1-1-2017

The Impact Of Telemedicine On Teamwork And Communication, Workload, And Clinical Performance: A Randomized Controlled Trial

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The Impact of Telemedicine on Teamwork and Communication, Workload, and Clinical Performance: a Randomized Controlled Trial

A Thesis Submitted to the

Yale University School of Medicine

in Partial Fulfillment of the Requirements for the

Degree of Doctor of Medicine

by

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2017

Abstract:

Telemedicine can be used to provide specialty care to critically ill patients in rural and community hospital settings. However, the effects of this technology on quality of care are unclear. The objectives of this study were to evaluate the impact of a telepresent team leader on teamwork and communication, workload, and quality of care during a simulated pediatric resuscitation, and to explore provider perspectives on the use of telemedicine during resuscitations.

Twenty standardized teams (lead MD + bedside MD + two confederate clinical team members) were randomized to have a telepresent or an in-person leader. Telepresent leaders were connected via videoconference from a remote location and displayed on a screen at the bedside. All teams participated in a standardized, pre-programmed 20-minute simulated resuscitation with a scripted parent actor present. Simulations were video recorded and scored on teamwork and communication as well as clinical performance metrics using the validated STAT instrument. After each case, team members completed demographic, workload (NASA rTLX), and teamwork and communication (TeamMonitor) surveys. Post-simulation debriefings were scripted to collect qualitative data from participants regarding utility, effectiveness, and acceptability of telepresence.

There was no difference in STAT teamwork and communication scores (73 v 66; *p*=0.118), TeamMonitor scores (91 v 94; *p*=0.251), or teamwork and communication

global rating scores (91 v 77; p=0.143). There was no difference in rTLX workload scores compared between team leaders (51 v 55; p=0.983) or between junior team members (44 v 59; p=0.123). Similarly, no difference was found in STAT clinical performance scores (72 v 64; p=0.168) or in time-to-defibrillation (238 sec v 253 sec; p=0.762).

Participating providers shared perspectives on the use of telepresence during resuscitation and expressed varying levels of comfort using the modality. Providers also highlighted strategies for the effective use of telepresence in the acute care setting, including enhanced verbal communication, role delineation, and mutual trust in clinical acumen of each provider involved.

Telepresence did not significantly impact teamwork and communication, workload, or clinical performance. Participating providers shared perspectives on the impacts of telepresence as well as strategies for effective use of telepresence in the acute care setting. Together, these data may inform future implementation of telepresence technology in emergency settings.

Acknowledgements: The author would like to thank project supervisor and mentor Marc Auerbach, MD, project mentor Ambrose Wong, MD, biostatistician Travis Whitfill, project contributors Lauren Crispino, Marcie Gawel, APRN, and Charmin Gohel, MD, simulation technicians Luis Cruz and Jeffrey Hoffman, as well as Leigh Evans, MD, and Jaydale Poyotte of the Yale Center for Medical Simulation. The author would also like to thank Dr. John Forrest, Mae Geter, Donna Carranzo, and Kelly Jo Carlson at the Yale School of Medicine Office of Student Research, and finally, the members of the Yale Emergency Medicine Residency who served as study participants.

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Introduction:

Effective teamwork and communication (TC) is fundamental to healthcare team performance (1-3). Breakdowns in TC are a major source of medical errors (4-6), and high quality TC has been associated with better care in several settings (7-9). In acute care medicine, high quality TC has been associated with reduced clinical errors, improved resuscitation performance, and improved overall patient safety (10-12).

Telemedicine, "the use of telecommunications and information technology to support the delivery of healthcare at a distance" (13), is a term encompassing a diverse array of applications that have been applied across many healthcare fields (14). Telemedicine has been proposed as a means to reduce disparities in access to and quality of care (13, 15-17).

During acute care telemedicine encounters, healthcare provider teams at the patient's bedside communicate via real-time audiovisual videoconferencing with remote specialists (14). This form of telemedicine is known as telepresence, a subset of telemedicine allowing remote healthcare providers to directly interact with the patient and to be directly involved in care as a member of the team (14, 18). During these interactions, the physical absence of the telepresent provider alters the teamwork dynamics of the traditional healthcare team (in which all providers are physically present at the bedside). Thus, the use of this technology likely has an impact on the quality and processes of TC (19, 20). However, despite the importance of TC to team performance, there is a paucity of literature examining the interaction between telemedicine and TC. As telemedicine systems are increasingly established (21, 22), it is important to understand the effects of this modality on TC as well as the broader implications this has on overall quality of care and patient outcomes.

The effect of videoconferencing on communication quality has been explored in several non-medical disciplines. According to media richness theory—a communication science theory which categorizes communication technologies by their ability to convey immediate feedback, language variety, verbal and nonverbal cues, and emotion—a “richer” medium such as face-to-face communication should be used when communicating complex messages requiring reciprocal feedback and discussion among team members (23, 24). In the business literature, research corroborating the media richness theory has demonstrated that face-to-face communication is preferred over videoconferencing when addressing more complex and more ambiguous tasks (25).

However, it is unclear whether the themes illustrated by research in these fields translate to TC in acute medical care. Furthermore, there is a lack of healthcare research exploring the impact telemedicine may have on TC in the resuscitative care environment, as most of the studies addressing the effects of telemedicine on TC have been conducted outside the field of acute care (19, 26-29). In addition, many of the studies on telemedicine and TC relied on post-event provider self-report surveys and interviews rather than more objective quantitative analyses (19, 27, 29-31). This is problematic because failing to analyze the processes of TC performance—i.e. *how* teams behave and interact while participating in care, rather than simply the outcomes they achieve—omits important indicators of true TC (32). To our knowledge, there have been no studies quantitatively investigating TC performance during the actual delivery of telemedicine-facilitated acute care. Understanding the impact of telemedicine on TC could lead to more effective use of the technology, which could subsequently improve care and patient outcomes. As hospitals continue to expand the use of telemedicine, it will be important to train participants on effective TC behaviors to employ when engaging in telemedical care, much in the way that medical trainees and hospital employees are now taught effective face-to-face communication behaviors to apply in the acute care setting (33, 34). However, this will not be possible until the interaction between telemedicine and TC is more thoroughly understood.

Therefore, the primary aim of this study was to evaluate the impact of telemedicine on TC during acute care. To do so, we compared the TC of resuscitative care teams with telepresent team leaders to teams whose team leaders were physically present at the bedside in a controlled, simulated environment. We hypothesized that emergency care teams with telepresent team leaders would exhibit improved TC behaviors. In addition, we aimed to explore how telemedicine impacted specific aspects of TC to drive future applications, research, and training.

To investigate the broader implications of telemedicine's effects on TC during resuscitative care, **our secondary aim was to analyze the workload of participating team members**. Workload, like TC, is a component of human factors. Studies have demonstrated that when excessive, workload is associated with poor TC performance as well as greater frequency of adverse events (35). We hypothesized that telepresent team leaders would experience lesser workload than in-room team leaders, and that bedside providers whose team leaders were participating via telemedicine would experience greater workload than bedside providers with in-room team leaders.

An additional **exploratory aim was to evaluate the relationships between differences in TC associated with the use of telepresence on overall quality of care**. We hypothesized that improved TC associated with the use of telemedicine (explained above) as well as a reduced propensity for the remote team leader to become distracted or overly focused on one task (36) would result in higher quality of care. Finally, providers' perceptions on comfort, teamwork, and quality of care related to the use of telemedicine in resuscitation were gathered.

Statement of Purpose:

The purpose of this study was to evaluate the impact of a telepresent team leader—as opposed to a standard in-room team leader—on the TC, workload, and quality of care provided during simulated resuscitations, as well as to assess provider perceptions on comfort, teamwork, and quality of care related to the use of telemedicine in resuscitation. We hypothesized that telemedicine would improve TC, improve quality of care, reduce team leader workload, and increase the workload of the bedside providers.

Methods:

Summary: This was a prospective interventional randomized controlled simulation trial. Twenty teams of emergency medicine residents were standardized to include a team leader (PGY-3/4), a bedside physician (PGY-1/2), and two confederate clinical team members; a scripted parent actor was also present. Teams were randomized to have a telepresent or an in-person team leader. Telepresent leaders were connected via videoconference from a remote location and displayed on a screen at the bedside; in-person leaders were present at the bedside. All teams participated in the same standardized, pre-programmed 20 minute simulated resuscitation of a critically ill infant. Simulations were video recorded and scored on TC as well as quality of care using a validated scoring instrument and time to critical interventions. After each case, subject team members completed demographic, workload, and TC surveys. Confederate clinical team members also completed a TC survey and assigned a global rating score. Semi-scripted post-simulation debriefings collected feedback from participants regarding perceptions of the impacts of utilizing telepresence during resuscitation. All simulations and debriefings took place at the Yale Center for Medical Simulation (simulation center) located in New Haven, CT.

Subjects: Study subjects were drawn from a convenience sample of Yale Emergency Medicine residents previously scheduled for a simulation elective at the simulation center. Forty individuals were recruited between December 2015 and June 2016. Study participation was voluntary and informed consent was obtained from all 40 recruited individuals. Each study team consisted of one PGY-3 or PGY-4 resident—the “senior” resident—and one PGY-1 or PGY-2 resident—the “junior” resident. Each subject team was randomized using an online random number generator (www.random.org) into the intervention arm—i.e. the “telepresent team leader group”—or the comparison arm—i.e. the “in-person team leader group”—such that 10 teams were assigned to each study arm. Each resident only participated in one simulation session.

Subject Role Delineation: Prior to each simulation event, the study investigators designated the senior resident as the team leader and the junior resident as the “team member” or “bedside physician.” Roles were designated as such to ensure that the most senior provider, who was assumed by the investigators to possess a greater degree of knowledge related to pediatric resuscitation, would lead the resuscitation. This was to ensure uniformity of provider roles between subject teams as well as to emulate the knowledge gradient present when specialists are consulted by community ED providers during actual acute care telemedicine consultations.

Confederate Clinical Team Members: Each team of subjects was provided with two standardized, scripted “confederate clinical team members” to help in the treatment of the simulated patient. In simulation, a confederate is "an individual other than the patient who is scripted…to provide realism, additional challenges or additional information for the learner" (37). Confederate clinical team members were selected from a pool of pediatric emergency nurses, a pediatric emergency technician, PGY-4 emergency medicine residents who had already participated in the study, a physician study investigator, and the primary study investigator—a fourth year medical student. The individual confederate clinical team members assigned to each study team were determined by availability of individuals during study collection events. All confederate clinical team members were standardized, participating in defined roles with scripted actions and responses. Confederate clinical team members were instructed to provide care solely in response to orders from the study subjects in order to control for any influence on teamwork, communication, or clinical management (see Appendix for the script provided to confederate clinical team members).

Parent Actors: Prior to the start of each scenario, the subject team was also introduced to a standardized, scripted, confederate parent actor. Parent actors were instructed to provide the subject team with information related to the patient's medical history only if and when prompted by the team. Parent actors were also instructed to request two updates on the child's status and the treatment plan at designated points in the case, and were instructed not to provide any additional information so as not to influence the teams' clinical performance (see Appendix for the script provided to parent actors).

