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14. ABSTRACT

OBJECTIVE: The overall objective of the proposed project is to improve trauma outcomes by developing, testing, and refining a simulation-based translational research model that can support highly effective trauma team leadership training and assessment across multiple outcome levels.

SPECIFIC AIMS:

***TRANSfeR Model Development*:** Develop a prototype of a translational simulation research model, TRANSfeR, which integrates task requirements, training elements, and outcomes.

TRANSfeR Model Validation: Assess the effect of a simulation-based LEADER training bundle on simulation-based skills (T1), clinical processes and performance (T2) and patient outcomes (T3)

TRANSfeR Model Refinement: Refine the TRANSfeR model using study data to reflect relationships between training, performance, and outcomes and prepare a protocol to conduct a large-scale, multicenter trial that is adequately powered to detect differences in clinically important outcomes.

MAJOR FINDINGS: The investigators performed a four-step process to develop the TRANSfeR model. This work involved integrating conceptual framework(s) of translational research, simulation-based education, team science, and educational transfer. We (1) identified the core task components, training objectives, training design elements, and performance constructs relevant to the proposed training domain, (2) determined relevant variables and relationships, (3) identified appropriate outcome measures and analytic approaches, and (4) determined pathways for training refinement. Dissemination in the form of a manuscript is in progress. Validation of the TRANSfeR model is the focus of project year 2. We will apply the model to trauma team leadership training (LEADER) and performance to determine the link between trained leadership behaviors and patient care during trauma resuscitations.

IMPACT: The TRANSfeR model and LEADER training will improve military medical team leader performance, thus providing a mechanism to increase team effectiveness and directly improve trauma readiness and care delivery across military and civilian institutions.

15. SUBJECT TERMS
Simulation; translational research; trauma care; resuscitation; leadership; teamwork; medical education; modeling

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1. **INTRODUCTION:** *Narrative that briefly (one paragraph) describes the subject, purpose and scope of the research.*

   It is the **overall objective** of this project to validate and refine a translational model of simulation-based research by evaluating the relationships between trauma team leader training and leader performance, patient care, and patient outcomes. This work is organized around two interrelated research efforts, one conceptual and one empirical. First, the proposed project integrates existing research, including a significant body of the investigators' preliminary work, to inform a conceptual model of translational simulation-based research. This conceptual work guides the design and execution of an empirical study to generate validity evidence for the translational research model. Finally, the conceptual work and empirical study data are used to develop and refine a roadmap that operationalizes translational simulation-based research and defines the activities necessary to support the translation from T1 to T2 and T2 to T3.

2. **KEYWORDS:** *Provide a brief list of keywords (limit to 20 words).*
   Simulation; translational research; trauma care; resuscitation; leadership; teamwork; medical education; modeling

3. **ACCOMPLISHMENTS:** *The PI is reminded that the recipient organization is required to obtain prior written approval from the awarding agency grants official whenever there are significant changes in the project or its direction.*

   What were the major goals of the project?
   List the major goals of the project as stated in the approved SOW. If the application listed milestones/target dates for important activities or phases of the project, identify these dates and show actual completion dates or the percentage of completion.

   Aim 1: TRANSfeR MODEL DESIGN (CONCEPTUAL WORK)
   The **primary outcome** of Aim 1 is a draft model of translational simulation research, TRANSfeR, with proposed variables and relationships specified. TRANSfeR integrates task requirements, training elements, and outcomes. The outcomes are broadly conceived to include individual, team, and unit performance; proximal and distal patient-centered effects, and system-level measures. Our existing training, metrics, data integration approaches, and research methods support model development. Work in this aim included defining relevant constructs, relationships, outcomes, and the level(s) (i.e., individual, team, patient, and organizational) at which these factors are expected to act.

   The tasks, timeline, and status of each step associated with Aim 1 is summarized in the table below, including overall project start up work.

SPECIFIC AIM 1	Timeline	Status
Task 1: Project Start-up	**Months**	
Establish subcontracts to enable purchasing.	0 – 3	A subcontract with the University of Washington was established on December 13, 2018. Subcontracts have been established with the University of Maryland and Virginia Tech University. **COMPLETED**

Local/Site IRB application submissions	0 – 3	IRB approval (exempt) for Aims 1-4 has been granted by all institutions. **COMPLETED**
Assemble / hire research support personnel	0 – 3	A research coordinator was hired at the primary site. Graduate students and site personnel are identified. **COMPLETED**
Establish multi-institutional research meetings	0 – 3	An initial research meeting was held and regular meetings established going forward. **COMPLETED**
Human Research Protection Office IRB submission	3	The HRPO has reviewed the IRB submission and has granted exempt status. **COMPLETED.**
Milestone(s) Achieved: 1. Project infrastructure in place 2. Local/Site IRB and HRPO Approval	6	**100% COMPLETED**
Task 2: Develop a draft of the TRANSfeR model for trauma team leadership	**Months**	
Literature search	0 – 3	Search strategy within healthcare literature, trauma performance literature, trauma outcomes literature, and team science has been defined. **COMPLETED**
Identify concepts and constructs of interest	0 – 3	Candidate variables have been identified. Measures and processes to obtain variables has been discussed. **COMPLETED**
Determine relevant variables and relationships between constructs	0 – 3	Preliminary relationships have been identified and candidate variables have been finalized. **COMPLETED**
Identification of appropriate outcome measures and mechanisms	3 – 6	We have identified multiple candidate outcome variables. We are in the process of identifying mechanisms to measure outcomes and determining feasibility of assessing outcomes as part of Aim 2. **COMPLETED**
Determine pathways for feedback and refinement	3 – 6	Feedback mechanisms and links have been identified. **COMPLETED**
Milestone Achieved: *Completed draft of the TRANSfeR model including task requirements, training elements, and outcome measures*	6	**100% COMPLETED**

TRANSfeR MODEL TESTING AND VALIDATION (EMPIRICAL)

We propose testing the TRANSfeR model at multiple levels within the model to evaluate skill transfer, identify optimal skills for training, and determine impact of training on the trauma team as a system.

Aim 2: Determine the correlation between simulation-based performance (T1) and clinical performance (T2) of team leadership skills.
Performance of team leaders in high fidelity simulations of trauma resuscitations will be correlated with performance during actual trauma resuscitations.
(H1) Individuals with better trauma team leadership assessment scores will demonstrate better clinical trauma team leadership scores during actual trauma resuscitations.

SPECIFIC AIM 2: Determine the correlation between simulation-based performance (T1) and clinical performance (T2) of team leadership skills		
Task	**Months**	**Description**
Determine coding procedures for simulation-based trauma resuscitations	9 – 12	We evaluated coding procedures and metrics and made necessary alterations to accommodate simulation-based trauma resuscitations **COMPLETED**
Prepare video of simulated trauma resuscitations	6 – 12	Existing video data available for simulation-based performances. We have assessments (2 videos each) for 30 subjects. Video processing of existing simulation video data is completed. **COMPLETED**
Rater recruitment	6 – 9	Raters to code simulated trauma resuscitations have been recruited from a pool of experienced coders **COMPLETED**
Rater training and evaluation	6 – 12	Training has been initiated and tested. Initial IRR calculations are completed. Raters have been trained and evaluated. Evaluation will continue throughout coding. **COMPLETED**
Coding of team leadership for simulated videos	9 – 16	Leadership coding of existing simulated trauma resuscitations is underway and near completion. **COMPLETED**
Local/Site IRB application submissions for revised Aim 5.	0 – 3	IRB application for revised Aim 5 has approved as an exempt protocol. **COMPLETED**
Preparation of T2 leadership and patient care data	12 – 16	Patient care and leadership data exist for prior video recorded actual trauma resuscitations. Data needs to be aggregated and linked to simulation data prior to analysis. **COMPLETED**
Data analysis	16 – 20	Validation of leadership measures and correlation of performance. **100% Completed (manuscript published)**
Milestone Achieved: *This Aim will meet the goal of analyzing the connection between training, T1, and T2 outcomes*	20	**100% Completed**

Aim 3: Determine which trained team leadership behaviors predict improved overall clinical care during trauma resuscitations (T2)

We proposed using data collected in Aim 1 and in prior work to create performance models to determine which trained leadership behaviors are most important for team clinical effectiveness. We used team leadership time-stamped behaviors and trauma team clinical care performance data to create models. This work identified trained leadership behaviors that translate into improved clinical care. Because training time is almost always too limited, these data can help to inform which trained behaviors should be the focus of trauma team leadership training.

(H2a) Early planning and information sharing results in improved overall clinical effectiveness.
(H2b) Quality and frequency of in-resuscitation briefs improve overall clinical effectiveness.

SPECIFIC AIM 3: Determine which trained team leadership behaviors predict improved overall clinical care during trauma resuscitations (T2)		
Task	**Months**	**Status**
Prepare existing database of leadership and patient care elements	14 – 18	Existing databases of team leadership elements and patient care elements for 60 subjects (360 resuscitations) need to be merged and prepared for analyses. **COMPLETED**
Prepare time-based data for analyses	18 – 20	Preparation of time-based data required for analyses **COMPLETED**
Set specific hypothesis statements for testing	18 – 20	Work with subject matter experts to determine specifically what leadership – patient care relationships to test **COMPLETED**
Data analysis	20 – 24	Analyze proposed hypotheses **COMPLETED, manuscript in process**
Milestone Achieved: *This Aim will meet the goal of identifying the trained leadership behaviors that most predict effective patient care (T2)*	28	**99% COMPLETED, manuscript in process**

Aim 4: Determine which trained team leadership behaviors predict improved adaptability in trauma resuscitation teams (T2/T3)

Adaptive performance is critical for healthcare team effectiveness, and is a characteristic of high functioning healthcare units. Within trauma resuscitations, non-routine events occur and require teams and systems to adapt their behaviors to meet unexpected needs. We applied an adaptive performance model developed through a ***prior JPC-1 MSIS grant*** (W81XWH-15-1-0403) to guide understanding of adaptation.

(H3) Leadership training focused on early establishment of priorities results in more effective adaptation to unexpected events as measured by improved clinical performance after unexpected event.

SPECIFIC AIM 4: Determine which trained team leadership behaviors predict improved adaptability in trauma resuscitation teams (T2/T3)		
Task	**Months**	**Status**
Prepare database of non-routine events	14 – 18	An existing database of non-routine events exists for 60 subjects (360 resuscitations).

		This database includes the timing and nature of non-routine events. This database has been merged with the leadership and patient care database to allow analysis of adaptive performance in response to unexpected clinical events. **COMPLETED**
Identify adaptive performance indicators	18 – 21	Use existing model of adaptive performance to identify approach to adaptation metrics – this work is near complete, but is iterative so reflected at 99%. **99% completed**
Set specific hypothesis statements for testing	21 – 26	Work with subject matter experts to determine specifically what leadership – patient care relationships to test – this work is near complete, but is iterative so reflected at 80%. **COMPLETED**
Data analysis	26 – 30	Analyze the impact of trained behaviors on adaptation. Data analyses are in progress. **80% completed**
Milestone Achieved: *This Aim will meet the goal of identifying links between trained behaviors, clinical care (T2), and team adaptation (T3)*	30	**In process, 99% completed**

Aim 5: Understand how team leadership training impacts team cohesion amongst untrained team members (T3)

We conducted interviews of team members in the emergency department to help understand the impact of trained concepts on execution of trauma resuscitations. We applied a conceptual model of team cohesion to the analyses. Team cohesion is relevant to job satisfaction and retention, developing team orientation, and team motivation. This Aim provides important information about provider-level outcomes (T3).

(H4) Simulation-based training in trauma team leadership improves dimensions of team cohesion across all team members.

