Closed-Loop Communication Improves Task Completion in Pediatric Trauma Resuscitation

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BACKGROUND: Pediatric trauma care requires effective and clear communication in a time-sensitive manner amongst a variety of disciplines. Programs such as Crew Resource Management in aviation have been developed to systematically prevent errors. Similarly, teamSTEPPS has been promoted in healthcare with a strong focus on communication. We aim to evaluate the ability of closed-loop communication to improve time-to-task completion in pediatric trauma activations.

METHODS: All pediatric trauma activations from January to September, 2016 at an American College of Surgeons verified level I pediatric trauma center were video recorded and included in the study. Two independent reviewers identified and classified all verbal orders issued by the trauma team leader for order audibility, directed responsibility, check-back, and time-to-task-completion. The impact of pre-notification and level of activation on time-to-task-completion was also evaluated. All analyses were performed using SAS® version 9.4(SAS Institute Inc., Cary, NC).

RESULTS: In total, 89 trauma activation videos were reviewed, with 387 verbal orders identified. Of those, 126 (32.6%) were directed, 372(96.1%) audible, and 101 (26.1%) closed-loop. On average each order required 3.85 minutes to be completed. There was a significant reduction in time-to-task-completion when closed-loop communication was utilized ($p < 0.0001$). Orders with closed-loop communication were completed 3.6 times sooner as compared to orders with an open-loop [HR = 3.6 (95% CI: 2.5, 5.3)]. There was not a significant difference in time-to-task-completion with respect to pre-notification by emergency service providers ($p < 0.6100$). [HR = 1.1 (95% CI: 0.9, 1.3)]. There was also not a significant difference in time-to-task-completion with respect to level of trauma team activation ($p < 0.2229$). [HR = 1.3 (95% CI: 0.8, 2.1)].

CONCLUSION: While closed-loop communication prevents medical errors, our study highlights the potential to increase the speed and efficiency with which tasks are completed in the setting of pediatric trauma resuscitation. Trauma drills and systems of communication that emphasize the use of closed-loop communication should be incorporated into the training of trauma team leaders.

LEVEL OF EVIDENCE: This is a prospective observational study with intervention level II evidence. (J Surg Ed 75:58-64. © 2018 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: pediatric trauma, trauma video review, closed-Loop communication, time to task completion, trauma team leader

COMPETENCIES: Interpersonal and Communication Skills

BACKGROUND

In health care, effective teamwork and communication are central to patient safety.[1] In the 1990s, the Institute of Medicine highlighted the effect of poor communication on health care outcomes.[2] Poor outcomes involving preventable incidents are usually a result of multiple human factors, and not a mistake by a single person.[3-6] As expressed by Reason et al.[7] every step in a process has potential for failure. Often, these failures are because of poor communication. According to Control Risk Insurance Company over 30% of malpractice awarded suits, where a patient is injured or killed, have miscommunication to blame.[8] Gaps in communication have

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been identified during patient handoff between departments or within a department, in interdisciplinary teams where misunderstandings, language difficulties, misinterpretations, and hesitations to speak up have been reported.[4,5,9-14]

As a defense against communication breakdown, many standardized schemes of communication have been developed.[15-18] The aviation industry has developed team training concepts, such as Crew Resource Management, that systematically increase safety and prevent errors through improvement in effective communication.[19-21] This is achieved by standardizing terminology and procedures. The term closed-loop communication, originating from military radio transmissions, is a standard terminology used to describe a team's ability to deliver concise information (the call out), confirm reception of information (the check back), and acknowledge correct understanding of information (closing the loop).[22] During simulation training comparing communication patterns between flight crews, Browers et al. found that high-performing crews used more closed-loop communication as compared to low-performing crews.[23] This is not only evident in high-reliability fields such as aviation and the nuclear industry, but also translates into obstetrics, anesthesia, emergency medicine, and military health care.[24-27] Closed-loop communication has been used successfully by teams in medicine to maintain clear communication and decrease preventable errors.[16]