Telemedicine Control Room: Telemedicine team leaders were placed in the telemedicine control room shortly before the start of each case. The telemedicine control room was equipped with a computer featuring two monitors (24" and 21" monitors), a webcam (LiveCapture®, B-Line Medical®, Washington, D.C.), a microphone, and headphones. The telemedicine control room also contained a Pediatric Advanced Life Support Card and a Broselow® Pediatric Emergency Tape, as these cognitive aids were also present in the treatment room and thus available to comparison arm team leaders. Intervention arm team leaders' computer screens featured a real-time display of the patient's bedside monitors, requested laboratory, ECG, and radiological results, as well as two live feeds of the resuscitation room: one showing a bird's eye view of the patient on the bed, and one showing a tilt-angle view from the corner of the room such that the patient, the parent, and all in-room providers were visible to the team leader (see Figure 1). The cameras in the treatment room (Simcapture®, B-Line Medical®, Washington, D.C.) featured zoom and pan-tilt technology which were controlled by the team leader. The footage recorded for later video review was the same that was seen in real-time by intervention arm team leaders during simulation events.

Figure 1. Two-camera view of treatment room seen by telepresent team leaders

Treatment Room: The treatment room was designed to resemble an actual pediatric resuscitation room and was stocked to provide all the equipment a pediatric resuscitation team would need to adequately manage the patient. A code cart available to the team included a tray of simulated medication vials and bags of intravenous fluids. In addition to medications, the code cart featured several sizes of laryngoscope handles, blades, and endotracheal tubes. A video laryngoscope was also available upon the subject team's request (Glidescope®, Verathon®, Seattle, WA). A cardiac defibrillator (Zoll® M Series, Chelmsford, MA), an intraosseus access kit (Arrow® EZ-IO® Intraosseus Vascular Access System, Morrisville, NC), a blood pressure cuff, oxygen saturation monitor, nasal cannula, nonrebreather mask, and a bag-valve-mask were also available to the team. Three 20" monitors were positioned on the wall behind the patient's bed. One monitor was used to display a video stream of the telepresent provider during intervention cases, while the other two displayed laboratory results, an ECG tracing, or a roentgenogram as ordered by the subject team.

Mannequin: A high-fidelity computerized infant patient mannequin (Laerdal® Simbaby™, Stavanger, Norway) was used for all simulations. This mannequin features mechanized, programmable heart and lung sounds, chest expansion, palpable pulses, a cyanotic oropharynx feature, an adjustable fontanelle, and audible crying sounds to increase realism. The mannequin is also compatible with a proprietary patient monitor which was used to display the patient's vital signs throughout the case. Vital signs were standardized and preprogrammed with an adjustable override feature controlled by the physician study investigators, allowing for adjustments in vital signs congruent with actions performed by the subject team.

Simulation Case Scenario: We chose to use a simulation research environment for this study as simulation provides a feasible means to ask diverse research questions, especially regarding infrequent, critical scenarios such as acute resuscitation (38). Furthermore, simulation-based research methods have been used to investigate the effects of telemedicine on quality of acute care in numerous previous studies (30, 36, 39-41).

Each team of subjects participated in the same pre-programmed simulated resuscitation scenario with standardized vital signs, laboratory studies, transition points at which critical events would occur, and handlers—i.e. pre-programmed sets of changes within the simulation that occurred in response to actions taken by the participants in a pre-packaged scenario. The case scenario featured a critically ill infant presenting to the emergency department with her mother. The patient was a six month old female presenting with three days of progressively worsening symptoms of rhinorrhea, fever, cough, and lethargy. This information was conveyed to the team at the start of the case during a scripted vignette which was read aloud to each subject team by the physician study investigator. Upon clinical evaluation by the team, the patient was found to be in septic shock secondary to pneumonia. After eight minutes of resuscitation efforts, regardless of clinical interventions performed prior to that point, the patient decompensated into ventricular fibrillation and became apneic. In order to regain organized cardiac activity, the patient then needed to be defibrillated by the team. After the patient achieved return of spontaneous circulation, the team was expected to provide post-resuscitative care until approximately twenty minutes had elapsed. At this point, a study investigator acting as a pediatric transport specialist or pediatric intensive care physician would request sign-out from the team, after which the case ended.

Case Selection: This case was chosen for several reasons. First, the study investigators sought a scenario with sufficient cognitive and physical tasks to elucidate the teams' TC skills. The level of difficulty of the case was expected to foster observable communication between subjects related to clinical management decisions, and the necessity for several procedural actions to be performed simultaneously was intended to create a significant amount of workload to strain the team leader's ability to delegate tasks (32). Second, the case allowed investigators to compare clinical performance in management of both pediatric sepsis and pediatric cardiac arrest—two domains with evidence based guidelines and time-dependent performance expectations. Finally, this case was chosen as it is the same case that was used in the development and validation of the instrument chosen to evaluate subject teams' performance: the Simulated Team Assessment Tool (42) (see description below).

Instructions for Subjects: Before the start of each scenario, study investigators recited a standardized case introduction to subjects regarding the nature of the study, instructions to following during the case, and role delineation for the study subjects. Subjects were given a tour of the treatment room, were demonstrated the available supplies, were oriented to the mannequin, and were encouraged to ask clarifying questions prior to the start of the simulation. Verbal consent to participate in the study was attained for all study subjects pursuant to the Yale University Institutional Review

Board Protocol #: 1511016757. After the orientation, designated team leaders in the intervention arm were led by a study investigator to the isolated telemedicine control room. Comparison arm team leaders were left in the treatment room to participate in the case as in-person team leaders. During the case, subjects were permitted to ask for clarification of physical exam findings while evaluating the simulated patient mannequin. Subjects were instructed to call consults as they would in a real resuscitation scenario. The physician study investigators provided clarifying details and acted as consultants during these interactions, speaking to subjects using an intercom system within the simulation center.

Debriefing: Immediately after completing the case, subjects participated in a standardized, semi-scripted debriefing process administered by physician study investigators. The first portion of the debriefing process inquired about general perceptions of the simulation, TC performance, and clinical management, then concentrated on teaching related to the management of pediatric sepsis, pediatric cardiac arrest, and pediatric airway management.

Although not a formal mixed methods study, the second portion of the debriefing process was scripted by study investigators to elucidate subjects' perceptions of using telemedicine in the resuscitation setting. Prompts for discussion explored participants' general perceptions of having a team leader physically absent from the treatment room, asked participants to compare whether teamwork, communication, and quality of care would differ based on the absence or presence of the team leader, and asked participants if they would feel comfortable participating in a resuscitation as a telemedicine provider in the future (see Appendix for the Debriefing script). Debriefing sessions were recorded using video cameras (SimCapture®, B-line Medical®, Washington, D.C.) in the simulation center. A study investigator made field notes in real-time during the debriefing. Video recordings were later reviewed to clarify and fill in details missed by the study investigator during debriefings. Participant feedback was reviewed to derive broad themes related to participants' experience of telemedicine during the scenario and its impact on TC and quality of care.

Summary of Outcome Measures: Multiple sources of data were collected (see Table 1). Subjects were scored during video review using a validated assessment instrument measuring TC as well as clinical management. Time to critical action was also collected. Subjects completed validated self-assessment surveys related to workload as well as TC. Confederate clinical team members completed a validated survey regarding subjects' TC performance. Finally, qualitative data regarding the use of telemedicine during acute care was gathered during semi-scripted debriefings.

Table 1. Outcome Measures

Measure	Data Type (persons completing)	Time Completed	Designed to Measure	Existing Validity Evidence
Simulated Team Assessment Tool (STAT)-Clinical Performance Section	Observational (Investigator-Video Reviewers)	During video review	Clinical Performance (Basics, Airway/Breathing, Circulation)	Reid *et al.* 2012 (42) Stone *et al.* 2014 (43) Auerbach *et al.* 2016 (44) Kessler *et al.* 2016 (45)
Simulated Team Assessment Tool (STAT)-Human Factors Section	Observational (Investigator-Video Reviewers)	During video review	Human Factors	Reid *et al.* 2012 (42) Stone *et al.* 2014 (43) Auerbach *et al.* 2016 (44) Kessler *et al.* 2016 (45)
NASA Task-Load Index (TLX)	Self-Report (subject providers)	Immediately after simulation	Workload during task	Byers *et al.* (46) See Review Article: Hart 2006 (47)
TeamMonitor Tool	Self-Report (subject providers)	Immediately after simulation	Teamwork	Stocker *et al.* 2013 (3) Zimmerman *et al.* 2015 (48)
TeamMonitor Tool	Observational (Confederate Clinical Team Members)	Immediately after simulation	Teamwork	Stocker *et al.* 2013 (3) Zimmerman *et al.* 2015 (48)
Global Rating Scale	Observational (Confederate Clinical Team Members)	Immediately after simulation	Teamwork	Rosen *et al.* 2010 (32)
Time-to-Defibrillation (TTD)	Observational (Investigator Video Reviewers)	During video review	Time-to-defibrillation after onset of	Chan *et al.* 2008 (49)

			Ventricular Fibrillation	Yang *et al.* 2016 (39)
Semi-scripted post-simulation debriefing	Qualitative Observational (Investigator notation)	Notes taken during debriefings & during video review	Perceived comfort, teamwork, & quality of care related to acute care telemedicine	Sullivan & Sargeant 2009 (50)

STAT Instrument and Video Review: To assess TC as well as clinical performance, investigators reviewed video footage of each team and scored their performance using the Simulated Team Assessment Tool (STAT) (42). The STAT instrument was created to assess the overall clinical performance of healthcare teams during simulated resuscitations. It was developed from guidelines put forth by the American Heart Association's Pediatric Advanced Life Support (PALS) course, the Tool for Resuscitation Assessment using Computerized Simulation, and several other checklists (42). The STAT instrument is a trichotomous scoring checklist, awarding two points for items performed "Complete and Timely," one point for items performed "Incomplete or Untimely," and zero points for items deemed "Needed and Not Done." There is also an option to select "Not Applicable." The STAT instrument was originally validated as an assessment instrument using the same clinical case used in this study, which may enhance the validity of our results. The study investigators have prior experience using the STAT instrument (44, 45), and both video reviewers who participated in scoring met with the developers of the STAT instrument for training on its use.

The STAT instrument is comprised of 94 items spanning four domains separated into sections: Basics, Airway/Breathing, Circulation, and Human Factors (see Appendix for STAT instrument). To calculate scores, investigators summed the total points awarded for each section and divided this number by the maximum possible score for that section. This percentage of maximum possible score is reported in the Results section.