SPECIFIC AIM 5: Understand how team leadership training impacts team cohesion amongst untrained team members (T3)		
Task	**Timeline Months**	**Status**
Develop interview guide based on conceptual model of team cohesion	26	Use existing conceptual model of team cohesion and team leadership to develop interview guide **COMPLETED**
Test and refine interview guide	24 – 26	Use interview guide on a subset of subjects and refine guide as needed **COMPLETED**
Develop codebook for interviews	26 – 27	Use existing conceptual model of team cohesion and team leadership to develop

		interview guide with the input of subject matter experts **COMPLETED**
Recruit subjects	24 – 28	Recruit trauma team members of team leaders. Recruitment underway, some delays due to COVID. Saturation has been reached based on analyses. **COMPLETED**
Conduct interviews with team members of trained team leaders	26 – 28	Conduct interviews and iteratively test codebook to determine when saturation reached. Initial interviews completed, some delays due to COVID. **COMPLETED**
Analyze qualitative data	28 – 32	Work with qualitative experts to code data and identify how team leadership behaviors impact team cohesion (T3) and constructs related to team cohesion. Initial coding has begun and software to execute this task has been purchased. **COMPLETED**
Milestone Achieved: *T3 qualitative data analyzed*	32	**COMPLETED (1st manuscript submitted)**

TRANSfeR MODEL REFINEMENT AND FURTHER EVALUATION (INTEGRATION)

We will synthesize the results from Aims 1-5 to refine the TRANSfeR model to reflect relationships between training, performance, and outcomes. This work requires completion of other Aims and thus is reflected as planned.

TRANSfeR Model Refinement and Further Evaluation		
Assess all relationships proposed in TRANSfeR model	32 – 40	Data analyses in process **COMPLETED**
Identify outcomes / relationships supported by empiric data	32 – 40	Data analyses in process **COMPLETED**
Identify outcomes / relationships requiring modification based on qualitative data	32 – 40	Data analyses in process **COMPLETED**
Develop roadmap for operationalizing TRANSfeR model	38 – 42	Data analyses in process **COMPLETED**
Milestone(s) Achieved: *A refined TRANSfeR conceptual model with proposed measurement targets, relationships, and level(s) of analysis*	44	Data analyses in process **COMPLETED**
Milestone(s) Achieved: *Report containing a detailed roadmap for operationalizing TRANSfeR*	46	**COMPLETED (manuscript in process)**

Report writing and dissemination		
Submit final reports and manuscripts	42-52	Metrics for patient care assessment have been accepted for publication to *Academic Emergency Medicine Education and Training* journal. Abstract was accepted for submission and presentation at *International Meeting for Simulation in Healthcare* Qualitative analysis manuscript submitted, BMJ Leader Manuscript of process mapping of trauma resuscitation accepted to *Simulation in Healthcare* Presentation accepted to Human Factors and Ergonomics Society annual meeting Proceedings paper submitted, Society for Industrial and Organizational Psychology Sequences of leadership behavior and performance, in preparation **In process, 90% completed**
Milestone(s) Achieved: Dissemination of methodological approach and empiric findings	48	**In process, 90% completed**

WHAT WAS ACCOMPLISHED UNDER THESE GOALS?
***Please see summary SOW table above for specific task details and progress**

AIM 1
We've completed all work for Aim 1.
The investigators completed IRB applications for Aim 1 at all four sites and HRPO exempt status was obtained. Subcontracts are now all established.
We applied the following 4-step approach to development of the model and its components. This methodology is summarized below:
Step 1. Identify concepts and constructs of interest: We identified the core task components, training objectives, training design elements, and performance constructs relevant to trauma team leadership. The data sources for this work included a comprehensive literature review, subject-matter expert review, video of simulated and real patient care events, and research validating existing curricula and outcome measures.
To determine relevant patient care variables, it was necessary to create a process mapping of trauma care for blunt trauma patients. We therefore created a process map using video recordings of actual trauma resuscitations. This work has been accepted for publication in *Simulation in Healthcare*. The

abstract from that manuscript and a sample component of the process map is provided in Appendix 1.

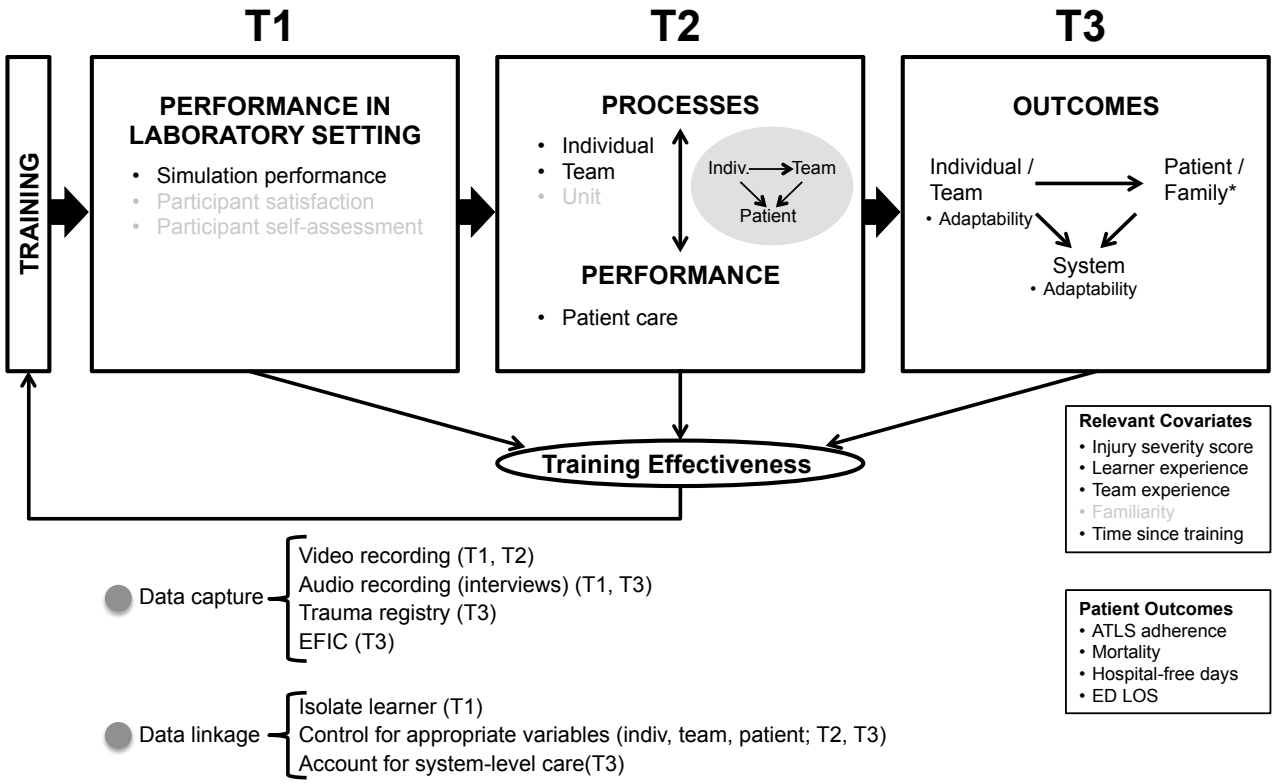
Step 2. Determine relevant variables and relationships: We constructed a network among these constructs that defines and specifies their key exogenous and endogenous relationships.

Step 3. Identify appropriate outcome measures and mechanisms: We identified appropriate (1) individual-, team-, patient-, and system-level measures, (2) affective, behavioral, and cognitive measures, and (3) proximal and distal measures. We identified appropriate mechanisms for data integration and analysis that best reflect training outcomes at all levels.

Step 4. Determine pathways for feedback and refinement: The investigators proposed mechanisms that facilitate the use of patient and systems-level outcomes to assess training effectiveness and identify areas where training should be modified.

The resulting overall model is presented in Figure 1. Individual components are described below and in relevant Appendices.

Figure 1.



Variables

Individual, team, and task-level variables will impact leader and team performance. We've identified key variables to include in models of the impact of trauma team leader training on trauma team resuscitation performance. These are summarized in Table 1.

Table 1

Level of Variable
Individual
• Years in training
• Specialty
Team*
• Team size
• Team familiarity
Task**
• Patient injury severity score
• Level of trauma team activation
• Patient age
• Length of time since training

*team variables describe the team members and structure present during the resuscitations that form the basis of the assessment

**task variables relate specifically to the patient resuscitation that forms the basis of the assessment

Measures

We've developed measures for team leadership and patient care (Appendix 2, 3). Leadership metrics are relevant to T1 and T2 assessments. Patient care metrics are relevant to T2 metrics and, when combined with key time-based metrics, provide assessment of adaptive performance (T3).

Current research does not describe a robust, applicable metric for team adaptability (T3) in action teams. We applied a qualitative approach to determine aspects of leadership training and leadership behaviors that impact key components of team and system performance, including adaptability, cohesion, and psychological safety.

Analysis Plan (T2 / T3 outcomes)

1. The investigation of the effects of leadership training on team leader behavior and patient care is a two condition (control, experimental training) pre- / post-test design with two pre-measurements (resuscitation prior to training) and four post-measurements (resuscitations following training / control).
    a. Dependent variables of interest include team leadership (T2), patient care (T2), team processes (T2), and adaptation (T3).
2. Because the effects of interest could be influenced by participant experience, the severity of the trauma case, and the timing of the trauma relative to training delivery, it is necessary to control for these key covariates (Table 2). However, controlling for these factors is complicated as they included (a) a *time invariant* measure of participant experience, coded as their year in residency, (b) a *time varying* measure of patient injury severity and trauma team activation, and (c) a *time varying* measure of the number of days pre or post the training event for a given trauma event.
    a. This is a complex design, with repeated measures of the dependent variables nested by participant (and the time invariant experience covariate) with time varying covariates that are associated with each trauma patient.
    b. Team level metrics would be time varying measures if included in the model.
3. Given this data structure, the use of random coefficient modeling (RCM) to account for nesting and the time varying covariates is necessary.

a. This approach allows us to statistically manage pre-training/control leadership behavior, as well as the time varying covariates, in testing the effects of the training/control conditions. The purpose is to ensure that the training and control conditions are statistically equivalent and to deal with the time varying covariates, necessitating the use of RCM. The statistical equating of the two groups prior to hypothesis testing follows the standard logic of a Repeated Measures Analysis of Covariance (RM-ANCOVA).
b. The pre-training scores and covariates need to be grand mean centered to improve interpretability of the parameters in the model.

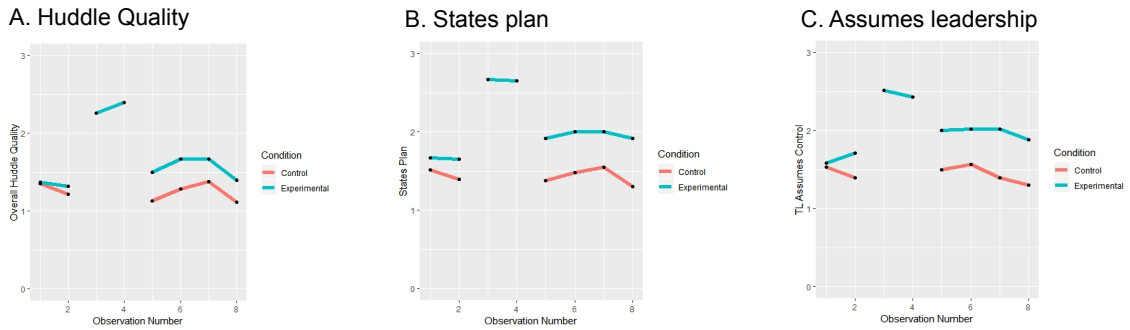
4. Where no significant direct effect was noted, we tested an indirect effect of training condition via leader behavior on key outcomes. These indirect effects are predicted by a conceptual model of team leadership by Kozlowski, et al that formed the foundation of our work.

Products from Aim 1 are described in Section 6.

AIM 2

Coding was completed for the simulated videos. Trained raters coded leadership behaviors for 60 videos. These data were reconciled, evaluated for inter-rater reliability, and prepared for analyses. Preliminary analyses demonstrate transfer of trained behaviors to the clinical environment (examples from 3 behaviors provided in Fig 2a, 2b, 2c). Observations 1 and 2 represent pre-simulation performance, observations 3 and 4 represent simulation-based performance, and observations 5 and 6 represent post-training performance (for intervention subjects). Analyses to evaluate correlation between simulated and clinical performance are completed.

Figure 2.



