Title of Project: Translating simulation-based team leadership training into patient-level outcomes

Principal Investigator and Team Members: Fernandez, R (PI); Rosenman, ED (Site PI); Nichol, G; Arbabi, S; Chao, GT

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A.ABSTRACT

Purpose
The objective of this research was to assess the clinical impact of simulation-based team leadership training on team leadership effectiveness and patient care during actual trauma resuscitations.

Scope
Trauma-related injuries are the leading cause of death in Americans ages 1-44 and are responsible for over 29 million emergency department visits annually. Despite implementation of recommended trauma system-based protocols, there remain significant rates of medical error associated with trauma resuscitation.

Methods
Eligible trauma team leaders were randomized to the intervention (4-hour simulation-based leadership training) or control (standard training) condition. Subject-led actual trauma patient resuscitations were video recorded and coded for leadership behaviors (primary outcome) and patient care (secondary outcome) using novel leadership and trauma patient care metrics. Patient outcomes for trauma resuscitations were obtained through the Harborview Medical Center Trauma Registry and analyzed descriptively. A one-way ANCOVA analysis was conducted to test the effectiveness of our training intervention versus a control group for each outcome (leadership effectiveness and patient care) while controlling for pre-training performance, injury severity score, postgraduate training year, and days since training occurred.

Results:
Sixty team leaders, 30 in each condition, completed the study. There was a significant difference in post-training leadership effectiveness [$F(1,54)=30.19$, $p<.001$, $\eta^2=.36$] between the experimental and control conditions. There was no direct impact of training on patient care [$F(1,54)=1.0$, $p=0.33$, $\eta^2=.02$]; however, leadership effectiveness mediated an indirect effect of training on patient care. However, across all trauma resuscitations, team leader effectiveness correlated with patient care ($p<0.05$), as predicted by team leadership conceptual models.

Key Words: team leadership, trauma resuscitations, patient safety, randomized controlled trial

B. PURPOSE

Trauma is a major public health burden; it is the fifth most common cause of mortality overall in the US and accounts for the majority of deaths 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. It is not entirely surprising that one third to one half of trauma patient-related errors occurred in emergency departments during the initial resuscitation period.[3-5] Effective team leadership can enhance teamwork and team adaptability, thus improving teams' ability to handle unexpected and rapidly changing situations.[6] Current studies suggest that team leadership is a trainable skill and that leadership training increases leadership confidence in trainees.[7] 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 and team leader training. Research in non-healthcare fields demonstrates an increase in transfer of learned behavior when simulation-based training is properly integrated into training curricula.[8] Unfortunately, mechanisms to rigorously assess the impact of simulation-based training on patient-level outcomes are lacking. In a recent review of simulation-based training and patient outcomes, Zendejas et al. found that all studies attempting to link simulation training with patient outcomes were focused on procedural skills.[9] Additionally, over half had data analysis issues, and only 26% used measures supported by evidence of validity.

The **objective** of the presented work was to assess the **clinical impact** of simulation-based team leadership training using a novel, theoretically grounded measurement system to further understanding and improve effectiveness of resuscitation teams. The main outcomes of this study were team leadership effectiveness (**primary outcome**) and patient care (**secondary outcome**) during actual trauma resuscitations. These measures provide a comprehensive assessment of training impact at the patient level. Pilot outcomes included the feasibility of assessing patient outcomes.

This work was organized into three specific aims:

Aim 1: Develop and assess the content validity of comprehensive trauma team leadership measures.
Aim 2: Assess the impact of simulation-based team leadership training on leadership and patient care during trauma resuscitations.
- H1. Team leadership training will improve team leadership during actual trauma resuscitations.
- H2. Team leadership training will improve critical patient care during actual trauma resuscitations.

Aim 3: Determine the feasibility of assessing the effect of simulation-based team leadership training on patient outcomes.

This project addressed several important gaps in simulation and patient safety science: (a) how does simulation training impact actual patient care, (b) how can leadership be leveraged to effect teamwork and patient safety, and (c) what are the methods necessary to evaluate the impact of simulation-based training on critical patient outcomes? Though we focused on trauma teams, the simulation-based training intervention developed can be easily adapted for multiple other healthcare settings. Additionally, the modular nature of the training is such that it can be incorporated into any existing teamwork, resuscitation, or critical care curriculum.

C. SCOPE

C.1. Background and Context

Organized, cross-disciplinary approaches to trauma care have been recommended as a way to address the issues that complicate the diagnosis and management of trauma patients.[10,11] Current literature cites high-quality interdisciplinary team performance as critical to patient safety and error reduction.[12-14] Trauma teams in particular depend upon effective team member interactions to coordinate, monitor, and adapt their collective skills to accomplish patient care activities.[4,15] These teams are ad hoc, multidisciplinary action teams that perform complex patient care and medical decision making under dynamic and time-pressured conditions.[16] Such a combination of environmental factors and patient characteristics contributes to frequent breakdowns in team interactions, resulting in poor communication and coordination, failure to recognize threats to patient safety, and overall decreased effectiveness.[17,18] Importantly, a study of trauma resuscitation-related errors noted that 50% of all errors were directly related to teamwork failures.[4] Although initial efforts aimed toward improving trauma team effectiveness are promising, gaps remain in knowledge and methodology that inhibit clinicians and organizational leaders from identifying and leveraging key teamwork processes to improve patient safety.

Preliminary work in trauma team science demonstrates a critical role for team leaders.[19,20] In theoretical models of trauma team structure, team leaders are positioned to influence team adaptability and team performance.[21,22] In practice, the Advanced Trauma Life Support (ATLS) curriculum provides recommendations for initial patient treatment and diagnosis but does not address the knowledge, behaviors, and skills necessary for effective trauma leadership and teamwork.[15,23] ATLS training reinforces a protocol-driven, vertical (i.e., sequential) approach to trauma care that is in conflict with the horizontal (i.e., simultaneous) approach employed by effective trauma team leaders.[19,24] Such training can markedly decrease team adaptability.[25] Poor team adaptability inhibits a team's ability to detect changes in patient condition and quickly modify current strategies to avoid diagnostic and treatment errors.[22,25] Highly adaptable team leaders capable of modulating their actions based on patient, team, and environmental cues can elevate team performance beyond pure protocol-based management to ensure the flexibility and high level of vigilance necessary for safe trauma care.[26,27]

An evidence-based leadership training intervention that improves healthcare team effectiveness would present healthcare organizations with a meaningful and feasible mechanism for patient safety improvement in the error-prone, high-risk setting of trauma resuscitations. Leader training would provide teams characterized by high membership variability with the skills and adaptive behaviors necessary to counteract threats to effective teamwork implicit within their structure. Current literature in other domains supports the hypothesis that training healthcare team leaders in leadership skills will improve overall team performance, and that improvement will be greatest in teams with low levels of team member and task stability (e.g., trauma teams).[26,28,29] **Simulation-based training, when appropriately constructed and employed, provides an excellent platform for training of team-based competencies, i.e., leadership.[30]** Simulation can provide opportunities for practice and feedback in a setting that reflects the patient care, team, and environment-related challenges (time pressures, noise levels, etc.) inherent to clinical practice. As such, simulation-based training can facilitate learning and transfer of new skills to the work environment.[31,32] Applying rigorous training design principles to simulation-based trauma team leadership training increases the likelihood of transfer of learned behavior to the clinical setting and potentially impacts a critical component in trauma-based patient safety. To date, a simulation-based trauma team leadership training program has not been implemented and rigorously evaluated for impact at the patient level.

