Simulation-Based Team Leadership Training Improves Team Leadership During Actual Trauma Resuscitations: A Randomized Controlled Trial

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Objectives: Trauma resuscitations are complex critical care events that present patient safety-related risk. Simulation-based leadership training is thought to improve trauma care; however, there is no robust evidence supporting the impact of leadership training on clinical performance. The objective of this study was to assess the clinical impact of simulation-based leadership training on team leadership and patient care during actual trauma resuscitations.

Design: Randomized controlled trial.

Setting: Harborview Medical Center (level 1 trauma center).

Subjects: Seventy-nine second- and third-year residents were randomized and 360 resuscitations were analyzed.

Interventions: Subjects were randomized to a 4-hour simulation-based leadership training (intervention) or standard orientation (control) condition.

Measurements and Main Results: Participant-led actual trauma resuscitations were video recorded and coded for leadership behaviors and patient care. We used random coefficient modeling to account for the nesting effect of multiple observations within residents and to test for post-training group differences in leadership behaviors while controlling for pre-training behaviors, Injury Severity Score, postgraduate training year, and days since training occurred. Sixty participants completed the study. There was a significant difference in post-training leadership behaviors between the intervention and control conditions (b_1 = 4.06, t (55) = 6.11, $p < 0.001$; intervention M = 11.29, SE = 0.66, 95% CI, 9.99–12.59 vs control M = 7.23, SE = 0.46, 95% CI, 6.33–8.13, d = 0.92). Although patient care was similar between conditions (b = 2.00, t (55) = 0.99, p = 0.325; predicted means intervention M = 62.38, SE = 2.01, 95% CI, 58.43–66.33 vs control M = 60.38, SE = 1.37, 95% CI, 57.69–63.07, d = 0.15), a test of the mediation effect between training and patient care suggests leadership behaviors mediate an effect of training on patient care with a significant indirect effect (b = 3.44, 95% CI, 1.43–5.80). Across all trauma resuscitations leadership was significantly related to patient care (b_1 = 0.61, SE = 0.15, t (273) = 3.64, $p < 0.001$).

Conclusions: Leadership training resulted in the transfer of complex skills to the clinical environment and may have an indirect effect on patient care through better team leadership. (*Crit Care Med* 2020; 48:73–82)

Key Words: leadership; medical education; randomized controlled trial; resuscitation; simulation training; translational medical research

Trauma is a major U.S. public health burden; it is the fifth most common cause of mortality overall and is the leading cause of death in patients younger than 45 (1, 2). Trauma resuscitations present unique patient care challenges due to the need to perform complex tasks under uncertain and time-pressured conditions. One-third to one-half of trauma patient-related errors occur during the initial emergency department (ED) resuscitation period (3–5).

Effective team leadership can address some of these challenges by enhancing teamwork (6). In theoretical models of resuscitation team structure, team leaders are positioned to influence team adaptability and performance (7, 8). In practice, Advanced Trauma Life Support (ATLS) and Advanced Cardiac Life Support curricula provide recommendations for patient treatment and diagnosis but include only cursory information on the behaviors necessary for effective trauma leadership and teamwork (9, 10). Current studies suggest that team leadership is a trainable skill, and that leadership training increases leadership confidence in trainees (11). However, there are no studies evaluating the link between leadership training, patient care, and patient outcomes.

Simulation-based training provides a clinically relevant practice environment that has been recommended for team leader training. Research in nonhealthcare fields demonstrates increased transfer of learned behavior when simulation-based training is integrated into training curricula (12). Unfortunately, rigorous translational simulation-based research (TSR) evaluating the impact of simulation-based training on patient-level outcomes is lacking. In a recent review, Zendejas et al (13) found that of studies linking simulation training with patient-level outcomes over half had data analysis issues and only 26% used measures supported by evidence of validity.

Existing work evaluating the impact of leadership training on leader performance and patient care is limited to pre/post design and observational studies that do not consider the impact of team and patient factors on leader performance (14). We sought to assess the clinical impact of simulation-based team leadership training on trauma resuscitations. The main outcomes of this study are team leader behaviors and patient care during actual trauma resuscitations. We hypothesize that simulation-based team leadership training will improve team leadership during actual trauma resuscitations. Pilot outcomes included the feasibility of assessing patient outcomes.