To evaluate each team's clinical performance, aggregate clinical performance scores combining the Basics, Airway/Breathing, and Circulation section scores were calculated (henceforth referred to as the "Comprehensive Clinical Performance" score), as were separate scores for each of those three sections of the instrument. To evaluate each team's TC performance, scores from the 26-item Human Factors section of the STAT instrument were compared between study arms. To specifically delineate leadership performance vs. performance of the team as a whole, scores from the "Leadership (Team Leader)" and "Management (Team Members)" subsections of the Human Factors section of the STAT instrument were also calculated. Finally, to assess for any possible correlations between TC and clinical performance, Pearson's correlation coefficients were calculated between each team's STAT instrument Human Factors scores and their individual STAT instrument Basics, Airway/Breathing, Circulation, and Comprehensive Clinical Performance scores.

Video Reviewing Protocol: Scoring with the STAT instrument was performed during video review using the B-Line Medical® SimCapture® website. Reviewers were permitted to watch each recording as many times as they deemed necessary in order to score each team as accurately as possible. A document containing behavioral anchors for each item on the STAT instrument was reviewed prior to beginning the study and was referenced for clarification throughout the reviewing process as needed. Several alterations were made to the original behavioral anchor document in accordance with updated PALS and other practice guidelines, though every effort was made to retain the content and construct validity of the original document. During video review, investigators used a stopwatch to evaluate certain time-sensitive STAT instrument items, e.g. the time needed for a team to establish intravenous access or to administer oxygen to the patient. All 20 videos were reviewed by the primary investigator. To explore inter-rater reliability, five of the 20 videos (25%) were also reviewed by a second study investigator—see additional description below.

Time-to-Defibrillation: In order to more objectively assess clinical performance, reviewers also compared the time required for each team to defibrillate the patient after the development of ventricular fibrillation (time-to-defibrillation). Time-to-defibrillation is a critical action in applicable cardiac arrest resuscitation protocols. It has been correlated with patient outcomes and has been used a proxy for overall quality of clinical performance in the simulation-based medical training literature (39, 49).

Post-Simulation Surveys Completed by Subjects: As explained by Rosen *et al.*, "implicit components of teamwork, including team cognition and implicit communication" are not easily captured by the aforementioned observation-based rating measures (32). Thus, to enrich our understanding of provider perceptions related to the use of telemedicine in the acute resuscitation setting, we administered several self-assessment surveys to subjects immediately after the simulation.

TeamMonitor Tool: The TeamMonitor tool (3) was completed by all subjects immediately following the simulation to evaluate subjects' perceptions of their team's TC performance. This instrument was chosen to capture provider perspectives of similar data as was collected in the Human Factors section of the STAT instrument. The TeamMonitor tool is a modified version of the Mayo High-Performance Teamwork Scale (51) designed and validated specifically for team-based self-monitoring after simulated resuscitation events (3). It is a nine-item survey with questions related to four key domains contributing to teamwork: Role Clarity, Communication, Resource Awareness and Utilization, and Situational Awareness. The TeamMonitor is trichotomously scored, with two points corresponding to "Consistently," one point corresponding to

“Inconsistently,” and 0 points corresponding to “Never/Rarely.” There is also an option to select “Not Applicable.” (See Appendix for TeamMonitor tool).

NASA rTLX: We analyzed the workload experienced by study subjects in order to more fully evaluate the effects of telemedicine in the acute resuscitation setting. To assess workload, each subject team member completed the NASA-developed Raw Task Load Index (rTLX) immediately following the case (46). The rTLX is a multi-dimensional scale developed to estimate the workload of individuals while, or immediately after, completing a task (47). The rTLX, its predecessor—the Task Load Index (52), and numerous other modified versions of the original instrument have been used to evaluate workload in over 550 studies spanning numerous fields, most notably aviation and healthcare (47). The rTLX features six domains evaluated on a 20-point visual analog scale. The domains represented in the rTLX are Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration. In order to evaluate the anxiety experienced by each subject during the simulation—which we hypothesized could be affected by the use of telemedicine—we added the following item and prompt to the rTLX survey provided to subjects: *“Anxiety—how nervous, uneasy, or apprehensive did you feel?”* This item was also scored on a 20-point visual analog scale (see Appendix for the modified rTLX survey provided to study subjects).

Post-Simulation Surveys Completed by Confederate Clinical Team Members: Immediately after each simulation, both confederate clinical team members who had participated in the case at the bedside rated the subject team's TC performance using the TeamMonitor survey. Confederate clinical team members then also assigned the subject team a Global Rating Score (0-10) related to the subject team's TC performance. The use of a global rating score was done to add additional validity to each team's TC performance assessment, congruent with literature describing the greater reliability of rating scales than checklists when evaluating interpersonal and communication skills (53).

Scoring by confederate clinical team members was intended to diversify the analysis of each subject team's TC performance. By allowing for study confederates who were present at the bedside and who had participated in the simulation to rate each subject team's TC, we intended for intangible elements of TC, e.g. the ambience and atmosphere created by the team, to be quantified.

Demographic Survey: In order to evaluate for potential confounding variables, a demographic survey of baseline subject characteristics was completed by each study subject immediately following the simulation. Items for the demographic questionnaire were adapted and modified from the *Resident Team Member Background Information* survey developed by Reid *et al.* (2012) when originally validating the STAT instrument

(42). Items selected by study investigators were those considered most relevant to performance in the resuscitation and most likely to confound any results. Themes selected include experience and comfort with simulation and pediatric resuscitation, level of training, experience working with one's fellow subject team member, and experience with TC principles (see Appendix for full Demographic Information survey).

Sample Size Calculation: Based on previous simulation studies conducted by the study investigators using a similar case and scored with the STAT instrument (44, 45), using a standard deviation of 6.5 we calculated a sample size of 18 teams necessary for an 80% power and Type I error = 0.05 to detect a 10-point difference in mean STAT instrument scores (our primary outcome measure).

Statistical Analyses: All data were manually entered into Microsoft Excel 2013 (Microsoft®, Redmond, WA), then transferred to SPSS version 22.0 (IBM® Corp., Armonk, NY) for all statistical analyses.

Bivariate analyses were calculated for independent variables, and independent 2-sample t-tests were calculated for normal continuous data, including the STAT scores, NASA rTLX scores, and time-to-defibrillation data. The Shapiro-Wilk and Kolmogorov tests of normalcy were used to evaluate for normalcy and heterogeneity. To analyze nonparametric data, including the confederate clinical team member global rating scores and the TeamMonitor scores completed both by study subjects and confederate clinical team members, the Wilcoxon-Mann-Whitney U test was calculated. Multivariable linear regressions were calculated to control for potential confounders. Pearson's correlation coefficients were calculated to assess for any correlations between STAT instrument Human Factors section scores and STAT instrument clinical performance indicators.

Inter-Rater Reliability: To validate the initial scoring by the primary study investigator, a second study investigator (formally trained by the developers of the STAT instrument) reviewed five of the 20 recorded sessions (25%) and scored teams on the clinical performance sections as well as the Human Factors sections of the STAT instrument. This reviewer was blind to the scoring of the original reviewer. The five teams selected were randomly chosen using an online random number generator (www.random.org) and included three comparison arm teams and two intervention arm teams. Inter-rater reliability was evaluated by calculating the intraclass correlation coefficient. An intraclass correlation coefficient >0.4 was decided prior to calculation to represent an acceptable level of agreement between raters (54).

Results:

Demographic Survey: Forty Emergency Medicine residents were enrolled as study participants to form 20 provider teams. Table 2 shows demographic survey results. Intervention team subjects reported having previously participated in a resuscitation code with their fellow subject teammate significantly more frequently than comparison team subjects (16 of 20 (80%) vs. nine of 20 (45%), p=0.048). There was no significant difference between study arms in terms of comfort and experience with simulation and pediatric resuscitation, level of training, extensive clinical experience with fellow subject team member, experience with TC principles, or experience with procedures relevant to the case scenario.

STAT Human Factors Scores: All 20 teams were scored during video review according to the Human Factors section of the STAT instrument (Table 3). There was no difference in Comprehensive Human Factors scores, "Leadership (Team Leader)" subsection scores, and "Management (Team Members)" subsection scores.

TeamMonitor Scores (Completed by Subjects): There was no difference in Overall TC as measured by subject-completed TeamMonitor tool scores. Subject teams' self-reported TeamMonitor data are displayed in Table 4.

Table 2: Participant Demographic Survey Data

	Comparison	Intervention	*p*-value
Level of training			0.630
PGY1	6 (30)	4 (20)	
PGY2	4 (20)	5 (25)	
PGY3	6 (30)	4 (20)	
PGY4	4 (20)	7 (35)	
Self-reported survey			
Ever participated in code with teammate?	9 (45)	16 (80)	0.048
Worked extensively (>1month on service) with teammate?	6 (30)	7 (35)	1.00
Participated in formal TC training program	8 (44)	4 (25)	0.297
Participated in mock code	20 (100)	20 (100)	--
Participated in mock code as team leader	15 (75)	14 (70)	0.596
Participated in real code	20 (100)	20 (100)	--
Participated in real code as team leader	16 (80)	16 (80)	1.00
Practiced skill: BVM in real code	20 (100)	20 (100)	--
Practiced skill: intubation in real code	19 (95)	19 (95)	1.00
Practiced skill: venipuncture in real code	14 (70)	17 (85)	0.451
Practiced skill: defibrillation in real code	19 (95)	17 (85)	0.605
Practiced skill: IO in real code	20 (100)	19 (95)	1.00
Comfort running code as team leader, median (IQR)	81 (61, 95)	81 (69, 94)	0.825
Familiarity with teamwork, median (IQR)	79 (54, 83)	81 (54, 86)	0.959

Table 3: STAT Human Factors Scores			
	Comparison	Intervention	*p*-value
Mean Comprehensive Human Factors Score (SD)	66 (10)	73 (15)	0.118
Mean Leadership (Team Leader) subsection score	61 (13)	70 (18)	0.071
Mean Management (Team Members) subsection score	76 (9)	77 (12)	0.730

Table 4: TeamMonitor Scores Completed by Subjects			
	Comparison	Intervention	*p*-value
Median Overall TeamMonitor Score (IQR)	94 (84, 100)	91 (78, 94)	0.251
Median Overall TeamMonitor Score (IQR)—Team Leaders Only	94 (76, 100)	89 (78, 100)	0.211
Median Overall TeamMonitor Score (IQR)—Team Members Only	94 (85, 100)	94 (82, 94)	0.211

TeamMonitor Scores (Completed by Confederate Clinical Team Members): There was no difference in Overall TC scores as assessed by confederate clinical team members using the TeamMonitor tool (median comparison arm score= 86 [IQR 67-100], median intervention arm score= 76 [IQR 68-94]; *p*= 0.462).

Global Rating Scores: There was no significant difference in global rating scores of subject teams' overall TC as assessed by confederate clinical team members (median comparison arm score= 91 [IQR 68-97], median intervention arm score= 77 [IQR 67-83]; *p*= 0.143).

NASA rTLX Workload Scores: There was no difference in comprehensive workload scores compared between team leaders or between junior subject team members as measured by the rTLX. Similarly, there was no difference in any of the individual workload items on the rTLX or in anxiety scores between team leaders or between junior subject team members. See Table 5 for complete modified NASA rTLX workload data.