C.2. Incidence

Trauma-related injuries are the leading cause of death in Americans ages 1-44 and are responsible for over 29 million emergency department (ED) visits annually.[1,2] Overall, trauma is the fifth leading cause of death in the United States. Despite dissemination and implementation of recommended trauma system-based protocols, there remain significant rates of medical error and preventable adverse outcomes associated with trauma care.[3,4] Recent studies demonstrated about one third to one half of trauma patient-related errors occurred in the ED during the initial resuscitation of the patient.[5] Considering the volume of trauma patients cared for annually, these errors represent a significant threat to the delivery of safe patient care and contribute substantially to unnecessary medical costs.

C.3. Settings

Training: The leadership training intervention (didactics + active discussion + simulation-based training) for this study was delivered at the WWAMI (Washington, Wyoming, Alaska, Montana, Idaho) Institute for Simulation in Healthcare (WISH). WISH is a fully operational multimodality simulation training facility with high-fidelity human patient simulation suites capable of re-creating a trauma resuscitation bay. Each suite was equipped with state-of-the-art video recording equipment enabling video-assisted debriefing and reflection. Conference room space was used for the didactic component of training and the debriefing following simulation-based training. WISH provided both a secure server for video storage and data management as well as data coding software (Noldus Observer®XT) licenses that facilitated the coding of leadership and patient care measures.

***Assessment*:** 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). Interdisciplinary teams of emergency medicine nurses, emergency medicine physicians, and surgeons manage trauma patients at Harborview Medical Center, where the designated "team leader" for all trauma resuscitations is a second- or third-year resident (emergency medicine or surgery). Dedicated trauma resuscitation bays were equipped with for recording, each with two cameras and one microphone.

C.4. Subjects

This study design incorporated two subject populations: team leaders and patients.

Team Leader Subjects (unit of analysis): Sixty study subjects were recruited from the pool of second- and third-year emergency medicine and general surgical residents at the study institution, the University of Washington. During their second and third year of training, general surgery and emergency medicine residents serve as the trauma team leader in the Harborview Medical Center emergency department for two nonconsecutive months. As the trauma team leader, they are assigned the task of directing all major and minor trauma resuscitations. Per ED protocol, these individuals all hold ATLS certification and had over 4 weeks of prior trauma care experience in the ED.

Inclusion Criteria

a) Second- or third-year emergency medicine or general surgical resident in good standing
b) Up-to-date ATLS certification
c) >4 weeks prior experience in trauma care at Harborview Medical Center
d) Scheduled for a trauma team leader month during the data collection period of the study

Exclusion Criteria

a) Unavailable for intervention or assessment

Patient Subjects (Trauma Resuscitations): All patients being cared for by a team leader subject during the data collection study period (see below) and presenting to the ED with a trauma-related complaint were screened using inclusion and exclusion criteria (below). Criteria were chosen to ensure a broad representation of trauma patient care and adequate opportunity to observe team leader behaviors. Certain exclusion criteria were selected to try to identify those patients with near 100% mortality or those inappropriate for resuscitative efforts. Additionally, pediatric and pregnant patients were excluded, as their team composition differs markedly from those involved in standard adult trauma resuscitations.

Inclusion Criteria

Age > 18
Patients with one or more of the following clinical presentations:
Witnessed trauma with intubation in the pre-hospital setting
Witnessed trauma with hypotensive (SBP < 90 mmHg for two consecutive readings) in the pre-hospital setting
Stab wound, impalement, or gunshot wound to the neck, chest, abdomen, pelvis, or groin
MVC with ejection from the vehicle
Fall > 20 ft
Pedestrian struck by a motorized vehicle
Motorcycle crash > 20 mph
Two or more obvious long bone/extremity injuries

Exclusion Criteria

Obstetric patient
Patients on whom resuscitative efforts ceased within 5 minutes of arrival to the ED
Patients with burns as a primary source of trauma
Patient dead on arrival to ED or pronounced dead within 5 minutes of arrival to ED
Patients arriving to the ED with do not resuscitate or comfort care orders
Patient removed from ED within 5 minutes of arrival
Prisoner
Patients without traumatic mechanism as primary diagnosis

D. METHODS

We executed an **individual, randomized controlled trial.** Eligible trainee subjects were randomized in a 1:1 proportion to either the intervention (team leadership training) or control (standard training) condition. Subjects were randomized each month to ensure that outcomes were not biased by opportunities for concurrent learning throughout the residency year. The main outcomes of this study were team leadership effectiveness (**primary outcome)** and patient care **(secondary outcome)** during actual trauma resuscitations. **Primary hypotheses** include that the intervention group will demonstrate improved leadership (H1) and patient care (H2) during actual trauma resuscitations. We collected baseline data (pre-intervention) and post-intervention/ control data. Time from intervention was used as a covariate to account for decay. Subjects are described above.

D.1. Intervention (Figure 1)

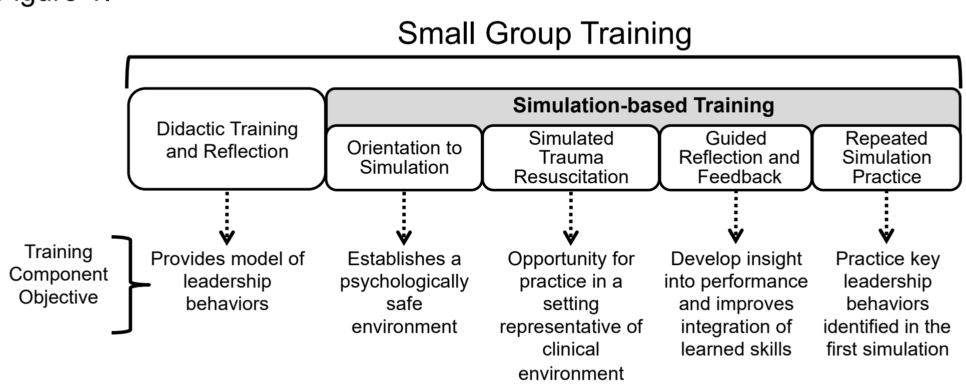
Control Condition: Subjects randomized to the **control condition** received a **standard orientation** to the trauma team leader role at the start of their month in the ED. This orientation involves review of key administrative information, including departmental policy on chart completion, attendance policy, and available resources. No further formal trauma or team leader training was provided for the control group.

Intervention Condition: Subjects randomized to the **intervention arm** of the study also received the standard orientation to the trauma leader role at the start of their trauma leader month in the ED. The study coordinator scheduled subjects for the leadership training intervention. Two to three faculty members delivered training to a pair of learners.

Leadership Training Curriculum (see Leadership Curriculum Guide, Attachment A)

Taxonomy/Framework: The investigators conducted a systematic review of leadership training in healthcare teams.[33] This review also helped to define critical competencies and training objectives for team leaders in emergency medicine teams.[34] These competencies link to the leadership behaviors presented in our leadership training curriculum. Our past work suggests that anchoring behaviors to clinical events and protocols helps learners transfer behaviors to the clinical setting. We therefore designed the training to optimize transfer/implementation. In Attachment A, we list the leadership behaviors trained, when they are expected to occur based upon existing trauma protocols (ATLS), and how they link to an existing evidence-based team leadership taxonomy. Below, we describe the leadership training strategies.

Figure 1.