Two measures were used to code leadership. One is a behaviorally-anchored rating scale designed for real-time coding, and one is a code system to categorize team leader utterances using a checklist designed for video-based coding. Validity evidence for the utterance coding system was presented in a recent publication (Appendix 4; DOI: 10.1097/CCM.0000000000004077). The construct validity of the BARS measurement tool was evaluated using a multimethod-multitrait (MTMM) approach. In general, MTMM analyses involve assessing the extent to which ratings of a given construct converge when assessed using different measurement methods. In the present analyses, eight team leadership constructs were assessed using two methods (BARS measure and utterance checklist). Three MTMM analyses were conducted reflecting increasing psychometric rigor:

1. Simple correlation computed between average of all BARS items and the overall leadership score from the checklist
2. "Classic" multitrait-multimethod analysis in which the correlations between each BARS item and the corresponding checklist items were computed; permits examination of convergent validity (same trait-different method correlations) and discriminant validity (different trait-same method correlations and different trait-different method correlations) evidence
3. Latent factor multitrait-multimethod modeling in which the scores on the observed BARS and checklist items were modeled as a function of their underlying leadership construct and measurement method; permits examination of convergent validity (strength of factor loadings on leadership constructs) and method bias (strength of factor loadings on measurement methods).

Consistent evidence of convergent and discriminant validity were observed across all three analytical approaches. The results indicated that leadership ratings obtained using the BARS measurement tool tended to correlate closely with those obtained using the behavioral checklist. To strengthen analyses, additional videos have been coded. This allows us to analyze performance decay post-training. Decay analyses are in process and manuscript preparation is underway.

We also evaluated the impact of simulation-based leadership training on actual clinical leadership performance and patient care. These results are shown in Figure 3. When compared with untrained subjects, team leaders receiving training demonstrated a significant improvement in clinical leadership performance during trauma resuscitations. (b1=4.06, se=0.66, t(55)=6.11, p< 0.001; d=1.07) (Figure 3a). An additional model predicted patient care scores from leadership scores across all videos; leadership behaviors significantly predicted patient care (b1 = 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 (Figure 3b).

Figure 3a.

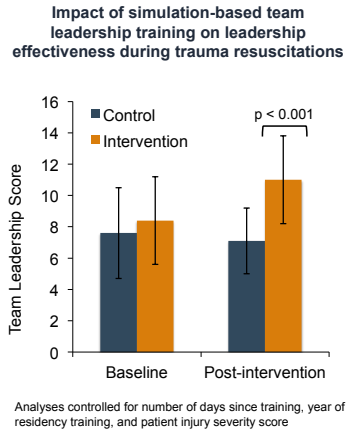
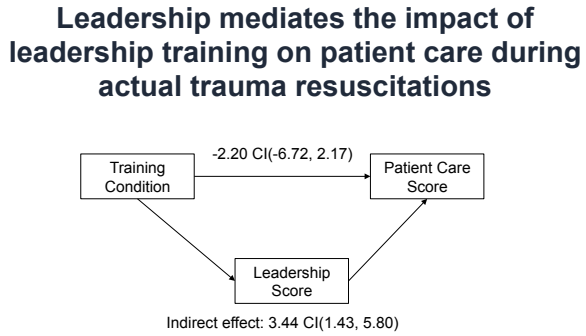


Figure 3b.



AIM 3

Work for Aim 3 focused on completing analyses. The construction of the database and data dictionary are complete. The primary task involved merging an existing database of time-stamped team leadership behaviors coded by raters with patient care elements for 60 subjects (360 resuscitations; Figure 3). The raw dataset contained over 73,400 coded observations of leadership

behaviors across all raters. Because many of the resuscitations were rated by multiple coders, the research team developed a protocol for aggregating the time-stamped observations within a given video recording across raters to maximize the number of unique data points retained for each resuscitation while maintaining high interrater agreement. In brief, this was completed by collapsing the time-stamped data for each video into a series of 10-sec time windows within which leadership behaviors observed by multiple coders could be tabulated.

Figure 3.

We utilized our time-stamped behavioral data of leadership behaviors collected during *in situ* observations to (a) identify unique *sequences* and/or *patterns* of leader behavior enacted by trained and untrained leaders, (b) attempt to extract unique "profiles" of leader behavior that better characterize *how*, *when,* and *why* leaders engaged in particular behaviors, and (c) attempt to establish correlations between these patterns of leader behavior and patient care outcomes.

The research team completed the *sequence analyses* planned for this study aim. Sequence analysis describes an approach for evaluating the order, trajectory, and characteristic patterns of events observed in a sequence of observations. The foundational concept of this analytic method is to cluster independently observed event series into a smaller number of representative sequences that can be interpreted, compared, and analyzed. These representative sequences can then be used as either predictors or outcomes to be predicted in subsequent analyses

The specific tasks and representative results accomplished during this quarter related to this study aim are summarized below. All data cleaning and analysis procedures were conducted in *R* and were written to ensure reproducibility.

1. *Dataset management.* Our primary data proved too complex (i.e., long durations/sequences of behavior, differing complexity of patient care needs across videos, etc.) to conduct the sequence analyses as intended when using the entire data stream collected from each video.

As a result, the research team developed and carried out a revised analysis plan that involved restructuring the dataset in several ways:

a. All videos were broken into smaller "chunks"/segments to simplify the examined sequences. The process for how and where to segment videos was established by using a separate patient care dataset to identify break points corresponding with commonly occurring patient care events (e.g., first x-ray, rolling patient, etc.) and then applying the break points across all videos.
b. An alternative coding scheme was developed by the research team to collapse several behavioral indicators into more discrete and easily distinguishable codes. This process did not alter the fundamental meaning of the behavioral codes recorded during data collection, but instead reorganized the codes into fewer and more interpretable categories to facilitate data analysis and interpretation.
c. Preliminary analysis of the behavioral data revealed the need to restrict the sequence analyses to only examining the *order* (i.e., Behavior A tended to follow Behavior B) rather than the specific *timing* of leader behavior sequences (i.e., Behavior A tended to follow Behavior B after 30 seconds). Consequently, new data cleaning/wrangling procedures were completed to restructure all observations into a format suitable for extracting ordinal sequential patterns.

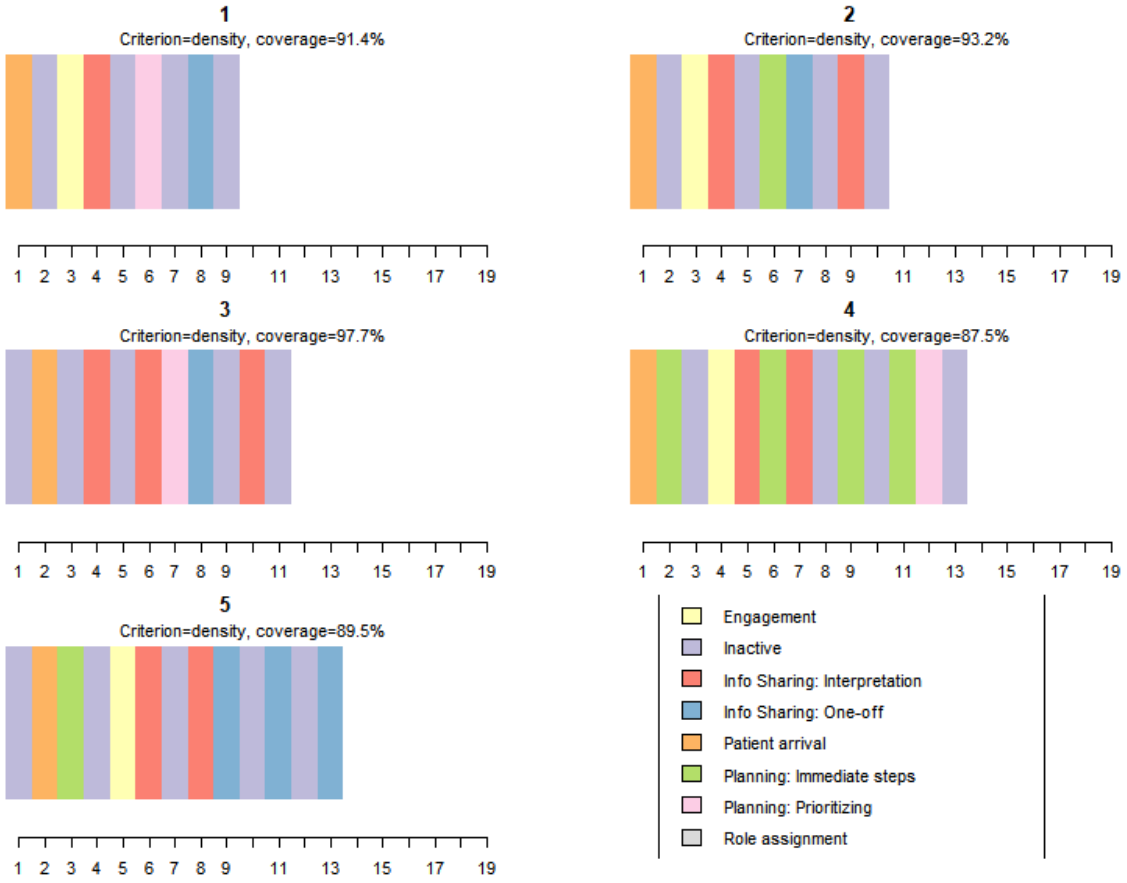
2. *Sequence analysis*. The general procedure for identifying and extracting representative sequences of leader behavior from our video data proceeded as follows:
    a. First, distance matrices were computed for all the sequences in each "chunk" separately. A distance matrix summarizes all the pairwise (dis)similarity (e.g., correlation) scores for sequences using an a priori selected distance computation algorithm. The method for computing distances between sequences in the present analyses was chosen to maximize differences in the observed *order* of events between sequences and was informed by previous statistical simulation research.
    b. Next, hierarchical cluster analyses were computed on the distance matrices to identify clusters of similar sequences. An adaptive "tree-cutting" algorithm was subsequently applied to the results of the cluster analyses to further collapse clusters into more interpretable and distinct groups of similar sequences.
    c. Lastly, an algorithm was applied to each cluster of sequences to identify the most "representative sequence" from that cluster. A representative sequence is chosen by identifying the single sequence with the highest density (as determined by the distance matrix) among the sequences located in its cluster.

Figure 4 provides an example of the sequence analysis results described above. These data are from the first "chunk" of each coded video and roughly correspond to the time between patient arrival and the completion of the team's primary survey. This figure reveals that during this time period, five distinct sequences of leader behavior were observed in the data (labeled 1-5 in Figure 1). Each sequence is comprised of a unique series and order of observed leader behaviors (with different behaviors corresponding to different colored bars as described in the figure legend). For example, the first representative sequence (top-left of Figure 1) describes a sequence of behavior in which the leader engaged their team in a huddle, followed by actively interpreting/sharing information with the team, prescribing a plan with priorities to their, and lastly engaging in some form of incidental information sharing. In contrast, the second representative sequence (top-right of Figure 1) shows a sequence in the leader engages their team in a huddle and actively interprets information for the

team, but who then prescribes a plan with only immediate next steps followed by additional exchanges of information with their team.

We used the results of these sequence analysis in inferential statistical models (i.e., regression) to examine whether trained versus untrained leaders were more likely to express different sequences of behavior, the degree to which contextual factors (e.g., patient severity) influenced whether leaders engaged in particular sequences of behavior, and whether different sequences of leader behavior were related to patient care scores.