Table 5. NASA rTLX Workload Scores

	Comparison	Intervention	*p*-value
Mean Team Leader Workload Scores (SD)			
Overall Workload score (max = 100)	51 (14)	55 (13)	0.983
Mental demand (max=20)	14 (5)	17 (2)	0.076
Physical demand (max=20)	4 (5)	3 (6)	0.996
Temporal demand (max=20)	14 (2)	14 (4)	0.470
Performance (max=20)	8 (4)	9 (5)	0.208
Effort (max=20)	13 (4)	15 (3)	0.917
Frustration (max=20)	9 (5)	8 (5)	0.710
Anxiety (max=20)	10 (5)	10 (5)	0.853

Mean Team Member Workload Scores (SD)			
Overall Workload Score (max = 100)	44 (9)	59 (5)	0.123
Mental demand (max=20)	14 (3)	15 (3)	0.548
Physical demand (max=20)	5 (4)	10 (5)	0.895
Temporal demand (max=20)	11 (3)	13 (3)	0.768
Performance (max=20)	7 (3)	9 (4)	0.239
Effort (max=20)	12 (3)	13 (2)	0.348
Frustration (max=20)	6 (4)	10 (5)	0.351
Anxiety (max=20)	7 (4)	12 (3)	0.682

STAT Clinical Performance Scores: There was no difference between study arms in Basics, Airway/Breathing, Circulation, or Comprehensive Clinical Performance scores (see Table 6). Pearson's correlation coefficients (r) assessing potential correlations between STAT instrument Human Factors scores and STAT instrument clinical performance indicators are listed in Table 7.

Table 6. STAT Clinical Performance Scores

	Comparison	Intervention	*p*-value
Mean Comprehensive Clinical Performance Score (SD)	64 (9)	72 (7)	0.168
Mean Basics Score (SD)	78 (7)	74 (10)	0.113
Mean Airway/Breathing Score (SD)	66 (110)	69 (11)	0.388
Mean Circulation Score (SD)	71 (10)	73 (12)	0.510

Table 7. Correlation between STAT Human Factors Scores and Clinical Performance Metrics		
Clinical Performance Variable	Pearson's Correlation Coefficient (r)	*p*-value
STAT Basics Score	0.433	0.056
STAT Airway/Breathing Score	0.135	0.569
STAT Circulation Score	0.086	0.717
STAT Comprehensive Clinical Performance Score	0.323	0.164

Time-to-Defibrillation: There was no difference in TTD between study arms (mean comparison arm TTD= 253 seconds [SD=166] vs. mean intervention arm TTD= 238 seconds [SD 155]; p=0.762).

Inter-Rater Reliability: Inter-rater agreement was calculated following video review of five of the 20 (25%) simulations. Inter-rater reliability was examined across the entire STAT instrument (Basics, Airway/Breathing, Circulation, and Human Factors). The Intraclass Correlation Coefficient was 0.585, indicating an acceptable level of agreement (54).

Debriefing Themes: Themes for subjects in the telepresent team leader (intervention) arm related to the use of telemedicine during acute resuscitation include:

- The propensity for role confusion to develop

- Reduced audiovisual perception as compared with standard face-to-face communication
- An improved ability for the telepresent team leader to maintain a “macroscopic” view of the case
- Improved quality of verbal communication necessitated by the lack of physical proximity
- No perceived reduction in overall quality of care
- A general willingness to use telemedicine technology in actual patient care in the future

Themes for subjects in the comparison arm related to the use of telemedicine during acute resuscitative care include:

- A general reluctance to attempt telepresence for emergency care in the future
- Concerns related to the telepresent consultant being unable to “jump-in” if issues arise with procedural tasks
- The belief that communication would improve as compared with standard face-to-face communication during resuscitations
- The belief that telepresence would prevent team leaders from becoming fixated on any particular task during care
- A reduced likelihood to miss changes in vital signs visible on the monitor

Discussion:

The primary purpose of this study was to evaluate the impact of telemedicine on TC during acute care. Additional aims were to analyze the workload experienced by providers when participating in acute telemedical care and to assess the impact that any differences in TC during the use of telepresence had on the overall quality of care. Providers' perceptions on comfort, teamwork, and quality of care related to the use of telemedicine in resuscitation were gathered.

Teamwork and Communication: We collected four metrics of quantitative data analyzing TC from three sources in order to include multiple perspectives in our assessment. Study investigators rated each team's performance, subjects rated their own performance, and confederate clinical team members, who had participated alongside the subject team at the bedside, rated the subject team's performance with both the TeamMonitor tool and by assigning a Global Rating Score. All four of these TC performance metrics demonstrated no difference in the quality of TC between teams with an in-room or a telepresent team leader.

Our study was powered to detect differences in mean overall STAT instrument scores, and not in specific STAT instrument sections or individual items. Despite this, we saw a trend towards higher leadership scores in the telepresent team leader arm as captured by the "Leadership (Team Leader)" subsection of the STAT instrument's

Human Factors section (*p*=0.071). An increased sample size may have revealed additional differences in STAT instrument subsections as well as individual items and other variables.

One possible explanation for the trend of higher leadership scores in the telepresence arm is related to the association between communication and leadership skills. In the business literature, it has been demonstrated that communication effectiveness is positively correlated with perceived leadership qualities (55). In our study, one theme that emerged during qualitative debriefings was that working in a telepresent relationship requires more explicit verbal communication. As one telepresent team leader described, "*being outside of the room, you're forced to use better communication… it's important to request feedback* [from bedside providers] *from the get-go, and to tell the team in advance to call everything out more."* It thus follows that if telepresent team leaders were compelled to communicate more effectively by virtue of their physical absence from the treatment room—even if this difference in communication was not captured by our TC assessment metrics—it is possible that any enhancement in communication was thereby perceived as improved leadership.

Our primary hypothesis was that the use of telemedicine would result in improved TC. TC literature frequently recommends using closed loop communication

(56-58) and encouraging junior team members (who are often reluctant to “speak up” due to perceived differences in expertise, experience, or authority (59-61)) to share their ideas as approaches for improving communication.

We hypothesized that the use of telemedicine would encourage junior team members at the bedside to share their ideas and participate in decision-making more frequently (indicators of improved TC) as they were the most highly-trained providers in the room. We also hypothesized that the physical separation of team members during telemedicine cases would lead to more frequent team “huddles” for sharing mental models—another hallmark of effective TC. Finally, we hypothesized that the use of telemedicine would result in improved closed-loop communication and more explicit verbal communication in general as compared with face-to-face communication, because face-to-face communication affords greater use of non-verbal communication cues (62) which may be more vulnerable to misinterpretation.

Although our data did not support these hypotheses, it is worth noting that we saw no difference in TC, suggesting that the quality of TC may not be reduced when telemedicine is used to connect providers to remote teams managing critically ill patients. Considering the correlation between quality of TC and clinical performance during resuscitation events (10, 11, 63), these findings may imply that the use of telepresence will not, for reasons associated with TC, diminish clinical performance.

Our assessment of clinical performance (described in detail below), which shows no difference in scores between study arms, corroborates this notion.

Few studies have investigated the impact of telemedicine on TC during acute care, and ours is one of the first to apply quantitative research methodologies to this area of inquiry. Previous work in this domain has generally found that telemedicine has positive effects on TC during acute care. For example, in a recent survey-based analysis of TC during telemedicine-facilitated newborn resuscitations, researchers found that both telemedicine consultants and local provider teams felt they were able to collaborate, provide recommendations, share information, and share a mental model effectively (30). In another study analyzing the use of a telepresence system between a university trauma surgery specialist team and a rural emergency department, participants described that videoconferencing during emergency care generally improved communication, increased interactions, and allowed experts to be more involved in the decision-making process as compared to standard telephone consultations (31).

Other studies evaluating the impact of telemedicine on TC, albeit in non-resuscitative care domains, have also demonstrated positive effects or else have demonstrated no difference in TC associated with the use of telemedicine. In a 2010 study analyzing teamwork before and after the implementation of a tele-ICU system across three ICUs, mean teamwork scores improved after the tele-ICU system was implemented (19). In a 2015 study analyzing teamwork attitudes, teamwork climate, cognition, and communication during tele-ICU rounds, investigators found no significant difference in any of these factors when compared with normal face-to-face ICU rounds (26). Extrapolating from the behavioral psychology literature, a 2007 study analyzing the impacts of various leadership styles across face-to-face, videoconference, and text-based communication media showed no difference in team cohesion scores—a measure of group dynamics correlated to TC (24).

Our quantitative data, which demonstrated no difference in TC scores associated with the use of telemedicine, is consistent with several of these latter studies. However, our debriefing sessions largely revealed that providers perceived telemedicine to be associated with better TC than in a standard face-to-face scenario. As participants explained, *"I think communication would be better* [than if we were face-to-face]*, because telemedicine requires more verbal communication since you can't assume the telemedicine physician can hear and see everything,"* and *"I think communication would be better* [with telemedicine]*, because if the team leader is not present it necessitates verbal communications to be more out-loud…the team leader would have to verbalize his mental process better."* Future work related to TC during acute care telemedicine should address this discrepancy in provider perspectives and our observational TC data.

Workload & Anxiety: In order to more fully understand the impact of telemedicine on TC during acute care, a secondary aim of this study was to analyze the workload experienced by participating providers. Like TC, workload is an important element of human factors and has been shown to affect TC as well as the frequency of adverse events (35). We also sought to analyze the impact that telemedicine had on provider anxiety during the cases, as the use of new technology (64) and altered healthcare team dynamics may affect providers' levels of anxiety and performance, especially during high-acuity situations (65). It has previously been suggested that telemedicine may reduce the task saturation, i.e. workload, of a remote team leader (66). Consistent with this notion, we hypothesized that telepresent team leaders would experience less workload as well as reduced levels of anxiety than team leaders who were physically present in the treatment room. We also hypothesized that junior team members with telepresent team leaders would experience greater workload and greater levels of anxiety than their counterparts with in-room team leaders, as they were the sole physician in the room managing the case (62).

However, our results showed no difference in the workload experienced by telepresent team leaders vs. in-room team leaders, or by junior team members with telepresent leaders vs. those with in-room team leaders. Likewise, there was no difference in levels of anxiety between team leaders or between junior team members by study arm.

It is possible that any increases in *physical* task load for bedside team members (whose team leaders were not present at the bedside to help with any procedural tasks) were offset by reductions in *cognitive* task load afforded by having a telepresent team leader whose role was, by virtue of being physically absent from the treatment room, entirely cognitive in nature. It is also possible that there is no true difference in workload associated with the use of telepresence for resuscitative care, or that our study was insufficiently powered to detect any true differences between study arms. Future analyses of workload and anxiety during acute care telemedicine should include greater sample sizes in order to more readily detect differences between groups.

Although our quantitative metrics showed no differences in workload and anxiety, providers expressed several opposing viewpoints during post-simulation debriefings related to their anxiety and workload while participating in the telemedicine-facilitated resuscitation. Several participants shared the position that the use of telemedicine had the potential to increase team leader anxiety.