Training Strategies (Figure 1)

a) *Didactic training and reflection (1 hr):* Learners (a) observed and discussed effective and ineffective examples of leadership through guided instruction, (b) reflected on their own practice and described the impact of effective and ineffective leadership on patient care, and (c) independently identified effective and ineffective leadership skills with formative feedback.[31,35] At the end of this component of training, each learner worked with faculty to identify leadership skills that would be the focus of their simulation-based learning.

b) *Orientation to simulation-based training (10 min):* All subjects began the simulation-based training with a brief orientation. This provided an overview of the goals of the simulation, the limitations of the simulated environment, and the role of standardized actors in the simulation. During this time, the formative nature of the training was stressed. Additionally, subjects were reminded that their performance and associated debriefing are confidential.

c) *Simulation-based training scenario (1 hr):* The investigators created two simulated trauma resuscitations scenario (*Attachment A*) using an event-based design methodology described by Fowlkes et al.[36] They selected scenario content that is representative of typical trauma team encounters, based upon trauma code data from an American College of Surgeons level 1 trauma center and supported by ATLS guidelines.[37] They then scripted the scenario, including the sequencing of events, timing, and requisite clinical responses that constitute a standardized event-based scenario. A team of standardized actors enacted scripted errors and delivered prompts to engage the subject and allow leadership skills to emerge. The scenarios were designed to run approximately 20 to 30 minutes, allowing sufficient time for teamwork and leadership processes to emerge across the series of context-specific events. The overall content, triggers (both physiologic and emotional), and actors' script underwent validity testing as described in Fernandez et al.[38] While one subject performed as the team leader, the second subject observed and completed a leadership checklist (*Attachment A*) to help guide the observation and reinforce learned skills. The first simulation was debriefed, and then the second subject completed his/her simulation while the first subject observed.

d) *Guided reflection and feedback (1 hr):* Debriefing was guided by the leadership principles. The observing subject was allowed to comment on what was done well and what behaviors could use reinforcement. Similarly, the subject completing the simulation was asked to reflect on his/her performance. Trainees were given directed feedback using leadership competency measures and were asked what strategies might help them incorporate behaviors in the future. The trainers also offered some strategies reviewed earlier in the training. Trainees were then given the opportunity to practice strategies in the second set of simulations (next).

e) *Repeated simulation practice (1 hr):* Following the debriefing, subjects had the opportunity for additional practice through a second simulation. The event-based approach to simulation design allowed the second simulation to be immediately adapted to the subjects' needs. Thus, the leadership challenges for a particular subject were prompted by the simulation, allowing additional time and practice in areas that were most challenging. Each simulation was followed by a brief guided reflection. Similar to the first set of simulations, each participant functioned as the team leader in one scenario and observed one scenario. The purpose of this component of the curriculum is to ensure that subjects train to proficiency in a simulated setting.

***A full training manual is provided in *Attachment A*.** This work is also outlined in a manuscript (Rosenman ED, Vrablik MC, Brolliar SM, Chipman AK, Fernandez R. Targeted Simulation-based Leadership Training for Trauma Team Leaders. *West J Emerg Med* [submitted October 2018]).

D.2. Measures

*Measure development constituted work outlined in Aim 1 in the grant proposal.

Primary Outcome (Aim 2)

(a) Trauma team leadership (Appendix 1):

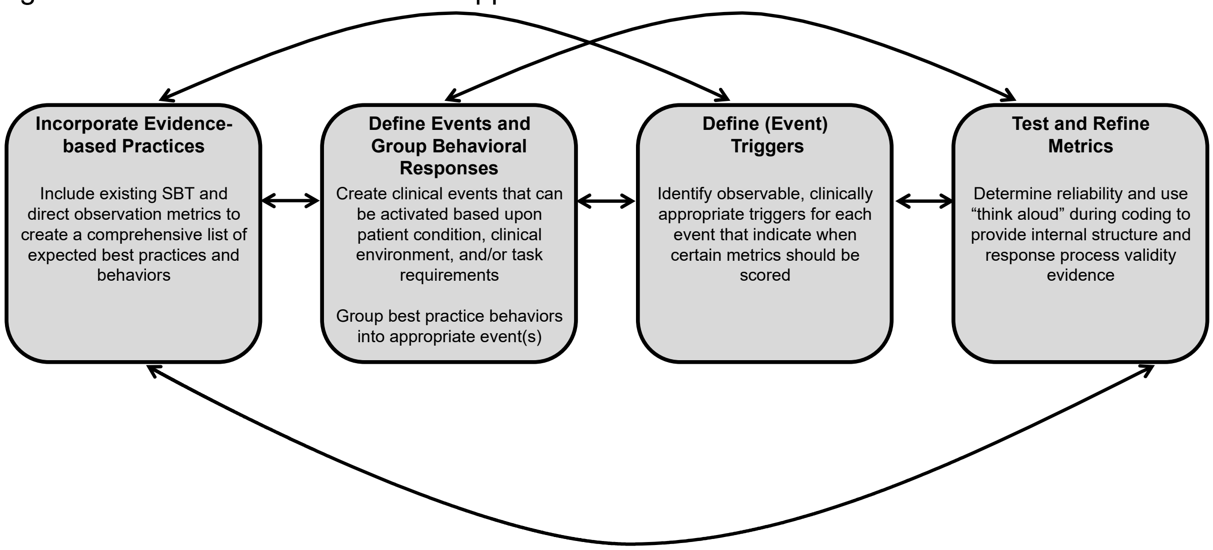
We utilized the dynamic leadership model[39] to create leadership measures that are distinct from team performance measures yet consistent with the team leadership taxonomy adopted for this study.[34] After development, the teamwork process measures were content validated by emergency medicine and team leadership subject matter experts (SMEs) external to the research team. A sample of six to eight SMEs reviewed the leadership measures, training curriculum, and leadership taxonomy to determine if leadership behaviors as a whole capture trauma resuscitation-related team leadership. After establishing evidence of content validity, we evaluated preliminary evidence of measure reliability. Two pairs of raters independently coded the leadership measures following training on the content and nature of rating scales. Raters reviewed several training videos designed to demonstrate leadership behaviors. Inter-rater agreement on leadership items was determined, with a cutoff of 0.8 providing empirical evidence for the convergence of rater judgments. When expert judgments indicated that specific aspects of the leadership measures were not sufficiently representative, measures were revised and re-evaluated to ensure that content validity of the measures was established.

Secondary Outcome (Aim 2)

***(b) Trauma resuscitation patient care (Appendix 2)*:**

We utilized an event-based approach to observational measurement that allows for highly granular measurement while maintaining the ability to adapt to high levels of clinical variability. One can still assess highly specific behaviors while considering that patient variability will inherently alter the task upon which the learner is being evaluated. The steps involved in measure development are briefly described below and outlined in Figure 2. Examples of metrics are provided in *Attachment A* and described in manuscript.

Figure 2. Overview of Event-based Approach to Observational Measurement



Step 1: Incorporate evidence-based practice
We identified published adult trauma patient care checklists that have been applied to both simulated[40] and live[41-44] patient care events as well as standards of trauma care, including ATLS.[37] Subject matter experts reviewed the guidelines and assessment measures to identify items that (1) were appropriate for trauma resuscitations, (2) apply across all types and severity of trauma resuscitations (universal items), and (3) were indicated in certain clinical presentations but were not universally relevant (conditional items). For conditional items, the SMEs determined under what conditions they should be performed. Finally, SMEs noted which items were time sensitive. All behavioral and time-based items, universal and conditional, were included in a single patient care behavioral measure.
Step 2: Define events
In Step 2, we defined and described trauma resuscitation behavioral events. Universal items from Step 1 were grouped into events expected to occur during every trauma resuscitation, such as "performs a primary survey." The conditional items were also placed into events as appropriate. SMEs reviewed all universal and conditional events and metrics to make sure that the associated events were appropriately assigned. Where disagreements existed, they were reconciled by two of the investigators (RF, EDR).
Step 3: Define event triggers
Step 3 focuses on defining the clinical triggers that prompt conditional event. The investigators worked with SMEs to identify observable clinical triggers. We prioritized specificity over sensitivity when identifying triggers. Event triggers were reviewed by SMEs after they had observed over 10 video-recorded resuscitations to ensure triggers met the criteria of being (1) observable, (2) clinically appropriate, and (3) specific.
Step 4: Test and refine metrics
Preliminary determination of reliability during metric development informed ongoing rater training and modifications to the event-based metric that were confusing, poorly defined, or assigned to an inappropriate event. Initial ratings were performed as a group with a "think aloud" approach to ensure that important metrics and events were captured to the best of our ability. The investigators then each independently coded a subset of videos using the trauma patient care metrics until reliability reached a kappa (>0.7).