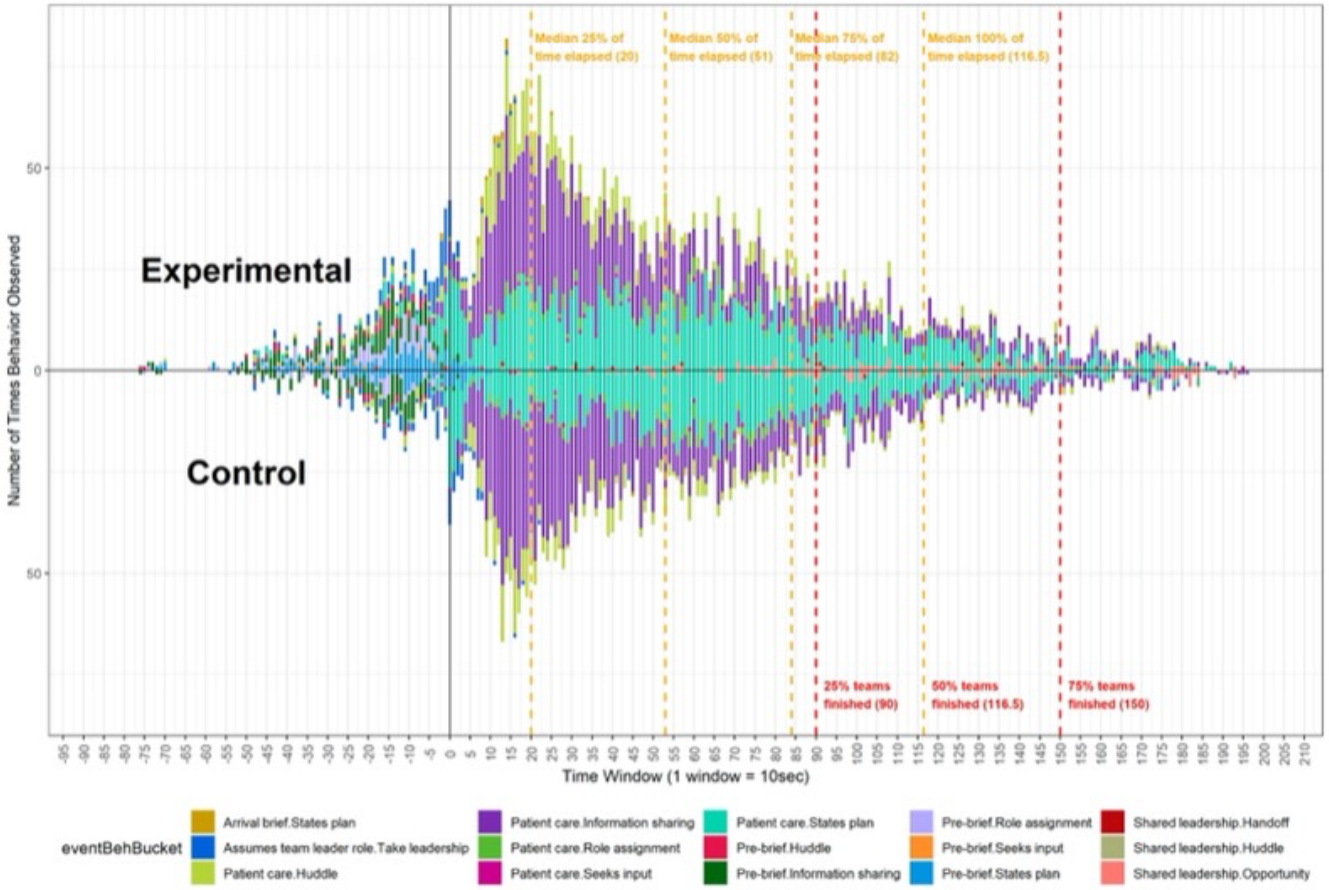
Figure 4. Representative sequences of observed leadership behavior between patient arrival and primary survey



The resultant dataset permits several unique analyses of the predictions advanced under Aims 3 and 4 (see below) and whether/how the timing, sequencing, and/or patterning of specific leadership behaviors relate to important patient outcomes. For example, Figure 5 provides a preliminary visualization of the frequency and timing of specific leadership behaviors observed within the dataset broken down by experimental and control conditions. These data offer a high-level and aggregate depiction of "flow" and pacing of observed leadership behavior, including periods where activity tends to be greatest and the duration of typical resuscitation events. Subsequent analyses of these data focused on statistically analyzing the proposed hypotheses for Aims 3 and 4 as well as

conducting more fine-grained analyses of the sequencing of leadership behaviors to determine whether particular patterns may have emerged which are correlated with improved patient care.

Figure 5. Frequency of timing of specific behaviors in control v intervention groups



AIM 4

Non-routine events have been identified and are described below. All non-routine events (Table 2) are time-stamped within videos, and timing of leadership behaviors, non-routine events, and patient care behaviors are synced to allow comparisons. Analyses as described in Aim 3 have been completed for Aim 4 data.

Table 2.

Level of Variable	Definition
New hypotension	Two consecutive systolic blood pressures less than 90 in the absence of pre-hospital hypotension
New hypoxia	Persistent (>1 min) pulse ox less than 90 in the absence of pre-hospital hypoxia
Loss of airway	Patient with decreased level of consciousness, obstruction, or other compromise of airway requiring emergent intubation. Includes problem with existing endotracheal tube.
Cardiac arrest	Cardiac arrest in emergency department without prior prehospital cardiac arrest

Positive FAST	Positive FAST exam
Critical equipment failure	Failure of equipment that directly impacted the ability to address potentially life-threatening issues
Critical medical condition identified	Presence of an acute life-threatening medical condition (e.g., acute myocardial infarction)

AIM 5

Aim 5 is a qualitative project in which we conducted interviews of team members in the emergency department to help understand the impact of trained concepts on execution of trauma resuscitations. We met with our qualitative experts and completed the process of identifying concepts and constructs. We have completed coding and analyses. Identified themes and sample quotes are provided in Appendix 7. A manuscript is completed and under review.

What opportunities for training and professional development has the project provided?

If the project was not intended to provide training and professional development opportunities or there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe opportunities for training and professional development provided to anyone who worked on the project or anyone who was involved in the activities supported by the project. "Training" activities are those in which individuals with advanced professional skills and experience assist others in attaining greater proficiency. Training activities may include, for example, courses or one-on-one work with a mentor. "Professional development" activities result in increased knowledge or skill in one's area of expertise and may include workshops, conferences, seminars, study groups, and individual study. Include participation in conferences, workshops, and seminars not listed under major activities.

- The project involved a graduate student at the University of Maryland. He has been involved in all aspects of the project and has benefited from attending weekly meetings. He has worked with his mentor, co-investigator James Grand on all aspects of the project. Opportunities to participate in conferences have been limited due to COVID; however virtual meetings allowed completion of work and his involvement in manuscript submissions.
- Training for subjects is a component of Aim 2.
- The trauma process mapping involves a graduate student. He has been involved in the entire mapping and variable identification process. He was to present this work but the meeting was cancelled due to COVID. Manuscript has been accepted for publication.

How were the results disseminated to communities of interest?

If there is nothing significant to report during this reporting period, state "Nothing to Report." Describe how the results were disseminated to communities of interest. Include any outreach activities that were undertaken to reach members of communities who are not usually aware of these project activities, for the purpose of enhancing public understanding project activities, for the and

increasing interest in learning and careers in science, technology, and the humanities.

- Leadership metrics (Appendix 2)
- Patient care metrics (Appendix 3)
- Patient care and leadership measures presented at the 2019 Society for Academic Emergency Medicine Annual Meeting, Las Vegas, NV. (Top 100 Abstracts)
- Translational model submitted and accepted for presentation at the 2020 International Meeting for Simulation in Healthcare; San Diego, CA.
- Patient care measurement approach accepted for publication in *Academic Emergency Medicine Education & Training* (Fernandez R, et al. An Event‐based Approach to Measurement: Facilitating Observational Measurement in Highly Variable Clinical Settings. *AEM Education and Training.* 2020;4(2):147-153.) – Appendix 8
- Translation of training to clinical performance is published in Critical Care Medicine (Fernandez R, et al. Simulation-Based Team Leadership Training Improves Team Leadership During Actual Trauma Resuscitations: A Randomized Controlled Trial. *Crit. Care Med.* 2020;48(1):73-82.) – Appendix 4
- Trauma care process map is accepted for publication in *Simulation in Healthcare (*Lodemann T, Akcali E, Fernandez R. Process modeling of ABCDE Primary Survey in Trauma Resuscitations: A crucial first step for agent-based simulation modeling of complex team-based clinical processes.) – Appendix 1

What do you plan to do during the next reporting period to accomplish the goals?
Describe briefly what you plan to do during the next reporting period to accomplish the goals and objectives.

Analyses for Aims 3 and 4 are completed. This work identified components of leadership that are most predictive of effective patient care, and will specifically evaluate adaptive performance during nonroutine events. Result interpretation and dissemination is planned for the NCE period. Two additional manuscripts are in preparation for submission to complete the dissemination of our work.

4. **IMPACT:** D*escribe distinctive contributions, major accomplishments, innovations, successes, or any change in practice or behavior that has come about as a result of the project relative to:*

What was the impact on the development of the principal discipline(s) of the project?
If there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe how findings, results, techniques that were developed or extended, or other products from the project made an impact or are likely to make an impact on the base of knowledge, theory, and research in the principal disciplinary field(s) of the project. Summarize using language that an intelligent lay audience can understand (Scientific American style).

What was the impact on other disciplines?

If there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe how the findings, results, or techniques that were developed or improved, or other products from the project made an impact or are likely to make an impact on other disciplines.

What was the impact on technology transfer?

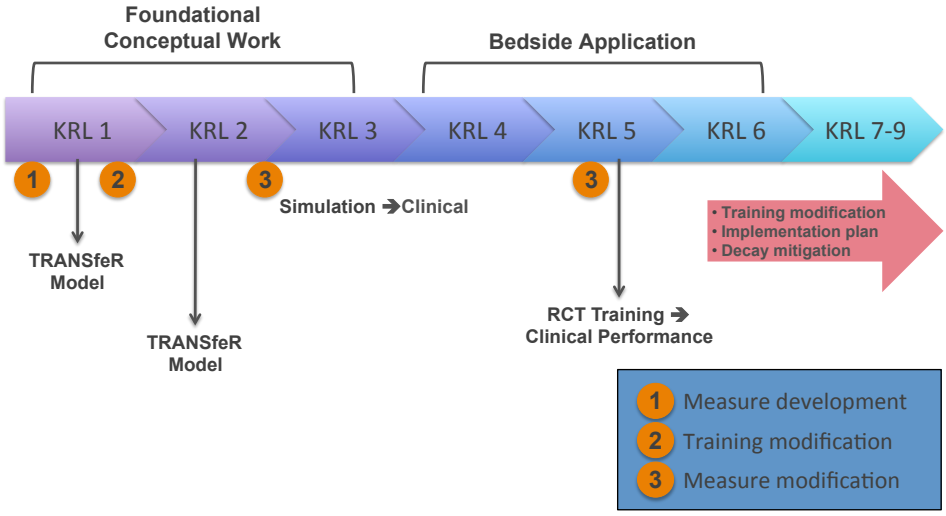
If there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe ways in which the project made an impact, or is likely to make an impact, on commercial technology or public use, including:

- *transfer of results to entities in government or industry;*
- *instances where the research has led to the initiation of a start-up company; or*
- *adoption of new practices.*

Figure 5 demonstrates KRL.

Figure 5.



What was the impact on society beyond science and technology?
If there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe how results from the project made an impact, or are likely to make an impact, beyond the bounds of science, engineering, and the academic world on areas such as:

- *improving public knowledge, attitudes, skills, and abilities;*
- *changing behavior, practices, decision making, policies (including regulatory policies), or social actions; or*
- *improving social, economic, civic, or environmental conditions.*

Our work may change how we view leadership performance and how we assess behavioral patterns within highly dynamic action teams.

5. **CHANGES/PROBLEMS:** *The PD/PI is reminded that the recipient organization is required to obtain prior written approval from the awarding agency grants official whenever there are significant changes in the project or its direction. If not previously reported in writing, provide the following additional information or state, "Nothing to Report," if applicable:*

The investigators encountered delays related to COVID-19 and resulting research restrictions. These restrictions resulted in delays with data collection related to Aim 5 (qualitative interviews). These restrictions have since been modified, and the investigators are able to resume this work. All data analyses are complete, remaining work centers on dissemination of findings.

Actual or anticipated problems or delays and actions or plans to resolve them
Describe problems or delays encountered during the reporting period and actions or plans to resolve them.

The investigators switched their approach to Aim 5 and are now conducting interviews via Zoom. All interviews are completed and analyses are done. The results of Aim 5 have been submitted in a mansuscript.

The investigators submitted a NCE that will allow the investigators to complete dissemination of results. Final approval is pending.

Changes that had a significant impact on expenditures
Describe changes during the reporting period that may have had a significant impact on expenditures, for example, delays in hiring staff or favorable developments that enable meeting objectives at less cost than anticipated.

There is no impact on budget.

Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

Describe significant deviations, unexpected outcomes, or changes in approved protocols for the use or care of human subjects, vertebrate animals, biohazards, and/or select agents during the reporting period. If required, were these changes approved by the applicable institution committee (or equivalent) and reported to the agency? Also specify the applicable Institutional Review Board/Institutional Animal Care and Use Committee approval dates.

Significant changes in use or care of human subjects

Interviews were performed via Zoom rather than in person due to COVID-19.