For example, some telepresent team leaders described feeling uneasy because their physical separation could prevent them from being able to "jump-in" and assist with procedural tasks causing the bedside provider difficulty. As one provider stated, "*being physically removed was anxiety-provoking in that I had to be reliant on the provider in the room to be competent,"* while another remarked that, "*in a way you feel* *handicapped because for some things, you're like, 'I wish I was in there, I know how to do this!'"* A third provider expressed anxiety with the use of telemedicine technology for acute care in general, stating: "*I'd feel nervous trusting an internet connection and computer screen during a serious case like this.*"

However, other telemedical team leaders described a diminished sense of anxiety related to being physically removed from the treatment room. As one provider commented: "*In a sense, there's some reduced anxiety, because* [as the telemedical team leader] *you're not in the danger zone, so to speak.*" Other providers commented on a reduced task load associated with being a remotely-located team leader. As one participant stated: "*It's good because there's no one tapping your shoulder asking you for stuff; no one barrages you with questions and EKGs to read.*" Another telemedical team leader mirrored this comment, stating simply, "*I felt less distracted.*"

Although there is a paucity of literature assessing the workload and anxiety experienced by providers during telemedical care with which to compare our data, several studies have supported the notion shared by some of our participating providers that real-time audiovisual communication may be less anxiety-provoking than standard face-to-face communication. For example, in a qualitative study analyzing a telepresence system between a university trauma surgery team and a rural emergency department, rural providers reported feeling "less stress than anticipated" after interacting with the telepresent specialist during resuscitative care (31). Work from an unrelated field—dental education—has similarly found that participants felt “surprisingly relaxed” when lecturing via videoconference as compared with the more “stressful” task of delivering face-to-face instruction (67). Similarly, medical educators have reported that remote videoconference-based assessment of trainees is “less stressful and intimidating” than standard face-to-face assessment (68). Although we are unaware of any empirical studies analyzing workload during telemedicine-facilitated care, it has been suggested that the use of a remote telemedical team leader may reduce the team leader’s task saturation (i.e. workload), potentially allowing the team leader greater oversight and even improved overall performance (66).

To our knowledge, this is the first study to analyze workload and anxiety during acute care telemedicine. Ultimately, our quantitative data demonstrated no difference in workload or anxiety for providers participating in telemedicine-facilitated acute care, thus demonstrating no clear negative implications on workload or anxiety when using telepresence for resuscitative care. Therefore, together, these findings may suggest that the use of telemedicine during critical resuscitation events does not overly burden the participating providers.

Clinical Performance: As an exploratory aim, we were interested in evaluating the impact of a telepresent team leader on the quality of care delivered to the patient, as well as any potential association between TC and quality of care. Video reviewers scored each team using the three sections of the STAT instrument pertaining to clinical performance—Basics, Airway/Breathing, and Circulation—and compared TTD between study arms so as to complement our analysis using another method less vulnerable to reviewer bias. We hypothesized that teams led via telepresence would adhere more closely to resuscitation guidelines and generally provide better care.

However, our data showed no difference for any of the clinical performance sections of the STAT instrument or for the aggregate Comprehensive Clinical Performance scores. Furthermore, there was no difference in mean TTD values between study arms. Despite being incongruent with our hypotheses, these results are consistent with several studies showing no difference in the quality of resuscitative care associated with the use of telemedicine.

For example, in a recent study by Yang *et al.* comparing community ED teams performing simulated pediatric resuscitations facilitated by telemedicine or by standard telephone consultation, there was no difference in TTD and the majority of additional metrics measuring adherence to resuscitation guidelines (39). Likewise, in a study analyzing EMS teams with a telepresent or a bedside physician team leader, there was no significant difference in case management, leading the authors to suggest that care with a telepresent team leader was not inferior to care with an in-room team leader (41). More broadly, numerous studies have shown that in the pediatric emergency setting, telemedicine has had similar diagnostic accuracy, reliability, and overall non-inferiority when compared with typical face-to-face encounters for a variety of non-emergent conditions (69-73).

However, a number of other studies examining the effects of telemedicine have demonstrated, rather, that the use of telemedicine has had generally positive effects on the quality of resuscitative care. For example, a 2012 paper by Skorning *et al.* showed that teams of EMS providers led by a telepresent physician adhered more closely to resuscitation guidelines than comparison groups featuring bedside team leaders (36). In a similar study, teams of EMTs assisted by telepresent physicians achieved better patient care than teams of EMTs communicating solely via radio during simulated resuscitations (40). In 2014, Fang *et al.* demonstrated that residents participating in simulated neonatal resuscitation more quickly established effective ventilation and adhered more closely to the Neonatal Resuscitation Protocol guidelines when video-assisted by neonatologists (74). Given the varied findings and methodological differences of these studies, future work must elucidate the optimal applications of telemedicine technology in various resuscitative scenarios and environments.

Finally, our data revealed a trend towards a moderately strong correlation ($r=0.433$; $p=0.056$) between STAT Human Factors section and STAT Basics section scores

(75). Although this trend was not seen for the other STAT Clinical Performance metrics analyzed, these results may indicate that the correlation between quality of TC and overall quality of care described in other contexts (7-9) also applies in the setting of telemedicine-facilitated acute care.

Provider Perceptions and Strategies for the Use of Telemedicine in Resuscitation:

During debriefings, providers described certain benefits of having a telepresent team leader as opposed to an in-room team leader. One frequently cited benefit was that the use of telemedicine provided team leaders with a "macroscopic" view of the case, thereby reducing the likelihood that team leaders miss any important changes in the clinical scenario. As one telepresent team leader commented, "*I felt more in control…it was easier to look at the big picture."* Another commonly mentioned benefit of using telemedicine was that the lack of physical proximity between team members necessitated enhanced communication. As one telepresent team leader explained, "*I felt like I had to the huddle the team more since I wasn't right there, and overall I might have increased verbalization in general.*"

Providers also shared several common concerns related to the use of telemedicine. Most relevant to TC principles, providers commented on the propensity for role confusion to develop. Specifically, an often-cited example of this concerned the roles related to communicating with the patient's family and nursing staff. As one participant mentioned, *"I wasn't 100% clear on my role, should I have been the one to talk to the parent?"* Mirroring this sentiment and adding a recommendation for future use, another provider remarked: *"Roles have to change if the team leader is not in the room…because in a normal situation,* [the team leader] *would have to talk to nurses and parents while* [the other physician] *was trying to do procedures and examine the kid."*

Another commonly discussed concern with using telemedicine in the resuscitation setting was related to audiovisual deficiencies, including difficulty hearing, seeing the patient, and the potential for the feed to cut-out entirely. This concern is consistent with results from several other studies examining the use of telemedicine in acute care (30, 39, 76).

Providers also shared several common recommendations for effective use of telemedicine during acute care. In addition to the aforementioned need for role clarification, providers pointed out the importance for participants to have developed a rapport *before* the initiation of telemedicine-facilitated care. As one participant summarized this theme: "*I think there's a big difference if you know the person on the other end. If you know them and trust them, it's much easier to take their advice, especially if a disagreement came up."* This finding is consistent with several studies that have found collaborative relationships between telemedicine specialists and remote hospital staff to be crucial to success of emergency telemedicine systems (15, 18).

Interestingly, several comparison arm subjects, who had not had the experience of participating in telepresent care, reported that they would be reluctant to use this modality in the future. (This finding may reflect a common apprehension about using new technology that has been reported in other settings (64).) However, the majority of individuals who had just participated in the telepresence arm of the study were more accepting of this modality and were more willing to use telemedicine in future clinical work. This theme is consistent with numerous studies showing that telemedicine in the emergency setting is acceptable to providers with experience using it, as well as to patients and their families who have been involved in telemedical care (17, 77-79). In addition, the reluctance of unexposed providers to use telemedicine in the future contrasted with the willingness of those who had used it reflects the findings of prior work demonstrating a positive correlation between the amount of experience using telemedicine and the perceived value of telemedicine (80).

Themes elucidated during debriefings highlighted advantages, concerns, and important elements to consider when communicating via telepresence. If these findings are replicable, they may inform understanding of effective TC behaviors to be leveraged for training on optimal use of telemedicine technology during resuscitation and other acute care scenarios.

Limitations: There are several limitations to our study. First, this study may suffer from a small sample size. Despite exceeding our estimated necessary sample size of 18 teams, which was calculated based on previous work by study investigators using a similar case and the same primary outcome measure—the STAT instrument (44, 45)—our small sample size may have reduced our ability to detect any true effects that a telepresent team leader has on resuscitative care. Furthermore, as our sample size was calculated for overall STAT instrument scores, our study may have been underpowered to detect differences between study arms using the additional metrics we analyzed. Specifically, these include the individual sections of the STAT instrument (i.e. Basics, Airway/Breathing, Circulation, and Human Factors), the modified NASA rTLX workload scale, the TeamMonitor tool, and our TTD measurements. In addition, study investigators scoring teams with the STAT instrument were not blinded to study arm or to study hypotheses, which may have led to bias in scoring.

Second, despite striving to maintain a realistic environment, using a high-fidelity mannequin, and instructing participants to engage in the simulation as if treating a real patient, there were obvious limitations to the realism of the scenario. In several instances, technical mishaps required a "pause" in the simulation to reboot the mannequin, patient monitor, or telemedicine video feed. Additionally, on several occasions, telemedicine team leaders indicated they could not hear conversations between in-room team members and clinical consultants (e.g. radiologists, transport teams) played by physician investigators. Thus, as with all simulation studies, there is a question of whether our results will generalize to the actual clinical environment. However, similarly designed studies are prevalent in the literature (36, 39, 41, 44, 45, 81, 82), and research has suggested that performance in simulation may translate to real patient care (83).

Third, there is also the question of whether our findings from this specific pediatric emergency medicine case will generalize to other fields of acute care telemedicine such as stroke, emergency medicine, critical care, cardiology, trauma, burn, ophthalmology, dermatology, orthopedics, and psychiatry (14, 84). Theoretically, however, the TC behaviors demonstrated as well as the impact of telepresent team leadership on provider workload should not case-dependent and should therefore generalize to other fields employing acute care telemedicine.

Fourth, despite scripting and attempting to standardize confederate clinical team members, variability between individual confederate clinical team members assigned to each subject team may have affected teams' performance. Perhaps more significantly, this meant that different confederate clinical team members completed TeamMonitor surveys and assigned global rating scores to subject teams. This introduced the potential for interrater variability, damaging the reliability of these assessments.

Fifth, although subject teams were randomized, regression analysis of demographic survey data revealed that intervention teams reported having previously participated in a code with their teammate significantly more often than comparison team members. This may suggest that intervention team members were more familiar with their teammates' strengths and weaknesses during code situations, which in turn may have affected their teamwork, communication, and clinical performance during the case.