The event-based approach to measurement (EBAM) process is outlined in a manuscript (Fernandez R, Rosenman ED, Chipman AC, Brolliar S, Vrablik M, Kalynych C, Shuluk J, Lazzara EH, Keebler JR, Samuelson H, Grand JA. An Event-based Approach to Measurement (EBAM): Facilitating observational measurement in highly variable clinical settings. *J Grad Med Educ.* [in preparation]).

Pilot Outcomes

***Feasibility of assessing the impact of leadership training on patient-level outcomes* (Aim 3):** To advance simulation science, team leadership, and patient safety, this project piloted patient outcome measures to determine the feasibility of assessing the impact of leadership training on patient-level outcomes. Patient outcomes were obtained by matching the team leader with trauma event data recorded in the Harborview Medical Center trauma registry. Patient outcomes included:

- ***a. Hospital morbidity*** defined as the number of days alive and permanently out of hospital up to 30 days post trauma. Patients who die before discharge are assigned zero days out of hospital.
- ***b. Intensive care morbidity*** defined as the number of days alive and permanently out of intensive care (ICU) during the first 30 days post trauma. Patients who die before discharge from ICU are assigned zero days out of intensive care.
- ***c. Neurological function at discharge*** defined as the Glasgow Coma Scale (GCS) at discharge. Patients who died were assigned a GCS of 3.
- ***d. Emergency department (ED) length of stay*** defined as the length of stay (minutes) in the ED of a level 1 trauma center.
- ***e. Functionality at discharge*** defined as the percentage of patients discharged to self-care.

Other Measures

Trainee Perceptions: Subjects randomized to receive the leadership training completed a brief questionnaire at 1 year post training that addressed (a) satisfaction and perception of the training, (b) self-perception of learning, and (c) self-perception of the degree to which learned behaviors were implemented in the clinical environment.

Covariates

Both team leader subject and trauma event characteristics were reviewed and evaluated as potential covariates.

Covariates and potential effect modifiers (team leader subjects): Our prior research demonstrated an effect of experience on teamwork.[38] We defined experience as total years of clinical residency training. Research suggests that decay of learned behaviors can be significant. We therefore considered the time interval between the training intervention and the observed clinical events and included this variable in our model. We also collected additional demographic data (gender, race/ethnicity) for each subject.

Covariates and potential effect modifiers (Patients):

A list of potential patient-related variables currently recorded and monitored as part of the Harborview Medical Center Trauma Registry underwent SME review for inclusion as covariates. Final variables to consider as potential covariates included (a) trauma team activation category *(http://providerresource.uwmedicine.org/flexpaper/trauma-team-activation-criteria),* which reflects the nature of the team response to the trauma resuscitation event, and (b) Injury Severity Score (ISS), which provides an overall injury score based on injury to specific *anatomic* regions.[45] The ISS correlates linearly with mortality, morbidity, and length of hospital stay.

D.3. Limitations

(1) Internal validity threats

Contamination: It is possible that the training administered in the intervention group influenced physician subjects in the control group. This could happen one of two ways: first, if individuals in the intervention group were to discuss the content of the training. The investigators minimized this possibility by having all subjects sign a confidentiality agreement.[46] Contamination could also be a threat if the intervention physicians were to display behaviors learned as a result of the training and the control group witnessed these behaviors. This risk is minimal, because trauma leaders do not work clinically with their peers.

Instrumentation: Assessments are conducted within the setting of actual trauma team resuscitations, which involve multiple different team members. These team members were part of the “environment” for subjects in both arms of the study. Knowing that leaders accomplish goals by influencing the behaviors of other team members, it is therefore possible that team members “learned” from subjects (leaders) in the intervention arm and changed their behavior during assessment of control subjects irrespective of the performance of the control subject (leader). Additionally, because data collection occurred over a 2-year period, it is possible that this learning effect would increase over time. We, in fact, saw evidence to support that this did occur near the end of the study, when nurses would specifically request that team leaders perform behaviors that were a major component of the training intervention. The analysis of pre-intervention data over time allows the detection of a lagged effect in the control condition. In the present study, this threat would minimize the overall effect of training. As there was a significant impact of training on the primary outcome, controlling for a lagged effect was not indicated.

Selection: The design included one potential component susceptible to selection bias. As noted above, leader assessment occurred in a team setting. Other members of the trauma team are not randomized, nor are they unique to one arm of the study (e.g., nonsubject team members served on teams with both intervention and control subjects). It is therefore possible that there could exist a significant imbalance in team member skill between groups. Assessing the maximal number of trauma resuscitations that is feasible within the parameters of the grant helped to minimize this threat.

(2) Sources of measurement error

Exam content: Measurement in an actual clinical setting introduces variability that does not exist in simulated-based testing. This variability is primarily represented by patient or environmental (patient illness severity, team member expertise, etc.) factors that cannot be standardized in a clinical setting. The study design attempted to minimize this threat in two ways. First, for each subject, two pre- and four post-testing resuscitations were measured to ensure a wide sampling of performance. Second, as described above, the investigators controlled for patient factors that may impact outcomes.

Scoring errors: Quality assurance strategies, such as those described by Boulet et al., are critical to identifying potential sources of measurement error and guiding subsequent modifications of the performance tasks, training procedures, and scoring rubrics.[47] We implemented a quality assurance process that resulted in good inter-rater reliability and thus mitigated rater-based error.

(3) External validity threats

We conducted this study at a single academic institution. Because trauma protocols and practices might differ in other institutions, the implementation of training and recommendations to leaders would benefit from a clear understanding of culture at the specific institution. Additionally, we trained residents within an academic setting. Although this posed some challenges for measurement of behavior, it also means that training would need to be modified 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.

E. RESULTS

E.1. Principal Findings and Outcomes

Aim 1: Develop and assess the content validity of comprehensive trauma team leadership measures.
We developed a 38-point leadership measure and a 20- to 38-point patient care measure. Agreement on leadership metrics was 0.95. For patient care measures, the average Cohen's $\kappa = 0.8$ (SD = 0.09) for categorical items.

Aim 2: Assess the impact of simulation-based team leadership training on leadership and patient care during trauma resuscitations.
A total of 79 subjects consented and were randomized (Figure 3). Sixty subjects, 30 in each condition, were analyzed; reasons for exclusion are shown in Figure 3. Subject characteristics are shown in Table 1 by condition. The intervention and control groups were similar with respect to demographics, institution, specialty, and postgraduate training year. Trauma resuscitation event characteristics were also similar across all groups (Table 2). The timing between trauma events and training date for control and intervention subjects for baseline events was (median) -4 (IQR -7,-2) and (median) -9 (IQR -28, -4), respectively. Negative numbers indicated that baseline events occurred prior to the intervention date. Timing between post-intervention trauma events and training date for control and intervention subjects was (median) 5 (IQR 2, 11) and (median) 10 (IQR 4, 22), respectively.

