, Armonk, NY). Assumptions for ANCOVA analyses were met.

TABLE 3. Sources of Validation of Measurement Platform

Sources of Evidence of Validity and Definitions[a]	Scenario	Teamwork Process Measures	Patient Care Measures
Content: The degree to which the components and entirety of the measurement tool represents the intended construct	Clinical content experts provided rating of the appropriateness of[b]: 1. Patient presentation 2. Clinical triggers 3. Clinical data (electrocardiogram, lab results, etc.)	Teamwork subject matter experts ($n = 17$) reviewed the teamwork measures and quantified the extent to which they represent dimensions of team processes critical for performance in medical action teams	Clinical subject matter experts ($n = 10$) reviewed the patient care measures and quantified the extent to which they: 1. Accurately captured appropriate team performance 2. Were critical to successful patient management[c]
Response process: Relationship of the thought processes and actions of the subjects and the intended construct	Scenarios were pilot tested among five teams. Postscenario interviews with participants elicited: 1. Representativeness of scenario 2. Diagnostic reasoning used during scenario 3. Degree of psychological fidelity 4. Team interactions provoked by scenario 5. Optimal team number required for scenario	Pilot teams were shown teamwork process measures after completing the scenarios. Subjects provided feedback with regard to: 1. Representativeness of measure 2. Ability of scenario to evoke the behavior being assessed	Pilot teams were shown patient care measures after completing the scenarios. Subjects provided feedback with regard to: 1. Representativeness of measures 2. Level of criticality of measured behavior to patient outcome 3. Ability of scenario to evoke the behavior being assessed
Internal structure: Acceptable reliability and factor structure	Reliability of scenario was assessed throughout the study to ensure that all clinical cues and triggers occurred in a standard fashion for all teams	Raters were trained and assessed prior to initiating data coding. Inter-rater reliability was calculated (see *Data Coding* section). Teamwork process and patient care measures were coded independently as recommended in the literature[d]	Raters were trained and assessed prior to initiating data coding. Inter-rater reliability was calculated (see *Data Coding* section). Teamwork process and patient care measures were coded independently to avoid bias during rating
Relations to other variables: Correlation with another outcome or variable for which correlation would be expected	Not applicable	Experience correlated with teamwork process measures	Experience correlated with patient care measures

[a]Defined by Cook DA, Beckman TJ: Current concepts in validity and reliability for psychometric instruments: Theory and application. *Am J Med* 2006; 119:166.e7-166.e16.

[b]Followed recommended practice of establishing evidence of content validity (Haynes SN, Richard DCS, Kubany ES: Content validity in psychological assessment: A functional approach to concepts and methods. *Psychol Assess* 1995; 7:238–247.)

[c]Used to determine weighting of items.

[d]Thomas EJ, Williams AL, Reichman EF, et al: Team training in the neonatal resuscitation program for interns: Teamwork and quality of resuscitations. *Pediatrics* 2010; 125:539–546.

RESULTS

Participant and team assignment information is shown in Figure 1. Excluding individuals who did not consent (26) and those with scheduling conflicts (20), a total of 231 individuals were randomly assigned to either the team training ($n_{team} = 23$) or placebo training ($n_{team} = 22$) condition. As shown in **Table 4**, the cTPT and placebo groups were similar with respect to demographics, simulation exposure, and overall experience.

The first ANCOVA examined whether the scenario used during assessment affected teamwork behavior or patient care

TABLE 4. Participant Characteristics by Intervention Group

Participant Characteristic	Computer-Based Teamwork Process Training Intervention	Placebo	*p*
Male, *n* (%)	74 (62.71)	67 (59.82)	0.66
Age, mean (SD)	27.71 (3.16)	27.32 (2.94)	0.33
Level of training, *n* (%)			
Medical student	83 (70.94)	82 (73.22)	0.58
PGY 1	12 (10.26)	11 (9.82)	
PGY 2	10 (8.55)	12 (10.71)	
PGY 3	12 (10.26)	6 (5.36)	
PGY 4	0 (0)	1 (0.89)	
How many resuscitations have you witnessed? (%)			
0	1 (0.84)	0 (0.00)	0.38
1–5	37 (31.09)	43 (38.39)	
> 5	81 (68.07)	69 (61.61)	
How many resuscitations have you participated in? (%)			
0	11 (9.24)	12 (10.81)	0.58
1–5	65 (54.62)	52 (46.85)	
> 5	43 (36.13)	47 (42.34)	
How many resuscitations have you led? (%)			
0	90 (75.63)	87 (77.68)	0.74
1–5	6 (5.04)	5 (4.46)	
> 5	23 (19.33)	20 (17.86)	
Experience composite[a], mean (SD)	0.03 (0.79)	−0.03 (0.77)	0.56
How many simulations have you been in? (%)			
2–5	74 (62.18)	64 (56.3)	0.33
> 5	45 (37.82)	48 (42.9)	