MATERIALS AND METHODS

Study Design

We executed a single-blinded randomized controlled trial (ClinicalTrials.gov Identifier: NCT03155490). The study coordinator randomized eligible trainee participants each month in a 1:1 proportion to either the intervention (team leadership training) or control (standard orientation) conditions. The main outcomes of this study were team leader behavior (primary outcome) and patient care (secondary outcome) during actual trauma resuscitations. Trauma resuscitations were video recorded and coded using outcome measures. We collected baseline, pre-intervention data (two resuscitations), and post-intervention data (four resuscitations) for each participant. The training date marked the transition from pre- to post-intervention data for the control participants that were enrolled for the same time period. The University of Washington Institutional Review Board approved this study.

Participants and Trauma Team Structure

We recruited and consented 79 second- and third-year emergency medicine and general surgical residents at the University of Washington from April 2016 to December 2017 (CONSORT diagram, **Fig. 1**). Participation was voluntary, and participants were compensated $100. During their second and third year of training at our institution, these residents served as the trauma team leader for all major and minor trauma resuscitations. They were directly supervised by attending physicians and senior residents in both emergency medicine and trauma surgery. All participants were ATLS certified and had at least 4 weeks of prior trauma care experience in the study site ED. Participants were excluded if they were unavailable for the intervention or did not have the appropriate number of resuscitations captured for data analysis. Sixty participants completed the study (30 in each condition). Demographic data for

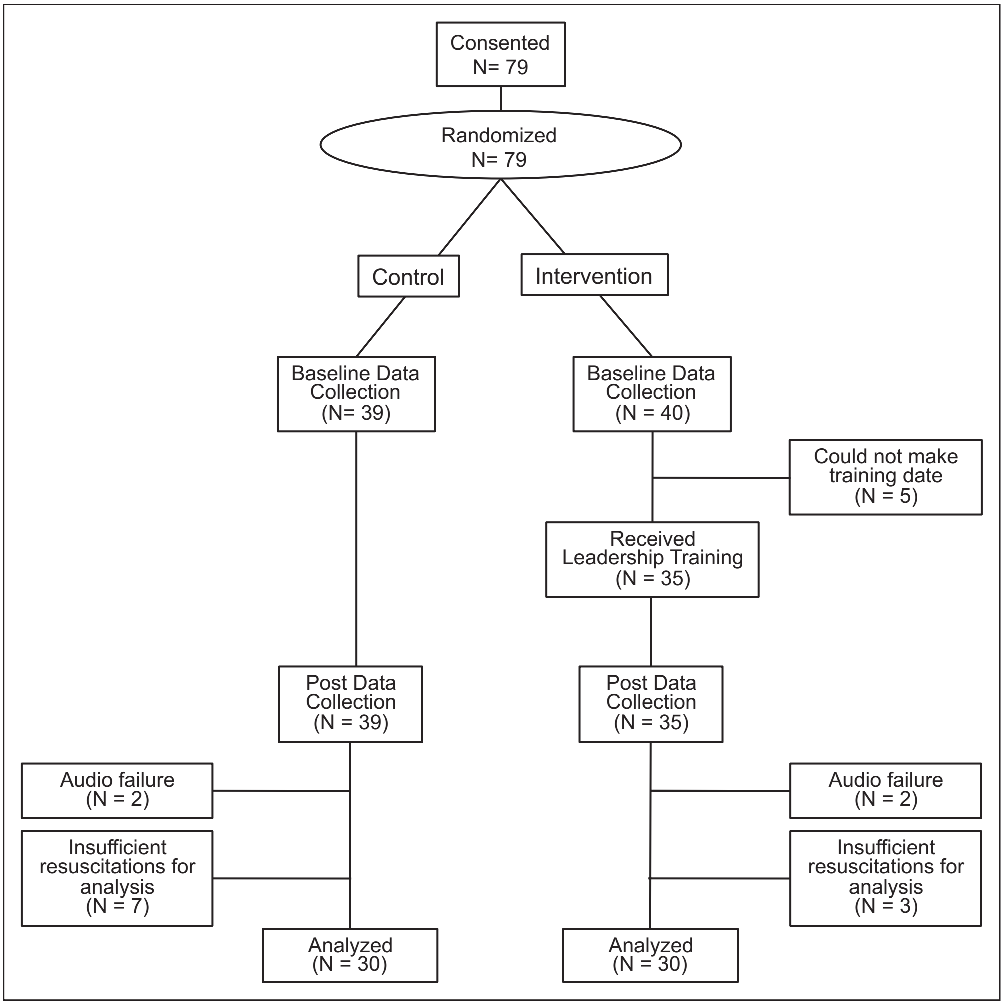

Figure 1. CONSORT diagram.

participants, including total years of clinical residency training, were collected at the time of recruitment.