Figure 3. Study CONSORT Diagram

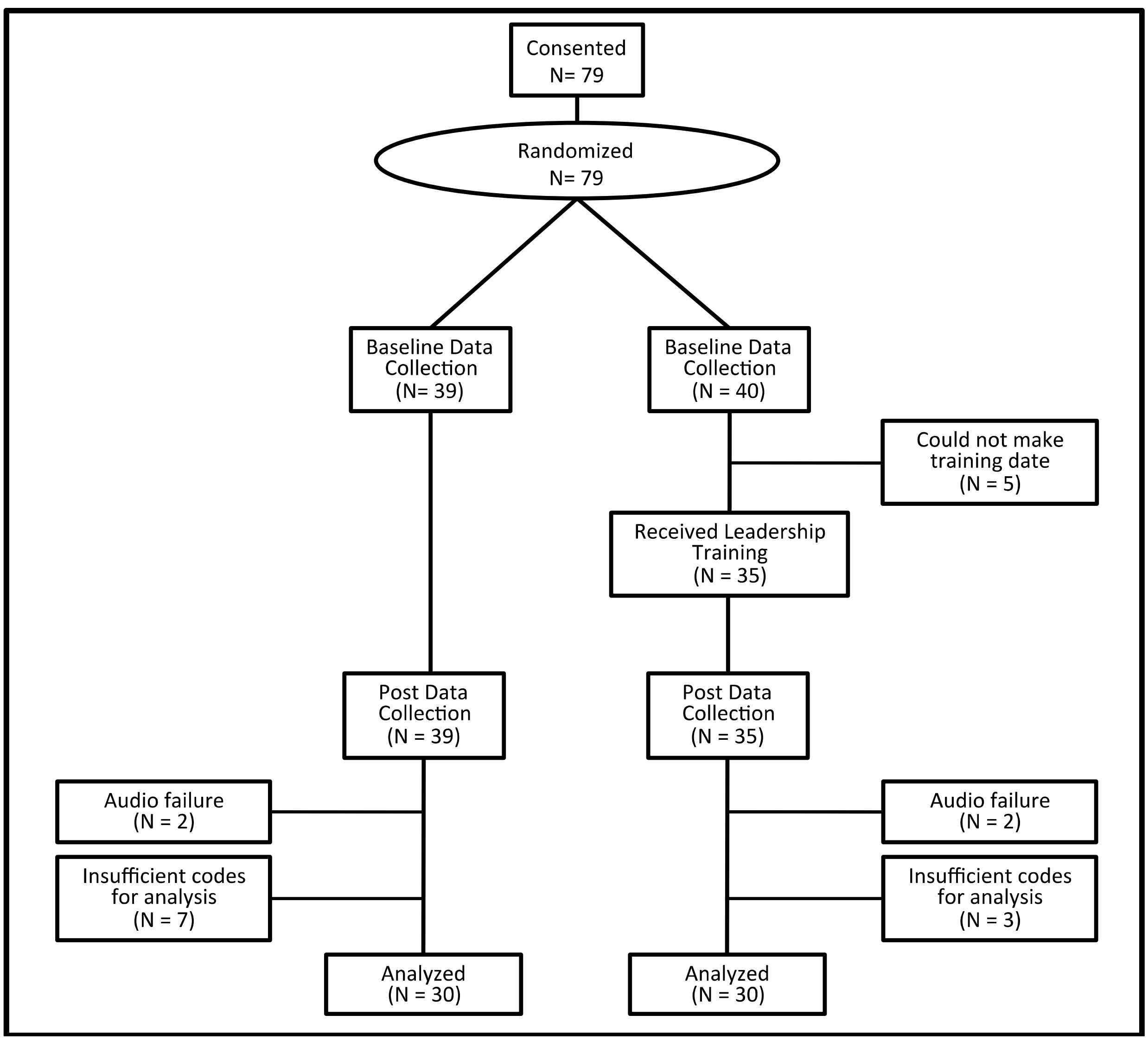


Table 1. Subject characteristics by intervention group

Subject Characteristic	Control (n = 30)	Intervention (n = 30)
Age, year; 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)

Table 2. Trauma resuscitation event characteristics

Characteristic	Baseline		Post-intervention	
	Control (n=59)	Intervention (n=59)	Control (n=112)	Intervention (n=112)
Patient gender Male, n (% total)	51(86)	47(80)	83(74)	84(75)
Patient age, mean (SD), years	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,* mean (SD)	20(14)	22(15)	22(14)†	20(15)‡
Trauma Team Activation Level§				
Full	35(59)	36(61)	66(59)	68(61)
Modified	24(41)	23(39)	46(41)	44(39)
Cause of trauma				
Blunt, n (%)	42(12)	45(13)	87(25)	80(23)
Penetrating, n (%)	17(5)	14(4)	24(7)	31(9)
Other, n (%)	0(0)	0(0)	1(.3)	1(.3)
Primary transport mode				
Ground transport, n (%)	36(61)	34(58)	70(63)	75(67)
Aeromedical transport, n (%)	23(39	24(41)	40((36)	37(33)
Self-presentation, n (%)	0(0)	1(2)	2(2)	0(0)
Type of response‖				
Transfer, n (%)	20(34)	24(41)	38(34)	32(29)
Field, n (%)	39(66)	35(59)	74(66)	80(71)

*Baker SP, O'Neill B, Haddon Jr W, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *Journal Trauma Acute Care Surg*. 1974;14(3):187-196.
†N=110; two events had no injury severity score reported
‡N=111; one event had no injury severity score reported
§Trauma activation criteria described at http://providerresource.uwmedicine.org/flexpaper/trauma-team-activation-criteria
‖Transfer patients arrived from another healthcare facility, whereas field responses did not receive care at another facility prior to arrival

H1. Team leadership training improves team leadership during actual trauma resuscitations.
Potential patient and subject covariates (ISS, trauma team activation level, subject experience, and number of days since training) underwent principal component analysis to determine if any variables loaded onto the same underlying factor prior to their inclusion in analyses. Both ISS and trauma team activation level loaded onto the same underlying factor. Thus, ISS, subject training level (PGY), and days since training were retained as covariates for the ANCOVA.
A one-way ANCOVA analysis was conducted to test the effectiveness of our training intervention versus a control group for improving leadership effectiveness while controlling for covariates listed above. Levene's test and normality checks were carried out and the assumptions met. There was a significant difference in post-training leadership effectiveness [$F(1,54)=30.2$, $p<0.001$, $\eta^2=.36$] between the experimental and control conditions. Examining the marginal means confirms that the experimental group scored higher on leadership effectiveness post-training than the control group. Table 3 describes the effect of training on all components of leadership behavior.

Table 3. Effect of leadership training intervention on leadership behaviors during actual trauma resuscitations

Measure	**Score (SD)**		**F**	**P value**	**Effect Size (η^2)**
	Control	Intervention			
Leadership Measure					
Overall Leadership Behavior Measure	7.1(2.1)	11.0(2.8)	30.2	<0.001	0.36
Explicit Assumption of Leadership	0.2(0.2)	0.4(0.4)	4.7	0.036	0.08
Pre-arrival Brief Frequency	0.03(0.1)	0.2(0.2)	12.6	0.001	0.19
Pre-arrival Brief Quality	0.2(0.3)	0.7(0.8)	11.1	0.002	0.17
Arrival Brief	0.01(0.05)	0.2(0.2)	13.3	0.001	0.20
Status Brief (Huddle) Frequency	0.2(0.2)	0.4(0.2)	9.9	0.003	0.16
Status Brief (Huddle) Quality	1.7(0.9)	2.7(0.9)	14.3	<0.001	0.21
Leader Behaviors	----	----	----	----	----
Information Sharing	0.9(0.2)	1.0(0.1)	3.3	0.07	0.06
States Plan	0.8(0.2)	0.9(0.2)	2.0	0.17	0.04
Role Assignment	0.6(0.3)	0.8(0.2)	6.0	0.02	0.10
Seeks Team Input	0.1(0.2)	0.3(0.2)	5.8	0.02	0.10
Patient Care Measure					
Overall Patient Care	60(7)	62(6)	1.0	0.31	0.02

H2. Team leadership training improves critical patient care during actual trauma resuscitations.
Patient care metrics were normalized to allow aggregation of patient care data from events with differential opportunity for patient care actions. As above, a one-way ANCOVA analysis compared the effectiveness of our training intervention versus a control group for improving patient care during actual trauma resuscitations while controlling for pre-training patient care, ISS, the level of training of the trainee, and days since training occurred. There was no significant difference in patient care [$F(1,54)=1.0$, $p=0.33$, $\eta^2=.02$] between the experimental and control conditions (Table 3). Although we did find a small effect size, we did not see a significant difference (p=0.3) between conditions.