PGY = postgraduate year.

[a]Five experience items (age, level of training, and number of resuscitations witnessed, participated in, or led) were standardized then averaged to create an experience composite. This is described further in the *Materials and Methods* section.

outcomes. Determining that there was no effect for the scenario used was a precondition for evaluating cTPT effects. The scenario used for assessment was treated as a grouping variable with the experience composite included as a covariate. As expected, after controlling for experience, there were no significant effects of scenario on teamwork behavior, $F(1, 40) = 0.06$, p = not significant, or patient care, $F(1, 40) = 0.07$, p = not significant. Scenario also did not interact with cTPT to influence teamwork behavior, $F(1, 40) = 0.02$, p = not significant, or patient care, $F(1, 40) = 1.70$, p = not significant. These findings established that the scenario used during assessment did not affect the outcomes, providing support for the potential generalizability of our training across two contexts (both involving resuscitation scenarios). Additionally, all models were considered with and without team size controlled. Since team size was not found to significantly affect team or patient care behaviors, it was removed as a covariate in the analyses reported below.

Teamwork Behaviors

ANCOVA was used to evaluate the effects of cTPT on teamwork behaviors. The experience composite was treated as a covariate, training condition (cTPT vs placebo) was the independent variable, and teamwork was the dependent variable. The experience covariate was significantly related to teamwork, $F(1, 42) = 8.14$, p value less than 0.01, indicating that those teams whose members had greater experience tended to engage in more teamwork behaviors, hence, the need to control for its effects. With experience controlled, the effect of training condition on teamwork behavior was significant, $F(1, 42) = 4.81$, p value less than 0.05, indicating that teams receiving the cTPT intervention engaged in a greater number of appropriate teamwork behaviors during the simulation than teams receiving placebo training (**Fig. 2*A***). The strength of this relationship was moderate, as assessed by η^2_p, with training accounting for 10% of the variance in teamwork behaviors. These results indicate that cTPT evidenced a positive effect on appropriate teamwork behaviors beyond that of members' experience.

Patient Care Behaviors

ANCOVA was also used to examine the effects of cTPT on patient care behaviors. The experience composite was the covariate, training condition (cTPT vs placebo) was the independent variable, and patient care was the dependent variable. The experience covariate was significantly related to patient care performance, $F(1, 42) = 25.39$, p value less than 0.001, indicating that those teams whose members had greater experience tended to execute more appropriate patient care behaviors. With experience controlled, the effect of training condition on patient care performance was significant and moderate, $F(1, 42) = 4.66$, p value less than 0.05, $\eta^2_p = 10\%$, indicating that teams receiving the cTPT intervention performed better with regard to standards for patient care than teams in the placebo condition (Fig. 2*B*). Similar to the findings for teamwork behaviors, cTPT positively influenced patient care behaviors beyond that of members' experience.