Sixth, in this study we assumed that a knowledge gradient existed between more senior subjects serving as team leaders and their assigned junior team members. This was designed to emulate the knowledge gradient between specialist teleproviders and general ED providers which forms the basis for the use of emergency telemedicine. However, the degree to which there existed a knowledge gradient between subject team members related to pediatric resuscitation was not established. Furthermore, it is possible that there was significant variation between the clinical acumen and TC skills of the individual PGY-3 and PGY-4 team leaders, as well as between the individual PGY-1 and PGY-2 junior clinical team members. Although regression analyses largely indicated successful randomization and equivalency between study arms, it is possible that there were significant differences between arms related to knowledge and skills. Theoretically, this could have resulted in sampling bias.

Finally, in two cases, subject teams did not adhere to the predetermined teammate-pairing rubric of one PGY-3 or PGY-4 resident paired with one PGY-1 or PGY-2 resident. In one instance, a PGY-4 team leader was paired with a PGY-3 as the junior clinical team member, and in the other instance, a PGY-2 team leader was paired with a

PGY-1 junior clinical team member. Fortunately, however, both of these instances applied to comparison teams. Thus, ideally, any positive effect on performance created by having two senior residents on the same comparison arm team was negated by having two junior residents on another comparison arm team.

Conclusions:

In this simulation-based study, we observed no difference in TC, workload, or clinical performance between teams with telepresent or in-person team leaders, although a small sample size may have limited our power to detect a difference. Despite limitations, these data suggest that quality of care, both in general and as specifically related to TC, may be equivalent during resuscitations led by telepresent or in-person team leaders. These data thus add to the growing body of literature supporting the argument for expanding the use of telemedicine in acute care. Future work should refine understanding of the effectiveness of telemedicine and investigate the optimal applications for this technology in the acute care clinical environment.

References:

1. Leonard M, Graham S, Bonacum D. The human factor: the critical importance of effective teamwork and communication in providing safe care. Qual Saf Health Care 2004;13 Suppl 1:i85-90.
2. Kohn LT, Corrigan J, Donaldson MS. To err is human: building a safer health system. Washington, D.C.: National Academy Press, 2000.
3. Stocker M, Menadue L, Kakat S, et al. Reliability of team-based self-monitoring in critical events: a pilot study. BMC Emerg Med 2013;13:22.
4. Risser DT, Rice MM, Salisbury ML, et al. The potential for improved teamwork to reduce medical errors in the emergency department. The MedTeams Research Consortium. Annals of Emergency Medicine 1999;34(3):373-83.
5. Gawande AA, Zinner MJ, Studdert DM, et al. Analysis of errors reported by surgeons at three teaching hospitals. Surgery 2003;133(6):614-21.
6. Hargestam M, Lindkvist M, Jacobsson M, et al. Trauma teams and time to early management during in situ trauma team training. BMJ Open 2016;6(1):e009911.
7. Capella J, Smith S, Philp A, et al. Teamwork training improves the clinical care of trauma patients. Journal of Surgical Education 2010;67(6):439-43.
8. Gilfoyle E, Koot DA, Annear JC, et al. Improved clinical performance and teamwork of pediatric interprofessional resuscitation teams with a simulation-based educational intervention. Pediatr Crit Care Med 2017;18(2):e62-e69.
9. Morey JC, Simon R, Jay GD, et al. Error reduction and performance improvement in the emergency department through formal teamwork training: evaluation results of the MedTeams project. Health Serv Res 2002;37(6):1553-81.
10. Thomas EJ, Sexton JB, Lasky RE, et al. Teamwork and quality during neonatal care in the delivery room. J Perinatol 2006;26(3):163-9.
11. Siassakos D, Fox R, Crofts JF, et al. The management of a simulated emergency: Better teamwork, better performance. Resuscitation 2011;82(2):203-06.
12. Weinstock P, Halamek LP. Teamwork during resuscitation. Pediatric Clinics of North America 2008;55(4):1011-24.
13. Latifi R, Weinstein RS, Porter JM, et al. Telemedicine and telepresence for trauma and emergency care management. Scand J Surg 2007;96(4):281-9.
14. Ward MM, Jaana M, Natafgi N. Systematic review of telemedicine applications in emergency rooms. International Journal of Medical Informatics 2015;84(9):601-16.
15. Uscher-Pines L, Kahn JM. Barriers and facilitators to pediatric emergency telemedicine in the United States. Telemed J E Health 2014;20(11):990-6.
16. Ellenby MS, Marcin JP. The role of telemedicine in pediatric critical care. Critical Care Clinics 2015;31(2):275-90.
17. Heath B, Salerno R, Hopkins A, et al. Pediatric critical care telemedicine in rural underserved emergency departments. Pediatric Critical Care Medicine 2009;10(5):588-91.
18. Bauman ZM, Azim A, Latifi R, et al. Advancing trauma and emergency education through virtual presence. Current Trauma Reports 2016;2(3):124-31.
19. Chu-Weininger MY, Wueste L, Lucke JF, et al. The impact of a tele-ICU on provider attitudes about teamwork and safety climate. Qual Saf Health Care 2010;19(6):e39.

20. Kahn JM. Virtual visits--confronting the challenges of telemedicine. N Engl J Med 2015;372(18):1684-5.
21. Dharmar M, Romano PS, Kuppermann N, et al. Impact of critical care telemedicine consultations on children in rural emergency departments. Critical Care Medicine 2013;41(10):2388-95.
22. Marcin JP, Schepps DE, Page KA, et al. The use of telemedicine to provide pediatric critical care consultations to pediatric trauma patients admitted to a remote trauma intensive care unit: A preliminary report. Pediatric Critical Care Medicine 2004;5(3):251-56.
23. Sivunen A, Valo M. Team leaders' technology choice in virtual teams. Professional Communication, IEEE Transactions on 2006;49(1):57-68.
24. Hambley LA, O'Neill TA, Kline TJB. Virtual team leadership: The effects of leadership style and communication medium on team interaction styles and outcomes. Organizational Behavior and Human Decision Processes 2007;103(1):1-20.
25. Denstadli JM, Julsrud TE, Hjorthol RJ. Videoconferencing as a mode of communication. Journal of Business and Technical Communication 2011;26(1):65-91.
26. Lazzara EH, Benishek LE, Patzer B, et al. Utilizing telemedicine in the trauma intensive care unit: Does it impact teamwork? Telemedicine and e-Health 2015;21(8):670-76.
27. Aas IH. Telemedical work and cooperation. Journal of Telemedicine and Telecare 2001;7(4):212-8.
28. Careau E, Vincent C, Noreau L. Assessing interprofessional teamwork in a videoconference-based telerehabilitation setting. J Telemed Telecare 2008;14(8):427-34.
29. Stronge AJ, Nichols T, Rogers WA, et al. Systematic human factors evaluation of a teledermatology system within the U.S. military. Telemed J E Health 2008;14(1):25-34.
30. Fang JL, Collura CA, Johnson RV, et al. Emergency video telemedicine consultation for newborn resuscitations: The Mayo Clinic experience. Mayo Clinic Proceedings 2016;91(12):1735-43.
31. Bolle SR, Larsen F, Hagen O, et al. Video conferencing versus telephone calls for team work across hospitals: a qualitative study on simulated emergencies. BMC Emergency Medicine 2009;9:22.
32. Rosen MA, Weaver SJ, Lazzara EH, et al. Tools for evaluating team performance in simulation-based training. Journal of Emergencies, Trauma and Shock 2010;3(4):353-59.
33. Lisbon D, Allin D, Cleek C, et al. Improved knowledge, attitudes, and behaviors after implementation of TeamSTEPPS training in an academic emergency department: a pilot report. Am J Med Qual 2016;31(1):86-90.
34. Capella J, Smith S, Philp A, et al. Teamwork training improves the clinical care of trauma patients. Journal of Surgical Education 2010;67(6):439-43.
35. Davis B, Welch K, Walsh-Hart S, et al. Effective teamwork and communication mitigate task saturation in simulated critical care air transport team missions. Military Medicine 2014;179(8 Suppl):19-23.
36. Skorning M, Bergrath S, Rörtgen D, et al. Teleconsultation in pre-hospital emergency medical services: Real-time telemedical support in a prospective controlled simulation study. Resuscitation 2012;83(5):626-32.
37. Lopreiato JOE, Downing D, Gammon W, Lioce L, Sittner B, Slot V, Spain AE (Associate Eds.), and the Terminology & Concepts Working Group. Healthcare Simulation Dictionary. Retrieved from http://www.ssih.org/dictionary, 2016.

38. Cheng A, Auerbach M, Hunt EA, et al. Designing and conducting simulation-based research. Pediatrics 2014;133(6):1091-101.
39. Yang CP, Hunt EA, Shilkofski N, et al. Can telemedicine improve adherence to resuscitation guidelines for critically ill children at community hospitals? A randomized controlled trial using high-fidelity simulation. Pediatric Emergency Care 2016;Publish Ahead of Print.
40. Charash WE, Caputo MP, Clark H, et al. Telemedicine to a moving ambulance improves outcome after trauma in simulated patients. Journal of Trauma and Acute Care Surgery 2011;71(1):49-55.
41. Rörtgen D, Bergrath S, Rossaint R, et al. Comparison of physician staffed emergency teams with paramedic teams assisted by telemedicine – a randomized, controlled simulation study. Resuscitation 2013;84(1):85-92.
42. Reid J, Stone K, Brown J, et al. The Simulation Team Assessment Tool (STAT): Development, reliability and validation. Resuscitation 2012;83(7):879-86.
43. Stone K, Reid J, Caglar D, et al. Increasing pediatric resident simulated resuscitation performance: A standardized simulation-based curriculum. Resuscitation 2014;85(8):1099-105.
44. Auerbach M, Whitfill T, Gawel M, et al. Differences in the quality of pediatric resuscitative care across a spectrum of emergency departments. JAMA Pediatrics 2016;170(10):987-94.
45. Kessler DO, Walsh B, Whitfill T, et al. Disparities in adherence to pediatric sepsis guidelines across a spectrum of emergency departments: a multicenter, cross-sectional observational in situ simulation study. The Journal of Emergency Medicine 2016;50(3):403-15.e3.
46. Byers JC, Bittner AC, Hill SG. Traditional and raw task load index (TLX) correlations: Are paired comparisons necessary? Advances in Industrial Ergonomics and Safety 1989(A. Mital (Ed.); Taylor & Francis:481-85.
47. Hart SG. Nasa-Task Load Index (NASA-TLX); 20 years later. Proceedings of the Human Factors and Ergonomics Society Annual Meeting 2006;50(9):904-08.
48. Zimmerman K, Holzinger IB, Ganassi L, et al. Inter-professional in-situ simulated team and resuscitation training for patient safety: description and impact of a programmatic approach. BMC Med Educ 2015;15:189.
49. Chan PS, Krumholz HM, Nichol G, et al. Delayed time to defibrillation after in-hospital cardiac arrest. New England Journal of Medicine 2008;358(1):9-17.
50. Sullivan GM, Sargeant J. Qualities of qualitative research: part I. J Grad Med Educ 2011;3(4):449-52.
51. Malec JF, Torsher LC, Dunn WF, et al. The Mayo High Performance Teamwork Scale: reliability and validity for evaluating key crew resource management skills. Simul Healthc 2007;2(1):4-10.
52. Hart SG, Staveland LE. Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In: Peter AH, Najmedin M, eds. Advances in Psychology: North-Holland, 1988:139-83.
53. Cohen DS, Colliver JA, Marcy MS, et al. Psychometric properties of a standardized-patient checklist and rating-scale form used to assess interpersonal and communication skills. Academic Medicine 1996;71(1):S87-9.