We evaluated the association between leadership effectiveness and patient care using random coefficient modeling. Random coefficient modeling is appropriate when the data are nested in nature, such as observations within individuals as we have in this experiment. The nested nature of the data violates the independence of errors assumption of regression, but random coefficient modeling accounts for that nonindependence and allows for more accurate parameter estimates between our variables of interest. We demonstrate a significant positive relationship (p=0.02; Table 4) between leadership effectiveness and patient care when assessed across all videos (n=360).

Table 4. The relationship between team leadership effectiveness and patient care scores controlling for injury severity score, days since training, and postgraduate year of training (n=360)

Variable	**Coefficient (β)**	**Standard Error**	**t**	**p**
Intercept	55.40	2.92	----	----
Injury Severity Score	0.11	0.08	1.33	0.19
Days since training	-0.01	0.03	-.22	0.83
Postgraduate year of training	-1.08	1.49	-.72	0.47
Leadership measure score	0.59	0.25	2.37	0.02*

Post-training Implementation Survey

Of 36 subjects who completed all (n=35) or a portion (n=1) of the leadership training, 23 (64%) completed a post-training survey (*Attachment A*) at 1 year after training. The purpose of the survey was to assess perceptions of implementation of trained team leadership principles. The survey respondents were similar to nonrespondents in terms of gender, year of training, and specialty. The responses are detailed in Tables 5 and 6 and in Figure 4.

Table 5. Survey responses to perceived value and realism of the training

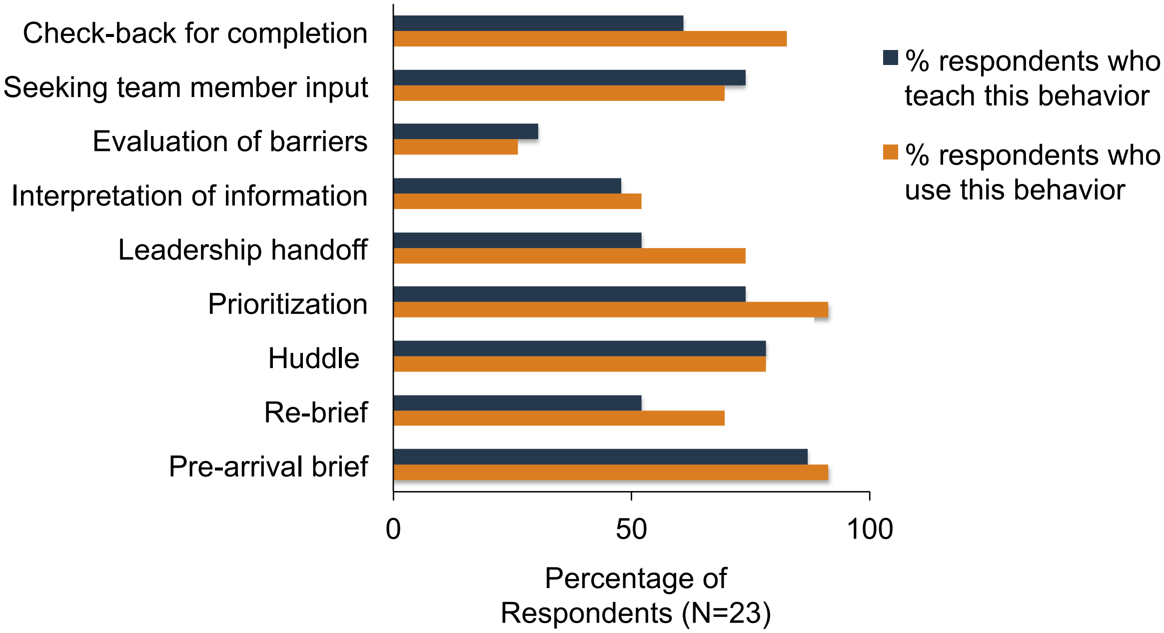
Question	Response Median (IQR)
Value of training to residency education 1 – Not valuable, residency training should not include this training 3 – Fairly valuable, residents in my specialty should have the option of taking this training 5 – Very valuable, it should be a part of all residency programs in my specialty	5 (5–5)
Value of training to current practice 1 – Not valuable, it was much less impactful than other teamwork or leadership training 3 – Fairly valuable, it was as impactful as other teamwork or leadership training 5 – Very valuable, it was more impactful than any other leadership or teamwork training	5 (4–5)
Realism of the simulations 1 – Not realistic, the simulation did not represent the stress and environment present in a trauma resuscitation 3 – Fairly realistic, some elements of the stress and environment of a trauma resuscitation were well represented 5 – Very realistic, the stress and environment of a trauma resuscitation were well represented	4 (4–5)
Realism of the simulations 1 – Not realistic, the simulation did not represent the stress and environment present in a trauma resuscitation 3 – Fairly realistic, some elements of the stress and environment of a trauma resuscitation were well represented 5 – Very realistic, the stress and environment of a trauma resuscitation were well represented	4 (4–5)

IQR = interquartile range

Table 6. Examples of free text responses organized by themes

Topic	Theme (number of related comments): Examples
Residency requirement	Training should be required/mandatory (13): • Should be mandatory. • Please incorporate this in our training! It is one of the single most helpful things I have done in residency regarding leadership. This has absolutely changed my practice. • Mandatory for all residents before leading a code. • Excellent training which gives a framework for myriad roles in daily clinical medicine. Should be a component of every resident's training. • Excellent, should be provided to all EM residents in all residency programs, it helps the quality of care in our specialty.
Useful components of the training	Nonclinical focus (1): • This was one of the most valuable simulations I participated in and made me a much more confident leader in these situations. Prior to the simulation, I was a bit of a wallflower, but this gave me some basics with which to take command and fall back on in difficult situations. Rather than focusing on the basics of resuscitation, the emphasis on teamwork was key. I recently had a very difficult code and was able to take command with many of the specific skills that I learned in this training. Small learner group (1): • Nothing to make it better, but the very small group (2 people) was very helpful. Repetition of simulations and debriefings (1): • Opportunity to do multiple SIMs after discussing how the first one went, and getting a second chance to incorporate the teachings. Realism of the simulations (3): • This was very helpful, and far more realistic than the average SIM. It would be valuable for all residents to receive this training! • The authenticity and stressful environment made this great training.
Opportunity for improvement	Frequency of training (4) • We need more of this kind of training. One day spent doing this training drastically changed my performance during traumas and medics codes and really helped with my confidence. • More of it. More repetitions. Coaching and performance review (5) • Ability to see feedback videos. Real-time feedback in a real clinical scenario. • More check-ins after the training to see how things were going. Timing of training (4) • If it had happened earlier in my training, at the end of R1 or beginning of R2, before I had certain set habits. • Ideal for junior residents to set them on the correct path.

Figure 4. Most Frequently Implemented Behaviors From the Trauma Team Leadership Training



Aim 3: Determine the feasibility of assessing the effect of simulation-based team leadership training on patient outcomes

We were able to link the subject (team leader) with patient resuscitation outcomes through the Harborview Medical Center trauma registry. Overall linkage was 95% (342/360). Descriptive data describing the trauma resuscitations (Table 2) and trauma resuscitation outcomes (Table 7) are provided.