Setting

The leadership training intervention for this study was delivered at the Washington, Wyoming, Alaska, Montana, Idaho (WWAMI) Institute for Simulation in Healthcare, a simulation training facility with high-fidelity human patient simulation suites capable of re-creating a trauma resuscitation bay. Trauma resuscitations took place at Harborview Medical Center, an urban, tertiary care center affiliated with the University of Washington that serves as the sole trauma center for a five-state region (AK, WA, WY, MT, ID). Two dedicated trauma resuscitation bays were each equipped with two cameras and one microphone. Resuscitations were included if 1) they were led by an enrolled study participant and 2) they met criteria as outlined in the Harborview Medical Center Trauma Registry (http://providerresource.uwmedicine.org/flexpaper/trauma-team-activation-criteria). Resuscitations were excluded if the patient was 1) pregnant, 2) pronounced dead or left the ED within 5 minutes of arrival, 3) under do not resuscitate or comfort care orders, 4) in police custody, or 5) found to have nontraumatic mechanisms or isolated burns as a primary diagnosis. Obstetric patients and patients with isolated burns were excluded because, in the study institution, these patients have markedly different resuscitation team compositions and patient care pathways. We processed video to de-identify patients prior to coding.

Intervention

Control Condition. Participants randomized to the control condition received a standard orientation to the trauma team leader role. This orientation involved reviewing the responsibilities of the trauma team leader, administrative information, attendance policy, and available resources.

Intervention Condition. Participants randomized to the intervention arm of the study also received the standard orientation to the trauma leader role. The 4-hour leadership curriculum for the intervention group is detailed in Rosenman et al (15). Briefly, the leadership training focused on behaviors identified as important for action team leadership, including 1) establishing the leadership role (assumes leadership); 2) sharing information and interpreting data; 3) planning and prioritizing tasks; 4) assigning roles and assessing team members' skills; and 5) seeking input and identifying task barriers (16, 17). Sessions began with a 1-hour didactic session, followed by a series of simulations in which one participant served as the team leader while the second participant observed. An instructor-led debrief occurred after each simulation. This cycle was repeated to allow both participants opportunity to practice with a second, individualized, simulation.

Outcomes

Team Leadership. The team leadership measure was adapted from a leadership taxonomy (16) grounded in the team science literature (17). Experts in team science (n = 5), emergency medicine (n = 4), and nursing (n = 1) reviewed metrics for relevance to trauma resuscitation teams and adherence to leadership process conceptual models. The leadership measure was pilot tested on five video recorded trauma resuscitations and revised to improve reliability and content validity. The leadership measure was designed to capture the team leader's best effort when target behaviors and communication events occurred multiple times, with a maximum score of 38. A higher score indicated more effective leadership behavior. The final measure is provided in **eTable 1** (Supplemental Digital Content 1, http://links.lww.com/CCM/F33) and validity evidence is provided in **eTable 2** (Supplemental Digital Content 1, http://links.lww.com/CCM/F33).

Patient Care. The patient care measure was a checklist that is based upon standards of trauma care, including ATLS (18), and a review of existing adult trauma patient care checklists that have been applied to both simulated (19) and live (20–23) patient care events. **eMethods** and **eTable 3**, ***a*** and ***b*** (Supplemental Digital Content 1, http://links.lww.com/CCM/F33) describe the measure and development process as well as supporting validity evidence (eTable 2, Supplemental Digital Content 1, http://links.lww.com/CCM/F33). The patient care measure was designed to adapt to different clinical situations, with maximum scores ranging from 20 to 38 points depending on the patient's condition. Scores were normalized to create a patient care score that could be compared across different resuscitation events, with higher scores indicating better patient care.