Clear communication in the midst of trauma resuscitation encompasses many fundamental aspects of team dynamics and collaboration oriented toward a common goal.[12,28,29] Pediatric trauma resuscitations may not always succeed in achieving this common goal with Burd et al. reporting over 337 errors in 39 pediatric trauma activations. In fact, 51% of the errors were never acknowledged or compensated for by the team.[30] The Department of Defense and the Agency of Healthcare Research and Quality developed Team Strategies and Tools to Enhance Performance and Patient Safety to improve the quality, safety, and efficacy of health care communication with significant emphasis on closed-loop communication.[31] Within the trauma community, the American College of Surgeons sets the standard for systematic care of the injured patient with the establishment of the Advanced Trauma Life Support program, but fails to include the importance of closed-loop communication. In this study, we evaluated the effect of closed-loop communication on the time required to complete a given task in pediatric trauma resuscitations. We hypothesize that closed-loop communication has the potential to improve the safety and efficiency of the care provided during pediatric trauma activations.

METHODS

This study was approved by the Northwell Health Institutional Review Board. All trauma activations at Cohen Children's Medical Center; an American College of Surgeons verified level 1 free-standing pediatric trauma center in the greater New York City area, from January to September 2016 were included in the study. All training activations were excluded from the study. TruVision Navigator 5.0 by Interlogix was used for trauma video review. Each trauma room is equipped with 3 high definition ceiling cameras and a microphone. Facility response guidelines direct responders to wear appropriate role identification stickers during trauma team activations. Trauma team leader sticker (bright pink in color) was used to properly identify the team leader for this study. In different activations, the team leader role may be filled by an attending pediatric surgeon or pediatric surgery fellow, surgical resident, emergency medicine attending, pediatric emergency medicine fellow, or emergency medicine resident. All verbalized orders articulated by the team leader were identified and evaluated for audibility, directed responsibility to a team member, and check-back by team member. Time from order call out to order completion was calculated. Closed-loop orders were defined as audible, directed to a team member, check-back by the team member, and acknowledgment by team leader. We recorded a description of task completed, the level of activation, and whether team members had prenotification from emergency medical services (EMS) personnel before the patient arrival.

Statistical Methods

A separate Cox proportional hazards model for time-to-task-completion was carried out controlling for type of communication (open- or closed-loop), prenotification (yes or no), team leader type, and level of activation (I/II). For each model, the robust sandwich estimate of the covariance matrix was used to adjust for the correlation among multiple trauma events that occurred in a given day. A generalized linear mixed model for binary clustered data was used to model closed-loop (yes or no) separately as a function of prenotification (yes or no) and level of activation

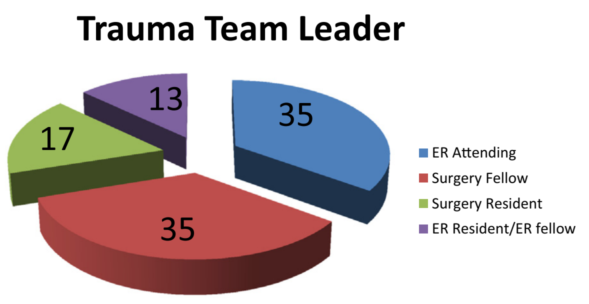

FIGURE 1. Trauma team leader. The role of trauma team leader was filled by a variety of specialists. The pediatric surgery fellow and emergency room attending were most frequently the trauma team leader.

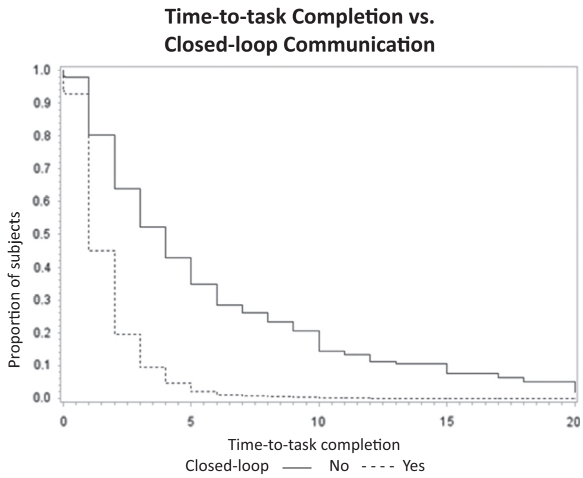

FIGURE 2. Time-to-task completion vs. closed-loop communication. Using a Cox proportional hazard model, team leader orders using closed-loop communication (dash line) were compared with open-loop communication (solid line) and time-to-task completion in minutes. Closed-loop was orders that were completed 3.6 times faster than open-loop communication.