Table 7. Description of trauma patient outcomes

Characteristic	Baseline		Post Intervention	
	Control (n=59)	Intervention (n=59)	Control (n=112)	Intervention (n=112)
ED Disposition, n (%)				
Home or Self-care*	5(8)	3(5)	6(5)	14(13)
Operating Room	17(29)	11(19)	32(29)	27(24)
Medical or Surgical Floor†	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*	35(59)	31(53)	61(54)	60(54)
Additional Care Setting‡	13(22)	20(34)	31(28)	25(22)
Died	6(10)	5(8)	14(13)	12(11)
N/A§	5(8)	3(5)	6(5)	14(13)
Not Reported	0(0)	0(0)	0(0)	1(1)
ED LOS, mean (SD), min	219(183)	268(170)	211(130)	245(151)
30-day ICU-free Days, mean (SD)	20(14)	22(12)	22(11)	23(11)
30-day Hospital-free Days, mean (SD)	13(21)	16(17)	14(19)	17(16)
Discharge GCS‖, mean (SD)	14.8(0.7)	14.6(1.4)	14.8(0.9)	14.7(1.1)

*Home or self-care includes patients discharged to home, a shelter, jail, or the street and those who left against medical advice

†Medical–Surgical floor without ICU capabilities

‡Reflects discharge to a setting requiring additional levels of medical care (skilled nursing facility, rehabilitation facility, home health care, psychiatric care)

§Patient never admitted to hospital

‖Discharge GCS was not always recorded; therefore: baseline control (n=48), baseline intervention (n=51), post control (n=91), post intervention (n=84)

GCS=Glasgow coma scale; RTS=revised trauma score; ICU=intensive care unit

E.2. Discussion

This work demonstrates definitive evidence that simulation-based training of a complex skill (team leadership behavior) transfers to a complex clinical setting (emergency department) with highly variable clinical tasks (trauma resuscitations). Our novel team leadership training significantly improved overall leadership performance, demonstrating a large effect size. When evaluating subsets of leadership behavior, trained subjects demonstrated significant improvement all individual leadership behaviors except information sharing and states plan. This represents the first rigorous, randomized, controlled trial of a leadership or teamwork-focused training that systematically evaluates the impact on process (leadership) and performance (patient care).

Our team leadership training did not significantly impact patient care during trauma resuscitations; however, our study was not powered for this outcome. We included patient care as an outcome because it is clinically important and because team leadership conceptual models suggest that team leadership effects team performance (patient care). We therefore tested this relationship in our trauma teams to begin investigating why we might not have seen a positive effect of training on patient care. We demonstrated a strong correlation between team leadership and patient care across 360 resuscitation events. This suggests that we were underpowered to detect this effect. Because team leaders influence patient care directly and indirectly by impacting teamwork, it will be important to include teamwork as a factor in future analyses.

This work represents a critical step in advancing translational simulation-based research (TSR). Though there are several examples of high-quality translational research programs,[48-50] they primarily focus on procedural tasks and do not evaluate highly complex skills such as leadership.[51] Complex skills present significant measurement challenges, because individuals and processes are inter-related, with multiple components and emergent nature of tasks and related behaviors. These factors are not present in complicated skills (e.g., central line placement, physical exam performance). 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. We conducted a feasibility study (Aim 3) to determine our ability to link training and leadership effectiveness with patient outcomes. Our linkage rate was excellent (95%) and suggests that our methods would support a larger, multicenter study powered to detect differences in meaningful patient-centered outcomes. Although we were not powered to detect a training effect on patient outcomes, mortality and 30-day hospital-free days[52] are of interest based upon pilot data obtained in this study. There is one study from Neily et al. linking teamwork training to surgical mortality,[53] but that study did not demonstrate improved process (teamwork) or improved performance (patient care) in addition to mortality. Thus, the current proposal serves as a strong foundation for a robust TSR platform.

Trauma resuscitations pose a challenge to measuring learner performance, as there can be significant variability present in the patient's condition and the clinical environment that impacts which patient care behaviors are indicated and in which order. We extensively reviewed the literature for trauma care measures. Behavioral checklists that were shown to be reliable and capable of discriminating among learners in simulated settings were too inflexible to be valid measures of performance in the clinical environment. Similarly, metrics designed to allow for high variability in clinical tasks were too general to accurately discriminate performance quality or relied heavily on subject matter expertise for accurate scoring.[54-56]

We developed an Event-Based Approach to Measurement (EBAM) that supports EBAM and adapts the concepts used in event-based training[36] for clinical observation-based measurement design.[57] The core content of EBAM is based upon identification of clinical events and triggers. One could imagine that there is a set of universal behavioral responses that should occur for every trauma regardless of the patient, nature of trauma, or any environmental factors. However, it is likely that the need for certain treatment would be triggered by the patient's condition (e.g., the presence of shock physiology). A "shock" event would contain behavioral responses expected for a patient in clinical shock but not for a hemodynamically stable patient. Together, the universal and shock behavioral responses then become metrics that can flex to accommodate both hemodynamically stable and unstable patients. As a result, a complex clinical task with high patient variability can still be evaluated in a systematic and structured manner. EBAM therefore addresses a major gap in TSR.[58]

Our team leadership training program is designed to be easily integrated with TeamSTEPPS training as well as other leadership, team, and trauma care training programs. The training uses temporal cues present in ATLS algorithms to trigger key leadership behaviors. The feedback obtained from subjects 1 year after receiving training suggests ongoing incorporation of trained behaviors into clinical practice. Furthermore, they believe that they are teaching others to perform trained leadership behaviors. Subjects noted that the opportunity to practice simulations more than once was helpful and that more repetition and more training would be even better. Several subjects also noted that using video both during training and in post-training "coaching" sessions would improve training. Post-training coaching would be a strong addition to the training and would likely provide a foundation for implementation in different settings. Coaching sessions would also provide an opportunity to get information from trainees to understand how the clinical setting and organizational culture may be supporting or inhibiting their ability to perform trained behaviors.

E.3. Conclusions

The results from this study suggest that simulation-based leadership training can transfer to the clinical environment and that team leadership correlates with patient care. Subjects valued training and perceived that they continued to implement trained behaviors 1 year after training. Overall, our translational simulation-based research provides strong recommendations supporting team leadership training and establishes a foundation for further research definitively demonstrating the impact of training on patient outcomes.

E.4. Significance

Errors in trauma care resulting in adverse events present a significant threat to patient safety.[3-5] Despite implementation of recommended trauma system-based protocols, there remain significant rates of medical error associated with trauma resuscitation. We demonstrate that a well-designed team leadership simulation-based training program can improve performance in the actual clinical environment.

- Simulation-based training of complex skills (leadership) can transfer to the clinical environment.
- Simulation-based training resulted in participant-reported continued implementation of behaviors 1 year after training.
- Trauma events with effective leadership demonstrated improved patient care.

Prior to this study, translational simulation-based research has been limited to simple or complicated tasks due to significant limitations in measurement. We measured both team leadership and patient care across 360 highly variable clinical trauma resuscitations. To accomplish this task, we developed both leadership and patient care measures.

- Novel, highly reliable team leadership metrics are part of our robust simulation-based team leadership training curriculum.
- Our event-based approach to measurement (EBAM) supports translational simulation-based research and can be applied across multiple clinical tasks and environments.
- Novel, highly reliable patient care measures reliably captured patient care across highly variable clinical trauma resuscitation events.

Conceptual models are often used in education and healthcare research, but empirical support for models is rarely provided.

- We demonstrate a direct correlation between leadership effectiveness and patient care in trauma patient resuscitations, thus supporting a conceptual model[34,59] of team leadership in healthcare action teams.

Robust simulation-based research rarely includes patient/family/organizational outcomes, especially when training targets are complex skills (e.g., leadership, communication, teamwork). We address this issue and conduct important pilot work to support a large-scale study aimed at T3-level translational work.

- Linkage between training and patient outcome data was 95%.
- We have identified patient outcomes that would be important targets for future study.

E.5. Implications

Trauma team leadership training should be incorporated into national trauma training programs, such as Advanced Trauma Leadership Support (ATLS). We recommend further implementation research to optimize the implementation of training across different institutions and types of organizations.

We provide a roadmap for translational research in simulation and medical education that can be adopted by national bodies and organizations. We believe this evidence-based approach addresses a major gap in current translational research, as existing recommendations do not provide mechanisms to operationalize guidelines.