Significant changes in use or care of vertebrate animals

Nothing to report

Significant changes in use of biohazards and/or select agents

- Nothing to report

6. **PRODUCTS:** *List any products resulting from the project during the reporting period. If there is nothing to report under a particular item, state "Nothing to Report."*

- **Publications, conference papers, and presentations**
  Report only the major publication(s) resulting from the work under this award.

  Journal publications. *List peer-reviewed articles or papers appearing in scientific, technical, or professional journals. Identify for each publication: Author(s); title; journal; volume: year; page numbers; status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).*

Rosenman ED, Misisco A, Olenick J, Brolliar S, Chipman AK, Vrablik MC, Kozlowski SWJ, Grand JA, Chao GT, Fernandez R. Does team leader gender matter? A Bayesian reconciliation of leadership and patient care during trauma resuscitations. *JACEP Open*. Jan 2021;2(1). (https://doi.org/10.1002/emp2.12348)

Fernandez R, Rosenman ED, Chipman AK, Brolliar S, Vrablik M, Kalynych C, Shuluk J, Lazzara EH, Keebler JR, Samuelson H, Grand JA. An Event-based Approach to Measurement: Facilitating observational measurement in highly variable clinical settings. *Acad Emerg Med Educ Train*. 2020;4(2):147-153. PMID: 32313861

Fernandez R, Rosenman ED, Olenick, J, Misisco, A, Brolliar S, Chipman AK, Vrablik MC, Kalynych C, Arbabi S, Nichol G, Grand JA, Kozlowski SWJ, Chao GT. Simulation-based team leadership training improves team leadership and patient care during actual trauma resuscitations: A randomized controlled trial. *Crit Care Med* 2020;48(1):73-82. PMID: 31725441.

Lodemann T, Akcali E, Fernandez R. Process modeling of ABCDE Primary Survey in Trauma Resuscitations: A crucial first step for agent-based simulation modeling of complex team-based clinical processes. *Simul Healthc* (accepted).

Grand, Rosenman, Fernandez. Studying Leadership-as-Process by Mining Behavioral Sequences. *Proceedings of the Society for Industrial and Organizational Psychology* (submitted)

McFarlane A, Rosenman ER, Grand JA, Fernandez R. A Qualitative Exploration of Emergency Medicine Residents' Perspectives of Trauma Leadership Development. (submitted, *BMJ Leader*) [original research]

Books or other non-periodical, one-time publications. *Report any book, monograph, dissertation, abstract, or the like published as or in a separate publication, rather than a periodical or series. Include any significant publication in the proceedings of a one-time conference or in the report of a one-time study, commission, or the like. Identify for each one-time publication: author(s); title; editor; title of collection, if applicable; bibliographic information; year; type of publication (e.g., book, thesis or dissertation); status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).*

- None

Other publications, conference papers and presentations. *Identify any other publications, conference papers and/or presentations not reported above. Specify the status of the publication as noted above. List presentations made during the last year (international, national, local societies, military meetings, etc.). Use an asterisk (*) if presentation produced a manuscript.*

- Leadership training and outcome metrics presented at the 2020 Society for Academic Emergency Medicine meeting, Las Vegas, NV
- Overall translational model accepted for presentation at the 2020 International Meeting for Simulation in Healthcare

Website(s) or other Internet site(s)
List the URL for any Internet site(s) that disseminates the results of the research activities. A short description of each site should be provided. It is not necessary to include the publications already specified above in this section.

- None

Technologies or techniques
Identify technologies or techniques that resulted from the research activities. Describe the technologies or techniques were shared.

We developed a methodology to allow performance measurement in the clinical setting across highly variable clinical events. This methodology addresses an important knowledge gap that has limited translational educational research. This work has been published in *Academic Emergency Medicine Education & Training* journal.
Our approach to process modeling of complex events (trauma resuscitation) has been accepted for publication in *Simulation in Healthcare*. The process models will be published in their entirety as a supplemental file.

- **Inventions, patent applications, and/or licenses**
  Identify inventions, patent applications with date, and/or licenses that have resulted from the research. Submission of this information as part of an interim research performance progress report is not a substitute for any other invention reporting required under the terms and conditions of an award.

  - None

  Other Products
  Identify any other reportable outcomes that were developed under this project. Reportable outcomes are defined as a research result that is or relates to a product, scientific advance, or research tool that makes a meaningful contribution toward the understanding, prevention, diagnosis, prognosis, treatment and /or rehabilitation of a disease, injury or condition, or to improve the quality of life. Examples include:
  - *data or databases;*
  - *physical collections;*
  - *audio or video products;*
  - *software;*
  - *models;*
  - *educational aids or curricula;*
  - *instruments or equipment;*
  - *research material (e.g., Germplasm; cell lines, DNA probes, animal models);*
  - *clinical interventions;*
  - *new business creation; and*
  - *other.*

- Measures are noted in Appendix 2 and 3 and assessment methods described in manuscript (Fernandez R, Rosenman ED, Brolliar S, et al. An Event‐based Approach to Measurement: Facilitating Observational Measurement in Highly Variable Clinical Settings. *AEM Education and Training.* 2020;4(2):147-153.)
- The trauma resuscitation process models will be published as supplemental files in *Simulation in Healthcare.*

7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

What individuals have worked on the project?

Provide the following information for: (1) PDs/PIs; and (2) each person who has worked at least one person month per year on the project during the reporting period, regardless of the source of compensation (a person month equals approximately 160 hours of effort). If information is unchanged from a previous submission, provide the name only and indicate "no change".

Name:	Rosemarie Fernandez, MD
Project role:	Principal Investigator
era Commons ID:	av9546
Nearest person month worked:	1.8 cal.months (0.15 FTE)
Name:	James Grand, PhD
Project role:	Co-Principal Investigator
era Commons ID:	Grandjam
Nearest person month worked:	3 cal months (0.25 FTE)
Name:	Antionette McFarlane, PhD
Project role:	Research coordinator
Nearest person month worked:	12 cal months (1.0 FTE)
Name:	Elizabeth Rosenman, MD
Project role:	Co-Investigator
Nearest person month worked:	0.12 cal. Months (0.1 FTE)

Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

If there is nothing significant to report during this reporting period, state "Nothing to Report."

If the active support has changed for the PD/PI(s) or senior/key personnel, then describe what the change has been. Changes may occur, for example, if a previously active grant has closed and/or if a previously pending grant is now active. Annotate this information so it is clear what has changed from the previous submission. Submission of other support information is not necessary for pending changes or for changes in the level of effort for active support reported previously. The awarding agency may require prior written approval if a change in active other support significantly impacts the effort on the project that is the subject of the project report.

- None

What other organizations were involved as partners?

If there is nothing significant to report during this reporting period, state "Nothing to Report."

Describe partner organizations – academic institutions, other nonprofits, industrial or commercial firms, state or local governments, schools or school systems, or other organizations (foreign or domestic) – that were involved with the project. Partner organizations may have provided financial

or in-kind support, supplied facilities or equipment, collaborated in the research, exchanged personnel, or otherwise contributed.

Provide the following information for each partnership:
Organization Name:
Location of Organization: (if foreign location list country)
Partner's contribution to the project (identify one or more)

- *Financial support;*
- *In-kind support (e.g., partner makes software, computers, equipment, etc., available to project staff);*
- *Facilities (e.g., project staff use the partner's facilities for project activities);*
- *Collaboration (e.g., partner's staff work with project staff on the project);*
- *Personnel exchanges (e.g., project staff and/or partner's staff use each other's facilities, work at each other's site); and*
- *Other.*

Site 1: University of Florida
Gainesville, FL
Lead site

Site 2: University of Washington
Seattle, WA
Collaborating site

Site 3: University of Maryland
College Park, MD
Collaborating site

Site 4: Virginia Tech / Carilion
Roanoke, VA
Collaborating site

8. SPECIAL REPORTING REQUIREMENTS

COLLABORATIVE AWARDS: *For collaborative awards, independent reports are required from BOTH the Initiating Principal Investigator (PI) and the Collaborating/Partnering PI. A duplicative report is acceptable; however, tasks shall be clearly marked with the responsible PI and research site. A report shall be submitted to* ***https://ers.amedd.army.mil*** *for each unique award.*

QUAD CHARTS: *If applicable, the Quad Chart (available on https://www.usamraa.army.mil) should be updated and submitted with attachments.*

QUAD chart submitted separately as requested.

9. APPENDICES: *Attach all appendices that contain information that supplements, clarifies or supports the text. Examples include original copies of journal articles, reprints of manuscripts and abstracts, a curriculum vitae, patent applications, study questionnaires, and surveys, etc.*

APPENDICES

APPENDIX 1. Abstract of accepted manuscript (Simulation in Healthcare) and example process model

Process Modeling of ABCDE Primary Survey in Trauma Resuscitations: A Crucial First Step for Agent-Based Simulation Modeling of Complex Team-Based Clinical Processes

ABSTRACT

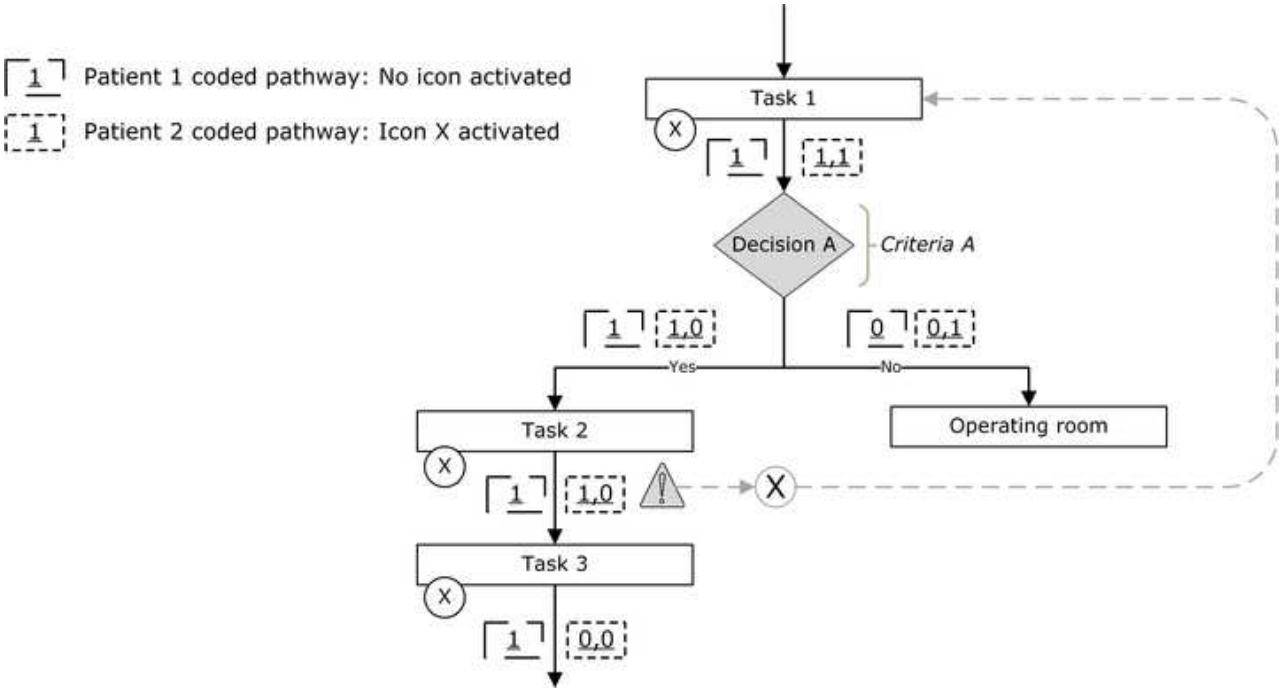
Introduction: Trauma teams are ad hoc, multidisciplinary teams that perform complex patient care and medical decision-making under dynamic conditions. The ability to measure and thus understand trauma team processes is still limited. Agent-based simulation modeling (ABSM) can be used to investigate complex relationships and performance within a trauma team. However, the foundational work to support such efforts is lacking. The goal of this work is to develop a comprehensive process model for the primary survey in trauma that can support ABSM.

Methods: A process model for the primary survey of patients with blunt traumatic injuries was developed using Advanced Trauma Life Support guidelines and peer-reviewed publications. This model was then validated using video recordings of 25 trauma resuscitations in a Level 1 trauma center. The assessment and treatment pathway followed in each video was mapped against the defined pathway in the process model. Where resuscitation performance did not follow the defined pathway, i.e., deviations, were noted.