Patient Outcomes and Related Data. Patient outcome data, patient characteristics, and patient-related covariates (e.g., Injury Severity Score [ISS] [24]) were extracted from the Harborview Medical Center trauma registry for each patient.

Data Collection

We assessed team leadership and patient care by coding video recordings of actual trauma resuscitations. Team leadership and patient care were each coded by a separate group of raters, with a subset of videos (40% and 10%, respectively) coded in duplicate to establish inter-rater reliability. Raters were blind to study hypotheses and experimental conditions of participants. Rater agreement ranged from 0.9 to 1.0 for individual items in the leadership measure. For the patient care metrics, the average Cohen's $\kappa = 0.8$ (SD = 0.09).

Sample Size Calculation

The study was powered to address the impact of leadership training on the primary outcome, team leadership. We used a meta-analysis of leadership training/development programs to estimate the effect size for leadership training (25). Based on 35 studies with a total sample size of 3,389, a mean effect size (Cohen's d, corrected for sampling and measurement error) of 0.65 was found for leadership training and all outcome criteria. Using this effect size, a power analysis indicated a sample size of 60 (30 per condition) would provide 0.80 power in detecting true effects (25).

Data Analysis

Demographics and Patient Data. We calculated descriptive statistics for participant demographics, patient characteristics, and patient outcomes.

Primary and Secondary Outcomes. Hypotheses were tested utilizing random coefficient modeling to account for the nesting effect of repeated observations within participants (26). Models for all tests were specified predicting the outcome of interest (post-training leadership behaviors, patient care) from intervention group membership (coded 0 for control, 1 for intervention), controlling for the time-varying covariates of number of days since training occurred, and case severity, along with the time-invariant covariates of year in residency, and pre-training scores. Controlling for pre-training outcomes forces intervention and control groups to statistical equality, allowing for a test of the effect of training similar to a repeated measures analyses of covariance procedure but with time-varying covariates (27). Control variables were grand-mean centered to improve interpretability of variables. Thus, model intercepts (b_0) represent the mean of the control group on the outcome of interest when all predictors are at their mean, and the variable for group membership (b_1) represents the difference in means between the control and intervention groups (28). Models were estimated using the lme function for the nlme package (29) in the open-source statistical program R Version 3.4.2 (R: A Language and Environment for Statistical Computing, Vienna, Austria; https://www.r-project.org/). Additional explanation for the analytic approach can be found in **eAnalytics** (Supplemental Digital Content 2, http://links.lww.com/CCM/F34).

Primary analyses used ISS as our control for patient severity. The ISS was not available for 20 videos; therefore, maximum-likelihood estimation was used as the least biased approach to variable estimation under most missing data conditions (30). A second set of models controlling for trauma team activation level were executed to verify that missing data for ISS did not impact results. Cohen's d for repeated measure designs were also calculated based on model results.

RESULTS

We consented and randomized 79 participants. Thirty participants in each condition completed the study and were included in analyses (Fig. 1). The intervention and control groups were similar with respect to demographics, institution, specialty, and postgraduate training year (**Table 1**). The median number of days between baseline trauma events and the training was 4 (interquartile range [IQR], 7–2) and 9 (IQR, 28–4) for control and intervention participants, respectively. The median number of days between post-intervention trauma events and the training date was 5 (IQR, 2–11) and 10 (IQR, 4–22) for control and intervention participants, respectively. Trauma resuscitation event characteristics were similar across all groups (**Table 2**). Participants (team leader) and patient resuscitation outcomes (Table 2) were linked through our institutional trauma registry with an overall linkage of 95% (342/360).