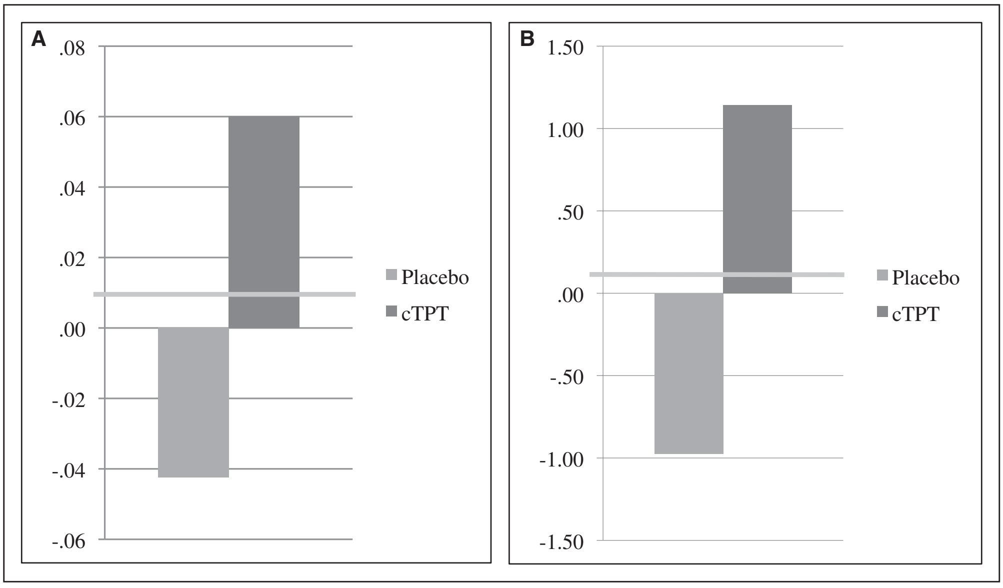

Figure 2. Teamwork (**A**) and patient care performance (**B**) during simulation-based assessment in teams receiving computer-based teamwork process training (cTPT) or placebo training. *Light gray columns* represent average scores for teams in the placebo condition; *dark gray columns* represent average scores for teams in the cTPT condition. The *dashed horizontal* represent the sample means for teamwork ($M = 0.01$) and patient care performance ($M = 0.11$). Teamwork and patient care performance are composite scores formed from checklist items as described in the *Materials and Methods* section. Higher scores represent better teamwork and patient care performance relative to the sample means.

DISCUSSION

In a randomized comparison study of cTPT versus placebo training, we found significantly higher levels of teamwork and patient care performance in teams receiving cTPT. The results of this study provide evidence supporting the relationship between team training and overall resuscitation performance, with implications for patient safety improvement during care of critically ill patients. Although we did not evaluate clinical or systems-level outcomes, the outcome measures used did capture both teamwork and patient care independently using a rigorously developed simulation platform (24, 29). As such, these results contribute significantly to the growing body of literature supporting team training in medical resuscitation teams.

In this study, our low-intensity cTPT intervention accounted for 10% of the variance in teamwork, even after controlling for team member experience. This is similar to team training effect sizes demonstrated in healthcare and other industries (26, 27). In a report by Risser et al (3), teamwork failures were directly linked with 29 out of 68 total closed malpractice claims. They also found that improved teamwork would translate into a savings of \$560,479 per closed case directly linked with ineffective teamwork. More importantly, Risser et al noted that 75% patient deaths reviewed were deemed to be preventable with appropriate teamwork. Given these findings, a 10% teamwork improvement could translate into a significant impact on mortality and malpractice-associated costs.

Our ability to detect significant training effects despite a relatively small sample size and low-intensity intervention was likely due to the rigor of the measurement and research design. As opposed to less objective self-report measures or retrospective perceptions about the effectiveness of training, the use of detailed checklists targeting observable teamwork and patient care behaviors permits a more rigorous examination of team functioning (37). During measure development, behavioral checklist items were carefully crafted and reviewed by subject matter experts to ensure content validity; extensive pilot testing of the scenarios and assessment tools were undertaken to ensure standardization of training delivery; raters using the observational checklists to assess teams were thoroughly trained and monitored for accuracy and reliability; and, lastly, the final observational data were checked extensively for errors then aggregated into composite measures which uniquely captured teamwork and patient care behaviors. Compared with other teamwork assessment tools that have been used in the past, our approach is unique with regard to measurement precision as well as the breadth, validity, and accuracy of data captured (24).

Despite widespread acknowledgment of the importance of teamwork in healthcare, there remain challenges in the implementation of successful team training programs (43). A recent report on the Agency for Healthcare Research and Quality's TeamSTEPPS program cited sustainability and dissemination as key problem areas (13). In acute critical care teams, the variability of day-to-day membership and of task requirements presents a challenge when implementing training (17, 44). Additionally, cost estimates for a simulation-based team training exercise are significant ($800–$2000 per participant, per day, exclusive of specialized equipment costs, instructor training, and lost trainee job productivity) (16, 45). The critical care literature describes several promising team training programs (46, 47); however, these programs require significant trainee time commitment (8 hr) as well as simulation equipment and instructor time. Less costly, more easily disseminated team training options such as the one described in this article offer attractive alternatives for smaller institutions and those with wide geographic distributions. It also has potential as a useful alternative for remediation training as well as refreshing/sustaining previously trained skills.