Result: Overall there were 106 tasks and 78 decision points within the model, with the greatest number appearing in the Circulation domain, followed by Airway and Breathing. A total of 34 deviations were observed across all 25 videos, and a maximum of 3 deviations were observed per video.

Conclusions: Overall our data offered validity support for the blunt trauma primary survey process model. This process model was an important first step for the use of ABSM for the support of trauma care operations and team-based processes.

Example of Process Model Items



APPENDIX 2. Team leadership measure

Behavior	Description	Assumes and maintains TL role This should be scored during the pre-brief or about 15 seconds after patient arrival, around the EMS report. If the TL is not present at p arrival, they should assume the role when they enter the room		
		Scoring		
		Poor	Average	Excellent
Assumes TL role	**Code after TL arrives.**	Examples: Allows another team member to perform initial organizational task Enters the room and starts examining the patient without talking to the team	**Implicitly assumes TL role.** Does not explicitly introduce him/herself in this role but does perform tasks consistent with early TL role • Provides a plan and/or delegates roles at the team level prior to patient arrival (i.e., performs a prebrief) • Provides a plan and/or delegates roles at the team level shortly after TL arrival to room if the patient arrives before the TL (i.e., rebrief) • Defines own role to the team: "I will be performing the primary survey while John does….." • **If you closed your eyes, does it sound like there is a leader at that start of the encounter? When you open your eyes, is it the TL (the person who circled at entry)?	**Explicitly assumes TL role** • States he/she is: "the leader, "the traun "running the resuscitation," "in charge," • Does not need to use the word "leader" should use some language that clearly he/she is in the leadership role (see ab • This should still happen even if the TL there when the patient arrives
Asserts control throughout the event	**Code at the end** Not all items might be necessary (like crowd control); each anchor just provides you with some examples of what you are looking for	• Makes little or no attempt to maintain leadership role • Seems to abdicate role without officially turning over leadership **Examples:** Gets involved in a task (e.g., ultrasound, abg, or other procedure) and is unaware of the other events and discussions taking place When another team members speaks up with an idea or order, allows the team to shift and stay focused on this person as a new team leaders **Note:** Asking for ideas or feedback on a plan is not automatically a "poor." If the TL can defer to another team member for a plan as long as the TL continues to coordinate and organize the team around this plan.	• May establish self as team leader early on, • Unable to maintain this role as more people arrive, or the team gets disrupted • Has difficulty centering the focus of the team	• Identifies self as team leader when app (e.g., at the beginning, if many new tea members arrive, if team becomes disorganized/disrupted) • Attempts 'crowd control' (e.g., asking observers to leave, or delegating some manage observers) • Centers the focus of the team effective

Behavior	Description	Pre-Brief This item is based on behaviors that occur prior to the patient's arrival. Score this just after the patient arrives. This is a summary. It is not a list of one-off sharing of information, planning, or role assignment. The idea is that this is a discreet summ the team that, optimally, includes the 4 components listed below. **For this item, look at the best performance and score. They may do several pre-briefs, you score the best one.**		
		Scoring		
		Poor	**Average**	**Excellent**
Pre-Brief Engagement	Clearly engages in a pre-brief by gathering the attention of the team *Watch the entire pre-brief and score the best effort.	TL provides information to a single person (e.g., bedside RN or attending physician) but does not include the larger team. Note: If there is only one person in the room this is still poor because we would expect the TL to take steps to get the entire team to the room (e.g., calling them overhead) to facilitate a pre-brief	**Implicit** Starts speaking in a loud voice to the room to **summarize**, but doesn't clearly mark the beginning with a mechanism to get attention **Just speaking loudly is not enough, this needs to precede a summary for the team.** It is not using a loud voice to provide a single piece of information or to communicate a single plan or order.	**Explicit** Example terms: "Let's *huddle.*" "So, what I know to this point…." "Let's *summarize..* "…*same page*." "I need *everyone's attention*." "*Listen* up." "Here is the report I was given…." *"OK to brief everyone . . ."*
Pre-Brief Content	Which behaviors were included in the pre-brief? *Watch the entire pre-brief and score the best effort.	TL may answer individual questions but does not summarize information, just gives one-off pieces of information Example: Team: "Is he intubated?" TL "Yes." OR Information, planning, or role assignment is fragmented or is just a string of findings, such as "BP is 70/30, lungs are clear, he's on the vent, he has a carotid pulse, his pupils are reactive . . . " or "now we will roll him, then splint his leg, then do a CT" Information is sort of announced as it comes, Here you **don't see a discreet summary event**	Does **2** of the 4 behaviors below listed below • Information sharing • States a plan • Assigns roles • Seeks input?	Does of **3 or 4** of the behaviors below list below • Information sharing • States a plan • Role assignment • Seeks input?

Behavior	Description	Re Brief Score 1 min after the EMS report ends. This does NOT include a quick report of vital signs, breath sounds, or presence of p (Ok to perform 1-2 quick tasks first, such as given initial orders, or confirming patients breathing status)		
		Scoring		
		Poor	Average	Excellent
Performs a "re-brief"	**Score after the EMS report OR early in the patient's care if no EMS report** Updates the team shortly after the EMS report *about the content of the EMS report.*	Does not comment on whether or not there was a change from prehospital report or how it impacts the plan. Note: Just repeating the EMS report is not an arrival brief, they must state that it has changed or that it is the same	Highlights whether the EMS report is the same/unchanged or summarizes updates/changes/new information based on report Examples: (1) "This patient is *as expected*." (2) "This patient has had a decrease in mental status since our prehospital notification. "	Highlights whether EMS report is the sam summarizes updates AND *communicates* *on the plan/role assignment/priorities.* Examples: (1) "This patient is as expected, *continue* *current plan*." (2) "This patient has had a decrease in m status and *I am concerned about a head* *need you to get the airway cart just in cas* *need to intubate.* "

Behavior	Description	Huddle (A *discreet* communication event to the team) This is a summary. It is not a list of one-off sharing of information, planning, or role assignment. The idea is that this is a discreet **summ** for the **team** that, optimally, includes the 4 components listed below. **This is scored EACH TIME it happens.**		
		Scoring		
		Poor	**Average**	**Excellent**
Huddle Engagement **Code for every huddle**	Clearly engages in a huddle by gathering the attention of the team	TL provides information to a single person (e.g., bedside RN or attending physician) but *does not include* the larger team. This score can also be considered "not done."	**Implicit** Starts speaking in a loud voice to the room to summarize, but doesn't clearly mark the beginning with a mechanism to get attention. THIS MUST PRECEDE A **DISCRETE SUMMARY** OF THE PATIENT TO COUNT. It is not using a loud voice to provide a single piece of information or to communicate a single plan or order. Note: You may end up scoring this AFTER the huddle because you won't realize one is coming until it happened	**Explicit** Example terms: "Let's *huddle.*" "So, to *recap*…." "Let's *summarize..* "…*same page*." "I need *everyone's attention*." "*Listen* up." "Let's *bring it back*…."
Huddle Content **Code for every huddle**	Which behaviors were included in the huddle?	TL may answer individual questions but does not summarize information, just gives one-off pieces of information Example: Team: "Is he intubated?" TL "Yes." OR Information, planning, or role assignment is fragmented or is just a string of findings, such as "BP is 70/30, lungs are clear, he's on the vent, he has a carotid pulse, his pupils are reactive . . . " or "now we will roll him, then splint his leg, then do a CT" Information is sort of announced as it comes, Here you **don't see a discreet summary event**	Does **2** of the 4 behaviors below listed below (irrespective of quality): • Information sharing • States a plan • Assigns roles • Seeks input? *This is NOT the team leader reporting out their exam findings as they do the primary survey	Does of **3 or 4** of the behaviors below list below (irrespective of quality): • Information sharing • States a plan • Role assignment • Seeks input?

Behavior	Description	Huddle (A *discreet* communication event to the team) This is scored once at the end of the video to reflect an average performance huddles across quality		
		Scoring		
		Poor	Average	Excellent
Overall Huddle Quality **This somewhat combines content and engagement** **Code once at the end**	Use the scores from the "huddle engagement" and "huddle content" to determine overall quality of huddles *across the patient care encounter*	Were consistently poor quality in engagement and/or content, or not done.	The TL huddled at least once, however huddles were: Consistently of average quality Example: • Used implicit engagement and 1-2 of the content categories (info sharing, planning, seeking input, delegating) OR Inconsistent in the degree of engagement and the content included	Huddles consistently used: • Explicit engagement • 3 or more of the content categories (i sharing, planning, seeking input, delegating)

Behavior	Description	TL Communication Behaviors (Score these when they occur as part of a "huddle" AND when performed separately)		
		Scoring		
		Poor	Average	Excellent
Information sharing **Code once at the end**	Updates team with new information and pertinent old information. **Can be scored as part of a huddle event, or as a separate behavior.**	Updates team with new findings (e.g., exam findings, vital signs) as the information becomes available (i.e., thinks aloud). Information is fragmented, announced as it comes. Can also score when not done. If TL takes this "thinks aloud" approach, this should be scored only once (not every time the TL shares information). Example: "His pupils are symmetric, no evidence of head trauma." ……. "He has abdominal tenderness on exam." …… "His blood pressure is now 80/50." …… "What liter of fluids is that? Ok. So he has received 3rd liters and we have two points of IV access."	Provides a summary of the situation. This should be a discreet event. Example: (prebrief: see italicized info in "poor") Huddle #1: "45 yo M in a high speed MVC, intubated at the scene, with hypotension and tachycardia prehospital, now with improving BP and HR after 2L NS. In additional to a scalp laceration, he has diminished breath sounds on the right." The difference between average and poor is that the information for average is organized into a discrete paragraph and delivered in a "chunk". If the TL is interrupted, but then keeps going, or regroups, that would be credited as an Average and not punished for the interruption. This is still just a transfer of known information, it does NOT include an interpretation of what the TL thinks it might mean.	Provides a summary of the situation AND includes an ***interpretation*** of the facts for t team. This *interpretation* could include a primary finding (e.g., hypotension), condition (e.g., hemorrhagic shock), or diagnosis (e.g., hemorrhagic shock due to a liver laceration The nature of the interpretation will change more information is gathered. Example: "45 yo M in a high speed MVC, intubated at scene, with hypotension and tachycardia prehospital, now with improving BP and HR after 2L NS. In additional to a scalp laceratio he has diminished breath sounds on the rig *so I am concerned about a pneumothorax.*" Examples of phrases that indicate interpreta -I am worried about... -This makes me think he may have… -I am concerned that… -I am suspicious of… -I suspect... -This may mean... -Because of this we will need to… *The summary can be somewhat separate the interpretation. The goal is to get an ove rating of how the TL shares information ove course of the event

***at any one time, the team leader may perform information sharing that represents less advanced behavior; this is not wrong, sometimes a single one-off announ final score should reflect overall performance and the performance of "higher" level information sharing when appropriate for the case.**

Behavior	Description	TL Communication Behaviors (Score these when they occur as part of a "huddle" AND when performed separately)		
		Scoring		
		Poor	Average	Excellent
States a plan **Code once at the end**	Provides a plan **Can be scored as part of a huddle event, or as a separate behavior**	Provides single one-off orders throughout the entire event; "Let's get a blanket" "Let's role him" but does not provide any clear, concise plan (the plan is limited to orders/requests as they come up). Can also score when not done.	**Provides a clear plan** that is more than just a single, one-off item. Likely to be more detailed than plan provided during the brief. Example: "My plan is to continue with IVFs, get the trauma series, establish a 2nd IV, finish my exam, and then get a CT pan-scan."	Provides a clear plan for what will transpire clearly states the *priorities* (must do both – not count if TL communicates a priority with context of larger plan). Listing a sequence of events is NOT the sa as stating a priority. Examples: (1) "My plan is to continue with IVFs, get th trauma series, and establish a 2nd IV while examine him. The *priority* is getting him to for a pan-scan." (2) "He needs a 2nd IV and UA, but nothing should delay him going to CT."