For all data, descriptive statistics and correlations can be found in **eTables 4–6** (Supplemental Digital Content 3, http://links.lww.com/CCM/F35). Model results for leadership behaviors showed a significant difference between control and intervention groups post-training ($b_1 = 4.06$, SE = 0.66, $t(55) = 6.11$, $p < 0.001$; $d = 1.07$) (**eTable 7**, Supplemental Digital Content 3,

TABLE 1. Participant Characteristics by Intervention Group

Participant Characteristic	Control ($n = 30$)	Intervention ($n = 30$)
Age, yr, mean (SD)	29 (2)	30 (3)
Male, *n* (%)	21 (70)	19 (63)
Race, *n* (%)		
American Indian or Alaskan Native	0 (0)	0 (0)
Black or African American	2 (7)	0 (0)
Native Hawaiian or other Pacific Islander	0 (0)	0 (0)
Asian	5 (17)	4 (13)
White	21 (70)	24 (80)
Other	2 (7)	2 (7)
Ethnicity, *n* (%)		
Hispanic or Latino	1 (3)	2 (7)
Not Hispanic or Latino	29 (97)	28 (93)
Residency year, *n* (%)		
Postgraduate training year 2	14 (47)	19 (63)
Postgraduate training year 3	16 (53)	11 (37)
Specialty, *n* (%)		
General surgery	11 (37)	4 (13)
Emergency medicine	19 (63)	26 (87)

http://links.lww.com/CCM/F35). There was no significant difference between groups on patient care ($b_1 = 2.00$, SE $= 2.01$, $t\ (55) = 0.99$, $p = 0.99$; $d = 0.15$). An additional model predicted patient care scores from leadership scores across all videos; leadership behaviors significantly predicted patient care ($b_1 = 0.62$, SE $= 0.17$, $t\ (273) = 3.64$, $p < 0.001$) even after controlling for experimental condition, year in residency, days since/until training, and ISS.

We performed follow-up analyses on subcategories of behaviors to better understand the effects of the training intervention. Significant differences in behavior qualities between groups were found on pre-briefs ($b_1 = 0.72$, SE $= 0.16$, $t\ (55) = 4.42$, $p < 0.001$; $d = 0.70$), and huddles ($b_1 = 0.99$, SE $= 0.26$, $t\ (55) = 3.77$, $p < 0.001$; $d = 0.60$).

We further examined the likelihood of performing specific behaviors at critical moments in the patient care sequence using logistic regression and controlling for the same variables in the models above. These analyses were completed in R using the glmer function in the package lme4 (31). Significant differences in likelihood were found for explicitly assuming leadership ($b_1 = 1.51$, SE $= 0.49$, $z = 3.07$, $p = 0.002$), performing pre-briefs ($b_1 = 2.72$, SE $= 0.79$, $z = 3.47$, $p < 0.001$), performing an arrival brief ($b_1 = 3.50$, SE $=1.21$, $z = 2.90$, $p = 0.004$), performing huddles ($b_1 = 1.11$, SE $= 0.34$, $z = 3.29$, $p = 0.001$), and specific communication behaviors such as seeking input ($b_1 = 0.94$, SE $= 0.43$, $z = 2.17$, $p = 0.030$), but not for other communication behaviors such as planning ($b_1 = 0.39$, SE $= 0.34$, $z = 1.13$, $p = 0.257$) and role assignment ($b_1 = 0.53$, SE $= 0.31$, $z = 1.73$, $p = 0.084$). Model results and predicted means controlling for covariates can be found in eTable 7 (Supplemental Digital Content 3, http://links.lww.com/CCM/F35) and **Table 3**. Models and predicted means controlling for trauma team activation status instead of ISS can be found in **eTables 8** and **9** (Supplemental Digital Content 3, http://links.lww.com/CCM/F35).

Finally, we performed a follow-up mediation analysis using the "mediation" package in R (32). Mediating variables transmit the effect of an independent variable through to ultimately affect a dependent variable (33, 34). These chain-like relationships clarify how the independent variable influences the dependent variable. We tested a causal mediation of the effect of training on patient care scores through improvements in leadership behaviors while controlling for pretraining leadership behaviors, patient care scores, ISS, and training level.

We ran 1,000 simulations to estimate effects, and findings suggest that at the resident level, leadership behaviors mediated an effect of training on patient care with a significant indirect effect (b = 3.44, 95% CI, 1.43–5.80). The direct effect of training on patient care scores was not significant after leadership behavior was added to the model. The core model with estimated effects can be found in **Figure 2**.

DISCUSSION

We demonstrate that a team leadership simulation-based training program can improve trauma leader performance in the clinical environment. Trained participants demonstrated significant improvement in five of seven leadership behaviors. This represents the first rigorous, randomized controlled trial of a leadership-focused training that systematically evaluates the impact of training on process (leadership) and performance (patient care).