The cTPT presented in this study was created using widely available slide presentation software and materials relevant to the clinical scenario and teamwork behaviors. As a computer-based product, it can be easily disseminated and accessed. Additionally, the content can be manipulated to address multiple different organizations, units, and team contexts. This is important, as extant team training program content may not readily transfer between different institutions, teams, and organizational cultures (48). By employing cTPT, team members from different disciplines (e.g., hospitalist vs intensivist vs nurse manager) can easily receive targeted instruction that is more focused and relevant to their function during a patient resuscitation.

The teamwork literature emphasizes that both the technology employed and the mode of training delivery are less critical than the rigor of training design and assessment (49, 50). This study used an evidence-based, theory-driven approach to both components (51). The steps taken during our training development mirror recommendations in the team training literature and focus on social learning theory to provide 1) declarative information around relevant teamwork behaviors and 2) observational modeling, i.e., demonstration of teamwork behaviors during patient care events (52). Using similar techniques, Ellis et al (30) demonstrated improved team function after a 25-minute team training intervention targeting undergraduates in low-fidelity, computer-based laboratory team simulations. The current study advances this work by evaluating healthcare learners on a high-fidelity simulation-based platform that mirrors the rich context of an acute care setting.

Our cTPT has several potential applications. First, system-specific training could be implemented across institutions as a primer for all acute care practitioners to provide awareness of teamwork principles and facilitate opportunities for on-the-job practice and feedback. Second, in institutions employing more active team training techniques, the described intervention could serve as a pretraining exercise to orient participants toward specific learning objectives that can increase overall training effectiveness (53). This would support a recommended integrated training approach where less resource-intensive training methods are used to deploy basic knowledge and skill implementation information prior to investing in more resource-intensive simulation-based training (50, 54). Third, cTPT could be used as refresher training to help prevent skill degradation. Finally, the presented training intervention allows for customization based on the nature and task work of specific teams (e.g., rapid response teams vs intensive care teams). This would allow cTPT to address competencies required for specific teams and enhance current generic teamwork training programs (e.g., TeamSTEPPS) (49, 55).

This study has several limitations. Although the number of participating teams is relatively large when compared with those from the simulation and team training literature, it does not provide sufficient power to detect effects in more complex models (e.g., those with additional variables). Additionally, the participants for this study were limited to medical students and resident trainees. It is possible that more expert practitioners would not benefit as greatly from the low-intensity team training intervention. However, it has been shown that medical experts are not necessarily teamwork experts (14, 56). Further work examining team training in learners with differing levels of expertise would help to direct specific teamwork interventions appropriately within the continuum of healthcare education.

Another potential limitation concerns the team composition. This study evaluated teams of physician trainees working with a confederate nurse. Such designs allow considerable control over scenario events and help provide a standardized event-based assessment platform (39, 57). However, caution must be exercised when generalizing findings to interdisciplinary teams. Future work extending this study should evaluate teams that include acute care practitioners from multiple disciplines, including physicians, nurses, and respiratory therapists.

Finally, this study evaluated teamwork and patient care behaviors immediately following the intervention. Although other studies have demonstrated retention of training effects over time, we did not evaluate decay of learning (14, 39). Such information would be helpful when developing an execution plan for the training; however, the fact that cTPT is so easily implemented makes frequent refresher training feasible.

CONCLUSIONS

This study demonstrates the positive effects of a computer-based team training intervention on teamwork and performance in code teams during simulated patient resuscitations. The low-resource and flexible aspects of its design and delivery suggest many potential uses in acute care education and healthcare education in general. We therefore present an option for improving teamwork within institutions unable to implement more resource-intensive training options or in those wishing to refresh trainee skills following those initiatives. Overall, our results uniquely complement the growing body of literature that links healthcare team training with improved teamwork and clinical care in acute care teams. Further study is needed to elucidate 1) What components of the training were most effective? 2) How training can impact different types of healthcare teams? 3) How cTPT compares with more resource-intensive training? and 4) How training impact extends to patient outcomes?

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