***at any one time, the team leader may perform planning that represents less advanced behavior ; this is not necessarily wrong, sometimes a single order in react However, the final score should reflect overall performance and the performance of "higher" level planning when appropriate for the case.**

Behavior	Description	TL Communication Behaviors (Score these when they occur as part of a "huddle" AND when performed separately)		
		Scoring		
		Poor	Average	Excellent
Assigns roles for tasks **Code once at the end**	Assigns roles **Can be scored as part of a huddle event, or as a separate behavior**	Identifies a few roles that need to be filled but doesn't identify who will be filling these roles. Can also score when not done. Example: "I need someone working on IV access, someone exposing the patient, and someone placing orders"	Assigns, confirms/restates, or inquires about specific roles AND identifies individuals using names, pointing, or making eye contact. Does not inquire about, or change role assignment, based on team member skill set. Example: TL: "I need *you* to place an IV. Who's getting meds?" RN: "I am"	Assigns, confirms/restates, or inquires abou specific roles AND Identifies individuals using names, pointing, making eye contact. AND At least one of the following "excellent" beha -asking about team member skill set or prio experience -asking about team member workload or availability -redistributing assignments based on team member skillset or workload -requesting a check-back from the team me (e.g., "let me know when that is done") Performing an advanced behavior for a sing assignment is adequate for excellent IF the has also delegating roles at some point duri patient care event. Example: TL: "Chris, are you working on the IV?" Chris: "Yes." TL: "Great. Katie, *have you done an ABG b* Katie: No. TL: "Ok, then Katie you work on undressing patient and Karen, you get the ABG. Karen, *know when you are done*."

***at any one time, the team leader may perform planning that represents less advanced behavior ; this is not necessarily wrong, sometimes a single order in rea However, the final score should reflect overall performance and the performance of "higher" level planning when appropriate for the case.**

Behavior	Description	TL Communication Behaviors (Score these when they occur as part of a "huddle" AND when performed separately)		
		Scoring		
		Poor	Average	Excellent
Seeks input from team **Code once at the end**	Specifically elicits the opinion(s) of the team; this is not about asking one individual their opinion because they are higher in the hierarchy, but rather inviting the team to give their input; should build psychological safety **Can be scored as part of a huddle event, or as a separate behavior**	Asks for input from an individual (e.g., the ED or trauma attending or a senior resident) but not from the team as a whole. Can also score when not done. Examples: "Dr. Smith, is there anything else you want us to do before he goes to the OR?"	General statements of inquiry regarding thoughts or ideas, but does this towards the end of the patient care event Note: Accepting/acknowledging suggestions from team members does not count. Examples: (1) "Any other thoughts?" (2) "Does that sound good, anything else?"	Explicitly encourages team input ***early*** in th patient care event and then follows through (i.e., is consistently open to suggestions fro others). Example: During the pre-brief, or shortly after patient a the TL states: "If anyone has any questions concerns at any time please speak up."

***at any one time, the team leader may perform planning that represents less advanced behavior ; this is not necessarily wrong, sometimes a single order in rea However, the final score should reflect overall performance and the performance of "higher" level planning when appropriate for the case. Ask yourself, at wha consistently.**

APPENDIX 3. Patient care measure

Row No.	Item variable name	Item Label	Type	Values
1	VIDID	Unique video identifier	String	n/a
2	STUDYID	Subject ID	String	n/a
3	DAYSTRAINING	DaysSinceTraining	Numeric	n/a
4	PREPOST	PreOrPost	String	n/a
5	PTPOSTM	Patient position, time noted	Numeric	seconds
6	PTPOSBDTM	Patient position on bed, time noted	Numeric	seconds
7	PTINTARRy	PT intubated at arrival, yes	Numeric	0, 1
8	BPPRARRLS90y	BP prior to arrival less than 90, yes (hypotensive)	Numeric	0, 1
9	LSTLUNGS	Listens to lungs	Numeric	0,1
10	GNAIRASS	General airway assessment	Numeric	0,1
11	AIRASSVER	Airway Assessment verbalized	Numeric	0,1
12	ETTBDPHV	ET tube depth verbalized	Numeric	0,1
13	AIRWAYLOSS	Loss of airway (eg ETT pulled, change in mental status)	Numeric	0,1
14	FASTPOS	Positive FAST (abdominal or PTX)	Numeric	0,1

15	CKPULSNORM	Checks pulse, peripheral or central - standardized	Numeric	0,1
16	CKPULSLA	Checks pulse, Left Arm	Numeric	0,1
17	CKPULSRA	Checks pulse, Right arm	Numeric	0,1
18	CKPULSLL	Checks pulse, Left Leg	Numeric	0,1
19	CKPULSRL	Checks pulse, Right Leg	Numeric	0,1
20	ACCEMSINTIV	Confirms access placed by EMS or orders initial IV	Numeric	0,1
21	ACCEMSINTIV2	Confirms 2nd IV or orders a 2nd IV	Numeric	0,1
22	IVFLUIDSV	Verifies total amount of fluids given	Numeric	0,1
23	ADDFLUID	Orders additional fluid or confirms additional fluid given	Numeric	0,1
24	INTTRANBLDV	Verbalizes intent to transfuse blood product	Numeric	0,1
25	ORDBLDTRAN	Orders blood transfusion, amount or type.	Numeric	0,1
26	BLDTRNS	Blood transfusion started	Numeric	0,1

27	BLOODCOMPOSITE	Any blood related action occurs	numeric	0,1
28	VASOGIVENANY	Vasopressors given, indicated, any reason	Numeric	0,1
29	VASOORD	Orders vasopressors	Numeric	0,1
30	BPNEWVERBTM	Verbalizes or interprets new BP, time noted	Numeric	seconds
31	BPNEWVERBNORM	Verbalizes or interprets BP - Standardized	Numeric	0,1
32	BPNEWLOWNORM	New low BP, standardized.	Numeric	0,1
33	BPLOWEXISTNORM	Existing or recurrent low BP standardized.	Numeric	0,1
34	HRVVERBALTM	New HR identified, time noted	Numeric	seconds
35	HRVERBALNORM	NEW HR IDENTIFIED Standardized		
36	OXVERBALTM	New oxygen level identified, time noted	Numeric	seconds
37	OXVERBALNORM	New oxygen level identified - Standardized		
38	MNTLSTATUSIND	Mental status assessment indicated	Numeric	0,1

39	MENTALASSM	Mental Status Assessed	Numeric	0,1
40	GCSVERBAL	GCS score identified	Numeric	0,1
41	PUPILASSM	Pupil size assesses	Numeric	0,1
42	EXTFUNCLA	Extremity function, left arm	Numeric	0,1
43	EXTFUNCRA	Extremity function, right arm	Numeric	0,1
44	EXTFUNCLL	Extremity function, left leg	Numeric	0,1
45	EXTFUNCRL	Extremity function, right leg	Numeric	0,1
46	CLOTHREMOVED	Clothing removed from patient	Numeric	0,1
47	ROLLVERBAL	Roll patient as next step, verbalized	Numeric	0,1
48	ROLLVERBALTM	Roll patient as next step, verbalized, time noted	Numeric	seconds
49	ROLLED	PT rolled	Numeric	0,1
50	ROLLEDTM	PT rolled, time noted	Numeric	seconds
51	ROLLEDVERBALTM	Time patient rolled from when verbalized as next step	Numeric	seconds
52	SPINEPALP	C-spine or T & L palpated	Numeric	0,1
53	CSPINEIND	C-spine immobilization indicated	Numeric	0,1
54	CSPINEIMM	Does NOT maintain C-spine immobilization	Numeric	0,1
55	CXRIND1	CXR #1 indicated	Numeric	0,1

56	CXRIND2	CXR #2 indicated	Numeric	0,1
57	CXRORD	CXR ordered	Numeric	0,1,2
58	CXRORDTM	CXR ordered, time noted	Numeric	seconds
59	CXRCOMM	CXR results communicated	Numeric	0,1
60	CXRCOMMTM	CXR results communicated, time noted	Numeric	seconds
61	CXRCOMMORDTM	Time CXR results communicated from time CXR ordered	Numeric	seconds
62	PXRIND	Pelvis XR indicated	Numeric	0,1
63	PXRORD	PXR ordered	Numeric	0,1
64	PXRORDTM	PXR ordered, time noted	Numeric	seconds
65	PXRCOMM	PXR results verbalized	Numeric	0,1
66	PXRCOMMTM	PXR results verbalized, time noted	Numeric	seconds
67	PXRCOMMORDTM	Time PXR results communicated from time PXR ordered	Numeric	seconds
68	POCUSDPLIND	POCUS or DPL indicated	Numeric	0,1
69	POCUSDPLPERF	POCUS/DPL performed	Numeric	0,1
70	STARTSECVIEW	Start of 2nd viewpoint	Numeric	0,1
71	STARTSECVIEWTM	Start of 2nd viewpoint, time noted	Numeric	seconds

72	OBSERDATEPSOT	this is the date that the intervention occurred for that month -		
73	STUDYARM	Study Arm	String	n/a
74	TRAINLEVEL	Training Level	String	Second year Third Year
75	TLPROCINVL2MIN	TL involved procedure for > 2 minutes	Numeric	0,1
76	TLLVS2MIN	TL leaves prior to team disbanding for > 2 minutes	Numeric	0,1
77	HANDOFFIND	TL leaves prior to team disbanding for > 2 minutes	Numeric	0,1
78	2NDVIEWSTART	Start of 2nd view	Numeric	seconds
79	VIDEODUR	Video Duration (end of video)	Numeric	seconds
80	BPADJTIME	Initial BP ED. Time to BP verbalized and interpreted, adjusted for start time.	Numeric	0,1
81	HRADJTIME	Initial HR ED. Time to HR verbalized and interpreted, adjusted for start time.	Numeric	seconds

82	OXADJTIME	Initial pulse ox ED. Time to oxygen level identified, adjusted for start time.	Numeric	seconds
83	ROLLINTADJTIME	Adjusted intent to roll Time from arrival	Numeric	seconds
84	ROLLPTADJTIME	Adjusted PT rolled Time from Arrival	Numeric	seconds
85	ROLLACTADJ	Adjusted time from intent to roll to actual roll	Numeric	seconds
86	CXRADJTIME	Adjusted CXR ordered Time from Arrival	Numeric	seconds
87	CXRCOMMADJTIME	Adjusted CXR results comm Time from Arrival	Numeric	seconds
88	CXRACTADJ	Adjusted time from ordered CXR to comm CXR results	Numeric	seconds
89	PXRORDTIME	Adjusted PXR ordered Time from Arrival	Numeric	seconds
90	PXRCOMMTIME	Adjusted PXR result comm Time from Arrival	Numeric	seconds
91	PXRADJTIME	Adjusted time from ordered PXR to comm PXR results	Numeric	seconds