In a recent Joint Commissions report, leadership failures were noted in 90% of sentinel events (35). Similarly, Risser et al (36) found that teamwork-related failures were directly linked with 29 out of 68 total closed malpractice claims and teamwork improvement would translate into a savings of $560,479 per closed case. Our simulation-based leadership intervention accounted for a 56% improvement in leadership behavior after controlling for subject and patient factors. Considering the critical role leadership failures have in adverse events, such leadership training could translate into a significant impact on patient safety, resuscitation-related adverse events, and malpractice-related costs. We acknowledge that this study was not powered to detect differences in patient care. Such outcomes can be challenging, especially in clinical domains where care is somewhat prescribed, for example, ATLS, and in settings where baseline clinical performance meets high standards, for example, level 1 trauma centers. It will be important to consider relevant proximal, intermediate, and distal outcomes when evaluating leadership training in the future.

The relationship between team leadership and patient care may help address some of the challenges in current team-based training programs. Over the past decade, team training has been a common approach to addressing patient safety issues related to teamwork failures. Unfortunately, there remain feasibility issues associated with implementing and maintaining effective team training programs across a healthcare system (37–39). Team leadership is a viable and potentially effective target for advancing patient safety via improved team performance (40, 41). Team leaders improve team performance by developing team-oriented goals, facilitating coordination, and increasing the monitoring of tasks and environment (17, 42, 43). These functions take on higher importance as task complexity and interdependency increases, conditions common in trauma teams (37). Conceptual models assert a link between team leadership, teamwork, and patient care,

TABLE 2. Trauma Resuscitation Event Characteristics and Patient Outcomes

Patient Characteristics and Outcomes	Baseline		Postintervention	
	Control (*n* = 59)	Intervention (*n* = 59)	Control (*n* = 112)	Intervention (*n* = 112)
Patient characteristics				
Patient gender				
Male, *n* (% total)	51 (86)	47 (80)	83 (74)	84 (75)
Patient age, mean (SD), yr	43 (16)	45 (19)	43 (18)	43 (18)
Patient race, *n* (%)				
White	43 (73)	48 (81)	79 (71)	81 (72)
Black	8 (14)	4 (7)	18 (16)	19 (17)
Asian	2 (3)	3 (5)	6 (5)	7 (6)
Pacific Islander/Native Hawaiian	1 (2)	0 (0)	1 (1)	1 (1)
Native American	2 (3)	3 (5)	3 (3)	1 (1)
Other or not identified	3 (5)	1 (2)	5 (5)	3 (3)
Patient ethnicity, *n* (%)				
Hispanic	6 (10)	9 (15)	7 (6)	14 (13)
Non-Hispanic	50 (85)	49 (83)	97 (87)	93 (83)
Not reported	3 (5)	1 (2)	8 (7)	5 (4)
Injury Severity Score[a], mean (SD)	20 (14)	22 (15)	22 (14)[b]	20 (15)[c]
Trauma team activation level[d]				
Full	35 (59)	36 (61)	66 (59)	68 (61)
Modified	24 (41)	23 (39)	46 (41)	44 (39)
Cause of trauma, *n* (%)				
Blunt	42 (12)	45 (13)	87 (25)	80 (23)
Penetrating	17 (5)	14 (4)	24 (7)	31 (9)
Other	0 (0)	0 (0)	1 (.3)	1 (.3)
Primary transport mode, *n* (%)				
Ground transport	36 (61)	34 (58)	70 (63)	75 (67)
Aeromedical transport	23 (39	24 (41)	40 (36)	37 (33)
Self-presentation	0 (0)	1 (2)	2 (2)	0 (0)
Type of response[e], *n* (%)				
Transfer	20 (34)	24 (41)	38 (34)	32 (29)
Field	39 (66)	35 (59)	74 (66)	80 (71)

(*Continued*)

TABLE 2. (*Continued*). Trauma Resuscitation Event Characteristics and Patient Outcomes