LIST OF PUBLICATIONS AND PRODUCTS

Products

1. Team leadership simulation-based training curriculum (Attachment A)
2. Team leadership measure (Appendix 1)
3. Trauma patient resuscitation measure (Appendix 2)
4. Video library containing 360 video recorded trauma resuscitation events with patient de-identification
5. Event-based approach to measurement (EBAM)
6. Methodology for video capture of live clinical events

Publications

1. Fernandez R, Grand JA: Leveraging Social Science-Healthcare Collaborations to Improve Teamwork and Patient Safety. *Curr Probl Pediatr Adolesc Health Care*, 2015; 45(12):370-377. PubMed PMID: 26573242.
2. Rosenman ED, Branzetti JB, Fernandez R. Assessing team leadership in emergency medicine: The milestones and beyond. *J Grad Med Educ*. 2016 Jul;8(3):332-40. PubMed PMID: 27413434
3. Fernandez R, Shah S, Rosenman ED, Kozlowski SWJ, Parker SH, Grand JA. Developing Team Cognition: A Role for Simulation. *Simul Healthc*. 2017 Apr;12(2):96-103. PubMed PMID: 28704287
4. Rosenman ED, Dixon AJ, Webb JM, Brolliar SM, Golden SJ, Jones KA, Shah S, Grand JA, Kozlowski SWJ, Chao GT, Fernandez R. A simulation-based approach to measuring team situational awareness in emergency medicine: A multicenter, observational study. *Acad Emer Med* 2018;25(2):196-204.
5. Rosenman ED, Fernandez R, Wong AH, Cassara M, Cooper DD, Kou M, Laack TA, Motola I, Parsons JR, Levine BR, Grand JA. Changing systems through effective teams: A role for simulation. *Acad Emer Med* 2018;25(2):128-143.
6. Fernandez R, Rosenman ED, Chipman AC, Brolliar S, Vrablik M, Kalynych C, Shuluk J, Lazzara EH, Keebler JR, Samuelson H, Grand JA. An Event-based Approach to Measurement (EBAM): Facilitating observational measurement in highly variable clinical settings. *J Grad Med Educ* (in preparation)
7. Rosenman ED, Bullard MJ, Jones KA, Welsh L, Brolliar SM, Levine BR, Grand JA, Fernandez R. Development and empirical testing of a novel team leadership assessment measure using simulated and live patient encounters. *Acad Emerg Med Educ Training* (submitted)
8. Rosenman ED, Vrablik MC, Brolliar SM, Chipman AK, Fernandez R. Targeted simulation-based leadership training for trauma team leaders. *West J Emer Med* (submitted)

Book Chapter

1. Kozlowski SW, Chao GT, Chang C, Fernandez R. Team dynamics: Using “big data” to advance the science of team effectiveness. In: Tonidandel S, King EB, Cortina JM, eds. *Big data at work: The data science revolution and organizational psychology*. Mahwah: Routledge; 2015.

Presentations

1. Description of a Novel Team Leadership Training Program. *International Symposium on Human Factors and Ergonomics in Health Care: Improving the Outcomes*, Baltimore, MD, 2015.
2. A multicenter, observational study of teamwork, team cognition, and leadership. *2016 Military Health System Research Symposium*, Orlando, CA.
3. Research methods for healthcare teams: Technology, opportunities and lessons learned. *2018 Society for Industrial and Organizational Psychology*, Chicago, IL.
4. Translational research linking medical education efforts to patient outcomes: Methodological constraints and solutions encountered during a randomized controlled trial. *2018 Society for Academic Emergency Medicine*, Indianapolis, IN.
5. Rosenman ED, Bullard MJ, Jones KA, Welsh L, Brolliar SM, Levine BR, Grand JA, Fernandez R. Creating and Validating a Team Leadership Assessment Measure for Emergency Medicine (accepted for presentation, 2019 International Meeting on Simulation in Healthcare, San Antonio, TX).

Appendix 1. Team Leadership Measure

Behavior	SubBehavior	Description	Max Points
Assumes team leadership role	Assumes team leadership role	Explicitly assumes team leadership roles	2
Pre-brief*	Pre-brief engagement*	Implicitly engages in pre-brief summary with team (1 point) Explicitly engages in pre-brief summary with team (4 points)	4
	Pre-brief content	One point for each leadership behavior performed in pre-brief: • Information sharing (1 point) • States plan (1 point) • Role assignment (1 point) • Seeks input (1 point)	4
Arrival brief	Arrival brief	Highlights if pre-hospital report is same or if it changed (2 points) Communicates impact of prehospital report on existing plan/role assignment or priorities (2 points)	4
Status Brief (Huddle)	Status brief engagement*	Implicit summary (huddle) engagement (1 point) Explicit summary (huddle) engagement (4 points)	4
	Status brief content	One point for each leadership behavior performed in Huddle: • Information sharing (1 point) • States plan (1 point) • Role assignment (1 point) • Seeks input (1 point)	4
Leader behaviors	Information sharing	One point for each component of information sharing behavior: • Summary of patient status/results (2 points) • Provided interpretation of the facts for the team (2 points)	4
	States plan	One point for each component of planning behavior: • Stated plan with future steps (2 points) • Stated plan with priorities (2 points)	4
	Role assignment	One point for each component of role assignment behavior: • Identifies individuals for tasks (2 points) • Factors in team member skill set AND/OR requests a check back when task is complete (2 points)	4
	Seeks input	One point for each component of seeking input behavior: • Asks for team input (2 points) • Asks for potential delays or barriers (2 points)	4
		Total Team Leadership Score Possible	**38**

*Points are awarded for either implicit or explicit engagement, not both; therefore, maximum score is 4.

Appendix 2. Examples of items within patient care measure*

Item	Item Label	Conditional/Universal
1	Listens to lungs	Universal
2	General airway assessment	Universal
3	Airway assessment verbalized	Universal
4	ET tube depth verbalized	Conditional
5	Checks pulse, peripheral or central - standardized	Universal
6	Checks pulse, left arm	Universal
7	Checks pulse, right arm	Universal
8	Checks pulse, left leg	Universal
9	Checks pulse, right leg	Universal
10	Confirms access placed by EMS or orders initial IV	Universal
11	Confirms 2nd IV or orders a 2nd IV	Conditional
12	Verifies total amount of fluids given	Universal
13	Orders additional fluid or confirms additional fluid given	Conditional
14	Verbalizes intent to transfuse blood product	Conditional
15	Orders blood transfusion, amount or type	Conditional
16	Blood transfusion started	Conditional
17	Orders vasopressors	Conditional
18	Verbalizes or interprets blood pressure	Universal
19	Verbalizes or interprets heart rate	Universal
20	Verbalizes or interprets oxygen saturation	Universal
21	Mental status assessed	Universal
22	GCS score identified	Universal
23	Pupil size assesses	Universal
24	Extremity function, left arm	Universal
25	Extremity function, right arm	Universal
26	Extremity function, left leg	Universal
27	Extremity function, right leg	Universal
28	Clothing removed from patient	Universal
29	Back examined	Universal
30	Cervical spine or thoracic & lumbar spine palpated	Universal
31	Maintains C-spine immobilization	Conditional
32	CXR ordered	Conditional
33	CXR results communicated	Conditional
34	Time CXR results communicated from time CXR ordered	Conditional
35	PXR ordered	Conditional
36	PXR results verbalized	Conditional
37	Time PXR results communicated from time PXR ordered	Conditional
38	POCUS/DPA performed	Conditional

*Time to certain actions included in a time-based metric
CXR=chest x-ray; PXR=pelvis x-ray; POCUS=point of care ultrasound; DPA=diagnostic peritoneal aspiration; GCS=Glasgow coma scale; EMS=emergency medical services; IV=intravenous catheter

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