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

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

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

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

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

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

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

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

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

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

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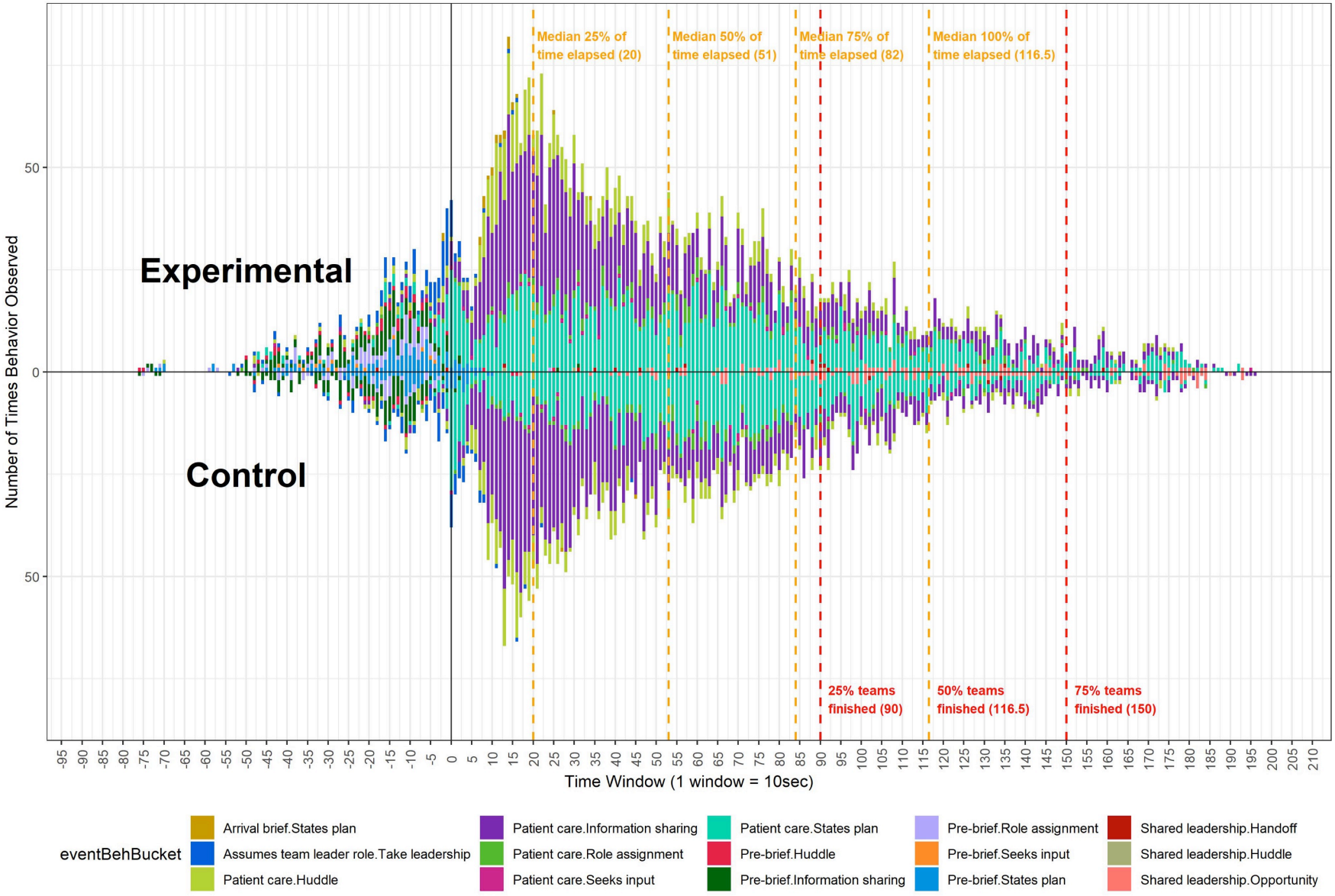
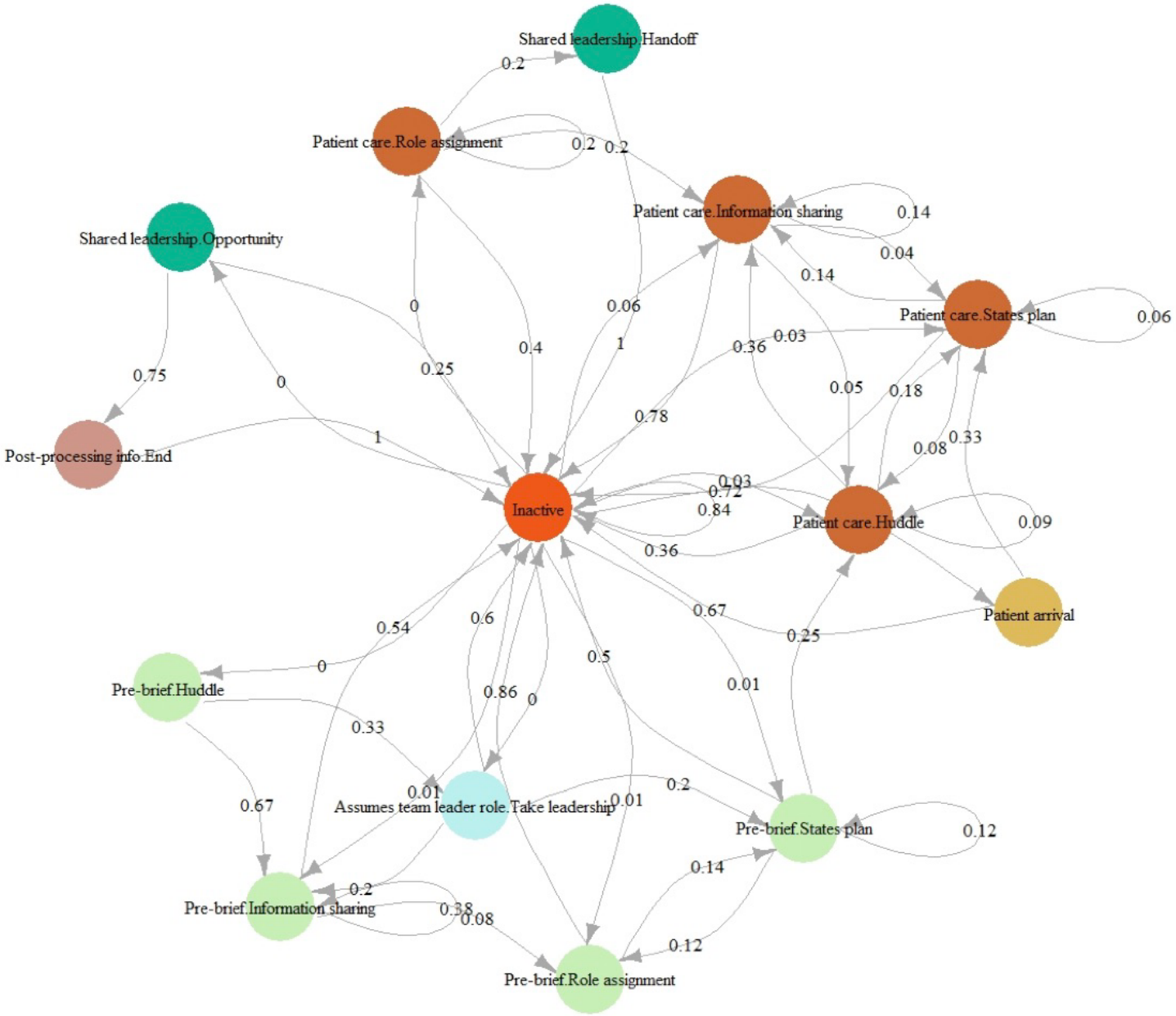
Communication breakdown and teamwork failures have been directly linked with medical error and adverse patient events (1–3). As a result, multiple efforts have been made to improve the performance of interdisciplinary healthcare teams (4). Code teams function in complex, dynamic, and time-pressured working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

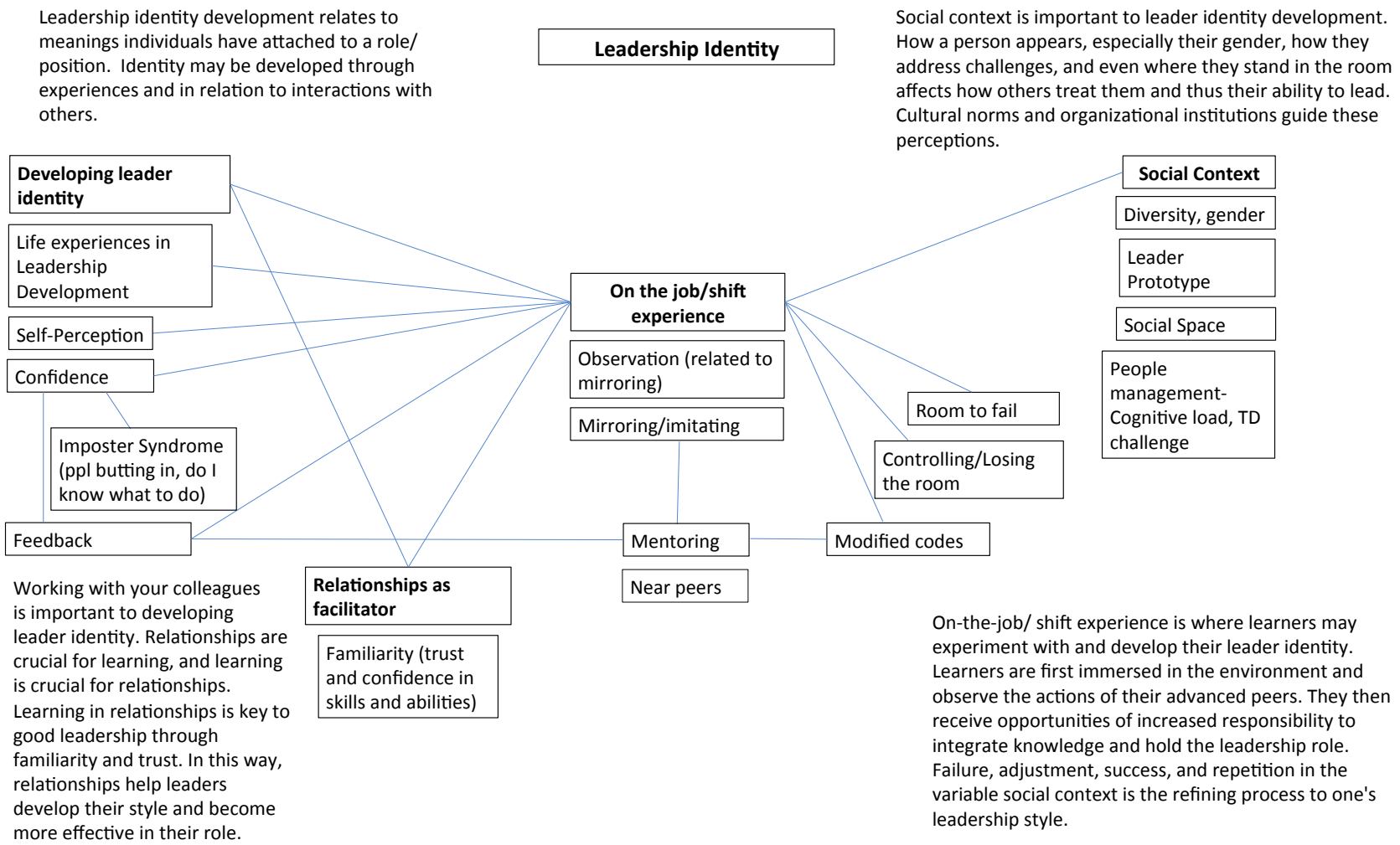
APPENDIX 5. Descriptive summary of timing data



APPENDIX 6. Multi-state Markov modeling



APPENDIX 7. Qualitative analysis framework



ORIGINAL CONTRIBUTION

An Event-based Approach to Measurement: Facilitating Observational Measurement in Highly Variable Clinical Settings

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ABSTRACT

Background: Translational research in medical education requires the ability to rigorously measure learner performance in actual clinical settings; however, current measurement systems cannot accommodate the variability inherent in many patient care environments. This is especially problematic in emergency medicine, where patients represent a wide spectrum of severity for a single clinical presentation. Our objective is to describe and implement EBAM, an event-based approach to measurement that can be applied to actual emergency medicine clinical events.

Methods: We used a four-step event-based approach to create an emergency department trauma resuscitation patient care measure. We applied the measure to a database of 360 actual trauma resuscitations recorded in a Level I trauma center using trained raters. A subset (n = 50) of videos was independently rated in duplicate to determine inter-rater reliability. Descriptive analyses were performed to describe characteristics of resuscitation events and Cohen's kappa was used to calculate reliability.

Results: The methodology created a metric containing both universal items that are applied to all trauma resuscitation events and conditional items that only apply in certain situations. For clinical trauma events, injury severity scores ranged from 1 to 75 with a mean (±SD) of 21 (±15) and included both blunt (254/360; 74%) and penetrating (86/360; 25%) traumatic injuries, demonstrating the diverse nature of the clinical encounters. The mean (±SD) Cohen's kappa for patient care items was 0.7 (±0.3).

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Conflict of interest: RF's institution has received grant money from the Agency for Healthcare Research and Quality, the Department of Defense, and the Washington State Department of Labor and Industries to conduct research conceived and written by RF. RF reports personal payment from Physio-Control, Inc. for speaker fees. EDR's institution has received grant money from the Agency for Healthcare Research and Quality and the Department of Defense to conduct research conceived and written by RF. EDR reports personal payment from Physio-Control, Inc. for speaker fees. SB's institution has received grant money from the Agency for Healthcare Research and Quality and the Department of Defense to conduct research conceived and written by RF. AKC reports no conflict of interest. CK's institution has received grant money from the Agency for Healthcare Research and Quality and the Department of Defense to conduct research conceived and written by RF. JRK reports no conflict of interest. EHL reports no conflict of interest. MCV reports no conflict of interest.
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