Patient Characteristics and Outcomes	Baseline		Postintervention	
	Control ($n = 59$)	Intervention ($n = 59$)	Control ($n = 112$)	Intervention ($n = 112$)
Patient outcomes				
ED disposition, n (%)				
Home or self-care[f]	5 (8)	3 (5)	6 (5)	14 (13)
Operating room	17 (29)	11 (19)	32 (29)	27 (24)
Medical or surgical floor[g]	8 (14)	6 (10)	11 (10)	11 (10)
ICU	27 (46)	36 (61)	62 (55)	56 (50)
Died	2 (3)	3 (5)	1 (1)	3 (3)
Other	0 (0)	0 (0)	0 (0)	1 (1)
Hospital disposition, n (%)				
Home or self-care[f]	35 (59)	31 (53)	61 (54)	60 (54)
Additional care setting[h]	13 (22)	20 (34)	31 (28)	25 (22)
Died	6 (10)	5 (8)	14 (13)	12 (11)
Not applicable[i]	5 (8)	3 (5)	6 (5)	14 (13)
Not reported	0 (0)	0 (0)	0 (0)	1 (1)
ED length of stay, mean (SD), min	219 (183)	268 (170)	211 (130)	245 (151)
30 d ICU-free days, mean (SD)	20 (14)	22 (12)	22 (11)	23 (11)
30 d hospital-free days, mean (SD)	13 (21)	16 (17)	14 (19)	17 (16)
Discharge Glasgow Coma Scale[j], mean (SD)	14.8 (0.7)	14.6 (1.4)	14.8 (0.9)	14.7 (1.1)

ED = emergency department.
[a]Baker et al (24).
[b]$n = 110$, two events had no Injury Severity Score reported.
[c]$n = 111$, one event had no Injury Severity Score reported.
[d]Trauma activation criteria described at http://providerresource.uwmedicine.org/flexpaper/trauma-team-activation-criteria.
[e]Transfer patients arrived from another healthcare facility, whereas field responses did not receive care at another facility prior to arrival.
[f]Home or self-care includes patients discharged to home, a shelter, jail, or an undomiciled situation, and those who left against medical advice.
[g]Medical-surgical floor without ICU capabilities.
[h]Reflects discharge to a setting requiring additional levels of medical care (skilled nursing facility, rehabilitation facility, home healthcare, psychiatric care).
[i]Patient never admitted to hospital.
[j]Discharge Glasgow Coma Scale was not always recorded; baseline control ($n = 48$), baseline intervention ($n = 51$), post control ($n = 91$), and post intervention ($n = 84$).

suggesting that leadership training may be a way to augment existing team training programs to improve overall team performance (44, 45).

We demonstrate that a well-designed team leadership simulation-based training program can improve leader performance in the actual clinical environment. This represents a critical step in advancing translational simulation research (TSR). Although there are several examples of high-quality translational research programs (46–48), they primarily focus on procedural tasks (50). Complex skills, such as leadership, present measurement challenges because processes are interrelated and constantly evolving. We definitively demonstrate transfer of a complex trained behavior (leadership) to the clinical setting. This is a critical and significant step in developing a larger program of TSR focused on leadership and teamwork skills.

A robust TSR program extends to include important patient/family/organizational outcomes. Although we were not powered to detect a training effect on patient outcomes, mortality, and 30-day hospital-free days (50) are of interest-based upon pilot data obtained in this study. There exists one study from Neily et al (51) linking teamwork training to decreased surgical mortality, however that study did not evaluate process (teamwork) or performance (patient care) to explain the observed decrease in mortality. The current study serves as a strong foundation for a robust TSR platform by assessing leadership process outcomes and identifying important distal outcomes. We are now positioned to conduct a large, multicenter study powered to detect critical patient-centered outcomes across multiple different types of institutions. Additionally, the current work supports future research designed to evaluate