54. Van Ness PH, Towle VR, Juthani-Mehta M. Testing measurement reliability in older populations: Methods for informed discrimination in instrument selection and application. Journal of Aging and Health 2008;20(2):183-97.
55. Neufeld DJ, Wan Z, Fang Y. Remote leadership, communication effectiveness and leader performance. Group Decision and Negotiation 2010;19(3):227-46.
56. Davis WA, Jones S, Crowell-Kuhnberg AM, et al. Operative team communication during simulated emergencies: Too busy to respond? Surgery 2017;161(5):1348-1356.
57. Salas E, Wilson KA, Murphy CE, et al. Communicating, coordinating, and cooperating when lives depend on it: Tips for teamwork. Joint Commission Journal on Quality and Patient Safety 2008;34(6):333-41.
58. Hargestam M, Lindkvist M, Brulin C, et al. Communication in interdisciplinary teams: exploring closed-loop communication during in situ trauma team training. BMJ Open 2013;3(10):e003525.
59. Ginsburg L, Bain L. The evaluation of a multifaceted intervention to promote “speaking up” and strengthen interprofessional teamwork climate perceptions. Journal of Interprofessional Care 2017;31(2):207-17.
60. Cosby KS, Croskerry P. Profiles in patient safety: authority gradients in medical error. Acad Emerg Med 2004;11(12):1341-5.
61. Okuyama A, Wagner C, Bijnen B. Speaking up for patient safety by hospital-based health care professionals: a literature review. BMC Health Serv Res 2014;14(1):61.
62. Tachakra S, Rajani R. Social presence in telemedicine. Journal of Telemedicine and Telecare 2002;8(4):226-30.
63. McKay A, Walker ST, Brett SJ, et al. Team performance in resuscitation teams: comparison and critique of two recently developed scoring tools. Resuscitation 2012;83(12):1478-83.
64. Stratham A, Bravo E. The introduction of new technology: Health implications for workers. Women & Health 1990;16(2):105-29.
65. LeBlanc VR. The effects of acute stress on performance: implications for health professions education. Academic Medicine: Journal of the Association of American Medical Colleges 2009;84(10 Suppl):S25-33.
66. Scheans P. Telemedicine for neonatal resuscitation. Neonatal Netw 2014;33(5):283-7.
67. Reynolds PA, Eaton KA, Mason R. Seeing is believing: dental education benefits from developments in videoconferencing. Br Dent J 2008;204(2):87-92.
68. Curran VR, Aziz K, O'Young S, et al. A comparison of face-to-face versus remote assessment of neonatal resuscitation skills. Journal of Telemedicine and Telecare 2005;11(2):97-102.
69. Siew L, Hsiao A, McCarthy P, et al. Reliability of telemedicine in the assessment of seriously ill children. Pediatrics 2016;137(3):e20150712.
70. Kew KM, Cates CJ. Remote versus face-to-face check-ups for asthma. The Cochrane Database of Systematic Reviews 2016;4:CD011715.
71. McConnochie KM, Conners GP, Brayer AF, et al. Differences in diagnosis and treatment using telemedicine versus in-person evaluation of acute illness. Ambulatory Pediatrics 2006;6(4):187-95.
72. Gattu R, Scollan J, DeSouza A, et al. Telemedicine: a reliable tool to assess the severity of respiratory distress in children. Hospital Pediatrics 2016;6(8):476-82.

73. Brennan JA, Kealy JA, Gerardi LH, et al. Telemedicine in the emergency department: a randomized controlled trial. Journal of Telemedicine and Telecare 1999;5(1):18-22.
74. Fang JL, Carey WA, Lang TR, et al. Real-time video communication improves provider performance in a simulated neonatal resuscitation. Resuscitation 2014;85(11):1518-22.
75. Evans J. *Straightforward Statistics for the Behavioral Sciences*. Pacific Grove, CA: Brooks/Cole Publishing Company, 1995.
76. Ray KN, Felmet KA, Hamilton MF, et al. Clinician attitudes toward adoption of pediatric emergency telemedicine in rural hospitals. Pediatric Emergency Care 2017;33(4):250-257.
77. Marcin JP, Nesbitt TS, Kallas HJ, et al. Use of telemedicine to provide pediatric critical care inpatient consultations to underserved rural Northern California. Journal of Pediatrics 2004;144(3):375-80.
78. Marconi GP, Chang T, Pham PK, et al. Traditional nurse triage vs physician telepresence in a pediatric ED. Am J Emerg Med 2014;32(4):325-9.
79. Nesbitt TS, Marcin JP, Daschbach MM, et al. Perceptions of local health care quality in 7 rural communities with telemedicine. J Rural Health 2005;21(1):79-85.
80. Sargeant J, Allen M, Langille D. Physician perceptions of the effect of telemedicine on rural retention and recruitment. Journal of Telemedicine and Telecare 2004;10(2):89-93.
81. Barsuk D, Ziv A, Lin G, et al. Using advanced simulation for recognition and correction of gaps in airway and breathing management skills in prehospital trauma care. Anesth Analg 2005;100(3):803-9, table of contents.
82. Murray DJ, Boulet JR, Avidan M, et al. Performance of residents and anesthesiologists in a simulation-based skill assessment. Anesthesiology 2007;107(5):705-13.
83. Tracey MR, Lathan CE. The interaction of spatial ability and motor learning in the transfer of training from a simulator to a real task. Stud Health Technol Inform 2001;81:521-7.
84. McSwain SD, Marcin JP. Telemedicine for the care of children in the hospital setting. Pediatric Annals 2014;43(2):e44-e49.

Appendices:

Confederate Clinical Team Member Script:

General: Thank you for participating in this study. Your role will be the nurse during the evaluation and resuscitation of a septic child who decompensates into ventricular fibrillation. Please pretend this is your first week on the job in a pediatric ED and that you do not feel comfortable performing any actions without explicit instruction from the team leader or another team member. (However, there is no need to feign excessive anxiety or unsureness or to ask unnecessary questions). This will ensure that teams are evaluated based on their performance and not based on the potential guidance of experienced nurses.

We aim to study the teamwork, communication, leadership, and overall quality of resuscitative care provided by a team of emergency medicine residents. As such, it *is crucial that you do not initiate care, prompt other team members to clinical indicators in the case, or preempt the request of upcoming tasks*. For example, please do not point out that the rhythm on the monitor has changed, and please do not begin to place IV lines or prepare medications until specifically requested to do so by the team leader or other team members. It may be important to remind yourself of this as the study goes on and you become familiar with the progression of the case. It is also essential that you *do not suggest next steps in management*, even if that which you are suggesting seems exceedingly obvious.

Similarly, please do not spur team members to enhance elements of teamwork and communication. For example, please do not suggest additional resources/personnel to recruit, or switch out of the nursing role to assist another team member. Please do not instruct others to use closed loop communication technique or to perform shared mental model huddles, interim summaries or assessments, etc.

That being said, when asked to perform a task, please use proper closed-loop communication technique, yourself. For example, after being asked to administer X medication, please say, “OK, I’ll draw up and give X medication,” and once you have successfully completed this task, look at the team leader and state, “medication X is in” loud enough to ensure that you have been heard.

If requested to share your opinion or thoughts on what to do next, please state “I’m not sure, whatever you think is best” or something to this effect.

If/when uncertainties and issues arise, please just remember that you are acting as a nurse on his/her first week on a new job in the pediatric ED. If major issues arise, the moderator may step in, but please remember: the show must go on!

Scenario Intro: You are working in the ED when the triage nurse tells you she just put an ill-appearing 6 month old girl in the resuscitation room. Sally was brought by her parents for concern of lethargy. She has been sick for 2 days with cough and runny nose. This morning she had a fever to 103°F. Mom put her down for a nap and found her difficult to wake up after 3 hours.

The triage nurse was concerned and brought her right back. The triage nurse has not obtained vitals; the patient is initially fully clothed and not on monitors. The patient is initially in decompensated septic shock and then decompensates to ventricular fibrillation.

Parent Actor Script:

General: Thank you for participating in this study. Your role will be the parent during the evaluation and resuscitation of a septic child who decompensates into ventricular fibrillation.

For the sake of this study, please act concerned for your child's wellbeing without being disruptive or overly inquisitive. Please adhere to the responses to questioning from the team listed below. When questions arise for which no responses are listed, please ad lib so as not to add complexity to the medical scenario as best as possible.

Scenario Intro: You brought your 6 month old daughter, Sally, in today for concern of lethargy. She has been sick for 2 days with cough and runny nose. This morning she had a fever to 103°. You put her down for a nap and found her difficult to wake up after 3 hours. The triage nurse was concerned and brought Sally right back.

Responses to Questioning:

HPI: 2 day history of mild fevers, rhinorrhea, cough, and decreased activity. Worse today, slept most of day, with coughing and fever this morning to 103°.

Last wet diaper 8 hours ago. Reduced urine output for 2 days. Last meal at 7am, difficult to take feeds.

Previously health. No travel, no sick contacts.

PMH: None. Full-term birth, no complications during pregnancy.

Allergies: No known drug/environmental allergies.

Meds: None

Weight: “I think she was about 13lbs last time I checked”

Suggested Inquiries—please ask 2 questions at specific parts in the case:

Towards the end of the first phase (which lasts 8 minutes), if not provided with an update from either the team leader or other team members, please ask for an update. Something akin to, “what’s going on?” or “what are you going to do to help her?”

As the team prepares to defibrillate, ask “What are you going to do with that?” “Is that going to hurt her?”

Debriefing Script:

Telemedicine-specific debrief for **Intervention** team:

1. Team leader (TL)/team member (TM), how did you feel about being/about having your TL physically removed from the patient and from your team?
2. TL/TM, do you think you would have been able to provide better or worse care had you/your TL physically been in the room? Why/why not?
3. TL/TM, do you think you and the team would have had more or less effective communication/teamwork had you/your TL physically been in the room? Why/why not?
4. TL/TM, would you feel comfortable leading a code/being led in a code remotely via telemedicine in the future? Why/why not?

Thank you for participating. We ask that you don't mention this study to your colleagues, since they may very well become involved in the future.

Telemedicine project-specific debrief for **Comparison** team:

As mentioned before the case, you guys were part of a study looking at telemedicine in pediatric resuscitation. You were in the control arm. Had you been in the telemedicine intervention group, the team leader would have been in another room using 2-way videoconferencing like the videophone interpreter service in the hospital.

1. TL/TM, how do you think your care may have differed had you/your TL been physically absent from you and the patient and located in another room while running the code?

2. TL/TM, how do you think your communication and teamwork would have differed had you/your TL physically been in the room?
3. TL/TM, do you think you would feel comfortable leading a code/being led in a code remotely via telemedicine in the future? Why/why not?