TABLE 3. Post-Training Descriptive Statistics After Controlling for Covariates

	Control			Intervention			
Outcome	**Mean (SD)**	**Low 95%**	**High 95%**	**Mean (SD)**	**Low 95%**	**High 95%**	***d***
Overall leadership score	7.23 (2.50)	6.33	8.13	11.29 (3.64)	9.99	12.59	1.07
Pre-brief quality	0.13 (0.62)	−0.09	0.35	0.85 (0.90)	0.53	1.18	0.70
Huddle quality	1.81 (0.98)	1.45	2.16	2.79 (1.43)	2.28	3.30	0.60
Patient care score	60.38 (7.52)	57.69	63.07	62.38 (11.03)	58.43	66.33	0.15
Outcome	***p***	**Low 95%**	**High 95%**	***p***	**Low 95%**	**High 95%**	**Percent Increase**
Assume leadership	0.14	0.07	0.25	0.42	0.22	0.65	203
Pre-brief	0.01	0.00	0.06	0.19	0.05	0.52	1155
Arrival brief	0.00	0.00	0.04	0.09	0.01	0.52	2908
Huddle engagement	0.18	0.11	0.27	0.39	0.25	0.56	123
Role assignment	0.52	0.36	0.68	0.65	0.51	0.77	24
Planning	0.59	0.35	0.77	0.68	0.52	0.80	15
Seek input	0.08	0.04	0.15	0.18	0.09	0.34	128

Note: Probabilities calculated from logistic regression model variables (coefficients and SEs can be found in corresponding model tables). Predicted probability is equivalent to observed means on dichotomous (0–1) outcomes controlling for covariates. Percent increase is percentage increase in probability of outcome occurring.

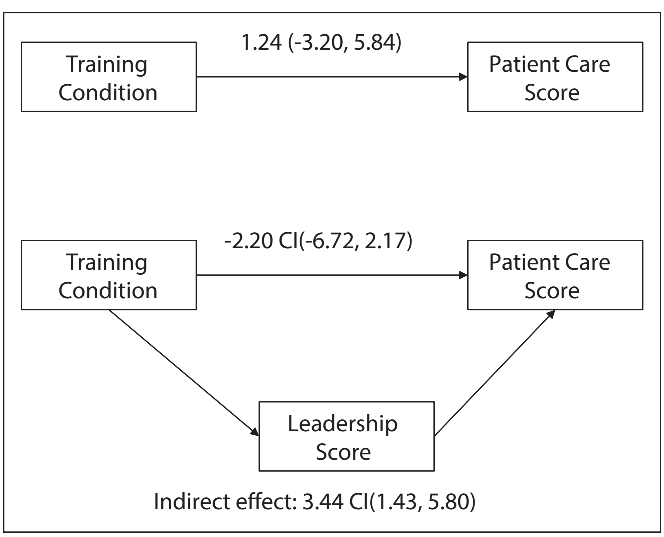

Figure 2. Causal mediation diagram of the effect of training on patient care through improvements in leadership behavior.

important education-related topics, for example, skill decay, as well as provider- and team-centered constructs such as job satisfaction, team cohesion, and psychologic safety.

Our study has several limitations. First, assessments were conducted within the setting of actual trauma team resuscitations, which involve multiple team members. Knowing that leaders accomplish goals by influencing the behaviors of other team members, it is possible that team members "learned" from participants (leaders) in the intervention arm and changed their behavior during assessment of control participants irrespective of the performance of the control participant (leader). Similarly, a previously trained team member may have functioned as a senior team member, however, due to the staffing structure such occurrences were rare. Since data collection occurred over a 2-year period, it is possible that this learning effect would increase over time. This would minimize the difference in performance between the two conditions resulting in an underestimation of the effect of the training. Second, the assessments occurred in a complex environment, with variable team composition and patient characteristics. Although we attempted to control for complexity using ISS as a proxy, we could not account for team variability. We were also unable to fully account for the possibility that other team members would take over leadership. Assessing the maximal number of trauma resuscitations that was feasible helped to address these limitations. Third, the study was conducted at a single academic institution. Since trauma protocols and practices might differ in other institutions, the training content and implementation would benefit from a clear understanding of the culture at the specific institution. Finally, we trained residents within an academic setting. It is possible the training could require modification to fit community and critical access institutions. This becomes an important implementation issue that would benefit from careful study across both academic and nonacademic settings.

CONCLUSIONS

We demonstrate a training intervention that transferred leadership skills to the clinical setting and improved team leadership behaviors during live trauma resuscitations. These leadership behaviors appear to have indirectly mediated improvements in patient care. Overall, our TSR provides strong support for incorporation of more robust team leadership training into trauma education and establishes a foundation for further research to definitively demonstrate the impact of training on patient outcomes and provider-centered outcomes such as job satisfaction, team cohesion, and psychologic safety.

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