Thank you for participating. We ask that you don't mention this study to your colleagues, since they may very well become involved in the future.

STAT Instrument:

BASICS					
Task Group	**Task**	**Complete & Timely**	**Incomplete or Untimely**	**Needed & Not Done**	**Not Required**
History & Physical	Obtains SAMPLE history (signs/symptoms, allergies, meds, past illness, last meal, events preceding)	2	1	0	N/A
	Performs primary survey (ABCDE)	2	1	0	N/A
	Performs secondary survey (head to toe exam, including back)	2	1	0	N/A
Patient Weight	Estimates/obtains pt weight	2	1	0	N/A
Monitors	Ensures cardiorespiratory and O2 monitors placed	2	1	0	N/A
Access	Obtains or confirms vascular access	2	1	0	N/A
	Attempts IO access	2	1	0	N/A
Labs	Orders appropriate lab testing	2	1	0	N/A
	Responds to lab results appropriately	2	1	0	N/A
X-rays/ studies	Orders appropriate imaging	2	1	0	N/A
	Responds to radiological study results appropriately	2	1	0	N/A
Recognition	Recognizes urgent/emergent situation (either start of scenario or with decompensation)	2	1	0	N/A
Universal precautions	Team uses appropriate universal precautions	2	1	0	N/A
Consults	Contacts appropriate consults	2	1	0	N/A
Family	Directs updates to family	2	1	0	N/A

AIRWAY/BREATHING					
Task Group	**Task**	**Complete & Timely**	**Incomplete or Untimely**	**Needed & Not Done**	**Not Required**
Assessment	Assesses airway	2	1	0	N/A
	Assesses breathing	2	1	0	N/A
Basic intervention	Performs airway maneuvers	2	1	0	N/A
	Provides supplemental oxygen	2	1	0	N/A
	Uses appropriate adjunct airway	2	1	0	N/A
Bag- mask ventilation	Initiates BMV	2	1	0	N/A
	Bags at appropriate rate	2	1	0	N/A
	Assesses chest rise	2	1	0	N/A
	Uses proper BMV technique and positioning	2	1	0	N/A
Airway RSI	Selects appropriate premed	2	1	0	N/A
	Uses appropriate premed dose (Broselow or code sheet or dose)	2	1	0	N/A
	Selects appropriate sedative/induction medications	2	1	0	N/A
	Uses appropriate sedative/induction dose (Broselow or code sheet or dose)	2	1	0	N/A
	Selects appropriate paralytic medication	2	1	0	N/A
	Uses appropriate paralytic dose (Broselow or code sheet or dose)	2	1	0	N/A
Endotracheal Intubation	Initiates team efforts for endotracheal intubation	2	1	0	N/A
	Pre-oxygenates patient	2	1	0	N/A
	Selects appropriate endotracheal tube size	2	1	0	N/A
	Selects appropriate laryngoscope size	2	1	0	N/A
	Ensures suction is on	2	1	0	N/A
	Provides cricoid pressure: from BVM to intubation	2	1	0	N/A
	Uses appropriate endotracheal tube insertion	2	1	0	N/A
	Places endotracheal tube in trachea	2	1	0	N/A

	Secures endotracheal tube	2	1	0	N/A
Intubation assessment	Check end-tidal CO2	2	1	0	N/A
	Assesses ventilation: chest rise, auscultation	2	1	0	N/A
	Requests portable chest x-ray to confirm tube placement	2	1	0	N/A
Gastric Decompression	Places NG or OG tube after intubation	2	1	0	N/A

CIRCULATION					
Task Group	**Task**	**Complete & Timely**	**Incomplete or Untimely**	**Needed & Not Done**	**Not Required**
Basics	Assesses heart rate	2	1	0	N/A
	Assesses pulses	2	1	0	N/A
	Assesses blood pressure	2	1	0	N/A
	Assesses distal perfusion (cap refill)	2	1	0	N/A
Management	Initiates volume resuscitation	2	1	0	N/A
	Selects isotonic fluid	2		0	N/A
	Initiates appropriate IV fluid dose	2	1	0	N/A
	Ongoing fluid resuscitation as needed	2	1	0	N/A
CPR	Correct hand placement	2	1	0	N/A
	Correct rate of compressions	2	1	0	N/A
	Uses appropriate surface (backboard, floor)	2	1	0	N/A
	Uses appropriate ventilation: compression ratio	2	1	0	N/A
	Assesses quality of CPR (pulse check)	2	1	0	N/A
	Minimizes interruptions in CPR	2	1	0	N/A
Arrhythmia	Recognizes abnormal rhythm	2	1	0	N/A
	Initiates CPR	2	1	0	N/A
	Recognizes need for electricity	2	1	0	N/A
	Doses electricity correctly	2	1	0	N/A
	Places pads/paddles correctly	2	1	0	N/A

	Clears patient appropriately	2		0	N/A
	Delivers shock	2		0	N/A
	Continues CPR after shock delivered	2	1	0	N/A
	Follows PALS guidelines	2	1	0	N/A
	Doses meds appropriately	2	1	0	N/A
	Reevaluates rhythm after 5 cycles of CPR	2	1	0	N/A

HUMAN FACTORS (TEAM MANAGEMENT)					
Task Group	**Task**	**Complete & Timely**	**Incomplete or Untimely**	**Needed & Not Done**	**Not Required**
Team	All team members exhibit professional attitude and interactions	2	1	0	N/A
Leadership (Team Leader)	There is a clearly identified team leader	2	1	0	N/A
	Assigns roles to team members	2	1	0	N/A
	Maximizes skill sets of personnel in assigned roles	2	1	0	N/A
	Directs/Redirects team members effectively	2	1	0	N/A
	Monitors actions of team members	2	1	0	N/A
	Addresses specific persons when requesting info/assigning tasks	2	1	0	N/A
	Uses closed loop communication (orders directed & confirmed)	2	1	0	N/A
	Resolves conflicts	2	1	0	N/A
	Engages team members in decision making	2	1	0	N/A
	Recruits additional personnel when appropriate	2	1	0	N/A
	Maintains global view (does not get sidetracked by procedures, details)	2	1	0	N/A
	Performs tasks in appropriate sequence/ prioritizes well	2	1	0	N/A
	Reprioritizes for urgent/emergent events	2	1	0	N/A
	Avoids fixation errors (considers full differential for problems	2	1	0	N/A

	Provides interim summary/assessment for team	2	1	0	N/A
	Summarizes case for transfer of care	2	1	0	N/A
	Work-load balancing	2	1	0	N/A
Management (Team members)	Carry out tasks in appropriate sequence	2	1	0	N/A
	Stay in roles, appropriately	2	1	0	N/A
	Adjust roles to address urgent events, appropriately	2	1	0	N/A
	Verbalize questions/info to team leader	2	1	0	N/A
	Use closed loop communication (confirm orders, task completion)	2	1	0	N/A
	Ask for assistance if unable to complete task/balance workload	2	1	0	N/A
	Engage in decision making	2	1	0	N/A
	Suggest additional resources (personnel, etc) appropriately	2	1	0	N/A

TeamMonitor Tool:

Use the following scale to rate the team on each dimension:

0 = never/rarely 1 = inconsistently 2 = consistently n/a = not applicable

Note: Please rate conservatively: Most teams that have not worked extensively together do not demonstrate many of the qualities.

1.	Do you feel that the leader was recognized by all team members?	**0**	**1**	**2**	**n/a**
2.	Do you think the leader assured maintenance of an appropriate balance between command authority and team member participation?	**0**	**1**	**2**	**n/a**
3.	Do you feel that each team member demonstrated clear understanding of his/her role?	**0**	**1**	**2**	**n/a**
4.	Do you think team members prompted each other to attend to all significant clinical indicators throughout the scenario?	**0**	**1**	**2**	**n/a**
5.	Do you think team members verbalized their activities aloud when they were actively involved with the patient?	**0**	**1**	**2**	**n/a**
6.	Do you feel that team members repeated back or paraphrased instructions and clarifications to indicate that they heard them correctly?	**0**	**1**	**2**	**n/a**
7.	Do you feel that disagreement or conflicts among team members were addressed without a loss of situation awareness?	**0**	**1**	**2**	**n/a**
8.	Do you think roles were shifted to address urgent or emergent events when appropriate?	**0**	**1**	**2**	**n/a**
9.	Do you think team members responded to potential errors or complications with procedures that avoided the error or complication?	**0**	**1**	**2**	**n/a**

Modified rTLX Survey:

Mental Demand: How mentally demanding was the simulation?

| | | | | | | | | | | **|** | | | | | | | | | |

Very Low Very High

Physical Demand: How physically demanding was the simulation?

| | | | | | | | | | | **|** | | | | | | | | | |

Very Low Very High

Temporal Demand: How hurried or rushed was the pace of the simulation?

| | | | | | | | | | | **|** | | | | | | | | | |

Very Low Very High

Performance: How successful were you in accomplishing what you were asked to do?

| | | | | | | | | | | **|** | | | | | | | | | |

Perfect ***Failure***

Effort: How hard did you have to work to accomplish your level of performance?

| | | | | | | | | | | **|** | | | | | | | | | |

Very Low Very High

Frustration: How insecure, discouraged, irritated, stressed, and annoyed were you?

| | | | | | | | | | | **|** | | | | | | | | | |

Very Low Very High

Anxiety: How nervous, uneasy, or apprehensive did you feel?

| | | | | | | | | | | **|** | | | | | | | | | |

Very Low Very High

Demographics Information Survey:

Have you previously participated in a mock or real code with your fellow team member?	yes	no
Have you worked extensively with your team member (on service ≥1 month)?	yes	no
Have you participated in a formal teamwork/communication training program (e.g. TeamSTEPPS, MedTeams, CRM course)?	yes	no
Familiarity with communication/teamwork principles:	(low) | | | | | **|** | | | | | (high)	
Comfort in running a code/leading a team:	(low) | | | | | **|** | | | | | (high)	
Level of Training:	PGY-4 PGY-3 PGY-2 PGY-1	
Number of previous training sessions with a human patient simulator:	1 to 2 3 to 4	≥5
Participated in a mock code in the past 3 years?	yes	no
As Team leader?	yes	no
Participated in a real code in the past 3 years?	yes	no
As Team leader?	yes	no
Have you Practiced the Following Skills?		
BMV…		
…in Real codes	yes	no
…in Mock codes	yes	no
ETT intubation…		
…in Real codes	yes	no
…in Mock codes	yes	no
Venipuncture…		
…in Real codes	yes	no
…in Mock codes	yes	no
Intraosseus placement…		
…in Real codes	yes	no
…in Mock codes	yes	no
Defibrillation…		
…in Real codes	yes	no
…in Mock codes	yes	no
Comfort in performing pediatric advanced life support?	Uncomfortable Comfortable w/ active team role Comfortable w/ team leader role	
Importance of mock code training in preparation for performing pediatric advanced life support?	Not Important Neutral Very Important	
Importance of resuscitation skills in your future:	Not Important Neutral Very Important	