(I/II). Generalized linear mixed model was used to account for the clustered (i.e., hierarchical) nature of the data; namely, multiple trauma events within a day. Mann-Whitney *U* test was applied to compare time-to-task completion for medication orders, placement of intravenous lines, obtaining laboratory test results, and administration of intravenous fluids. We used predicted survival curves for the set of covariate values of interest and based them on the adjusted Cox models. A result was considered statistically significant at the $p < 0.05$ level of significance. All analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC).

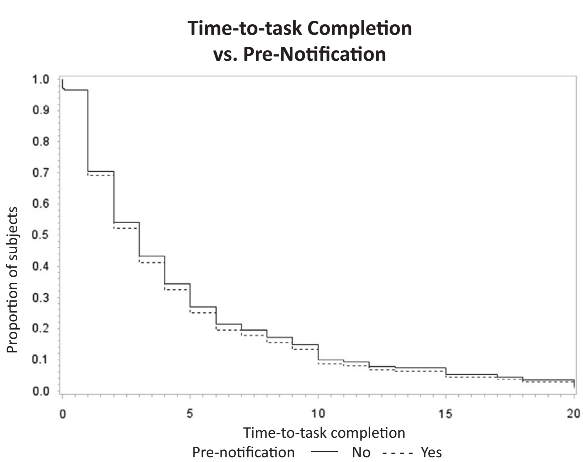

FIGURE 3. Time-to-task completion vs. prenotification. A Cox proportional hazard model comparing the proportion of team leader orders with prenotification (dash line) and no prenotification (solid line) and time required to complete each task. Prenotification did not demonstrate a significant difference on time-to-task completion.

RESULTS

In total 89 trauma activations were reviewed, 8 level I activations and 81 level II activations. Prenotification was seen in 44 activations (49.4%). The pediatric surgery fellow was the trauma team leader in 31 activations; the emergency room (ER) attending in 31 of the activation. The general surgery residents were identified as trauma team leader in 15 activations; whereas the remainder were lead by an emergency medicine fellow or resident (Fig. 1). In total, we observed 387 orders verbalized by the trauma team leaders. Of those, 126 (32.6%) were directed, 372 (96.1%) were audible, and 101 (26.1%) were closed-loop. Time required for task completion ranged from 0 to 20 minutes with a median of 2 minutes (interquartile range [IQR]: 1–5 min).

Closed-Loop Communication Resulted in Significant Improvement in Time-to-Task Completion

Time required for task completion for orders using closed-loop communication ranged from 0 to 12 minutes with a mean time of 1.53 minutes, median of 1 minute (IQR: 1–1 min). In comparison, orders without closed-loop communication had a mean task completion time of 4.68 minutes, median of 3 minutes (IQR: 2–6 min). A Cox proportional hazards model demonstrated a significant difference in time-to-task completion with respect to closed-loop communication (Y vs. N) ($p < 0.0001$). Orders with closed-loop communication were completed 3.6 times sooner as compared to orders without closed-loop communication (hazard ratio [HR] = 3.6 [95% CI: 2.5–5.3]) (Fig. 2).

EMS Prenotification and Level of Trauma Team Activation did not Demonstrate a Significant Difference for Time-to-Task Completion

Prenotification was identified by documentation of EMS prenotification or viewing of team preparationbefore the patient arrival in 49% of trauma activations. Prenotification did not have a significant effect on time-to-task completion ($p < 0.6100$) (HR = 1.1 [95% CI: 0.9–1.3]) (Fig. 3). Level I activation did not demonstrate a significant difference in time-to-task completion compared to a level II activation ($p < 0.2229$) (HR = 1.3 [95% CI: 0.8–2.1]) (Fig. 4).

Rate of Closed-Loop Communication was Not Significantly Affected by Level of Trauma Team Activation or EMS Prenotification

A significant difference was not seen in the rate of closed-loop communication use between prenotification and non-prenotification trauma team activations (24.8% vs. 23.3%,

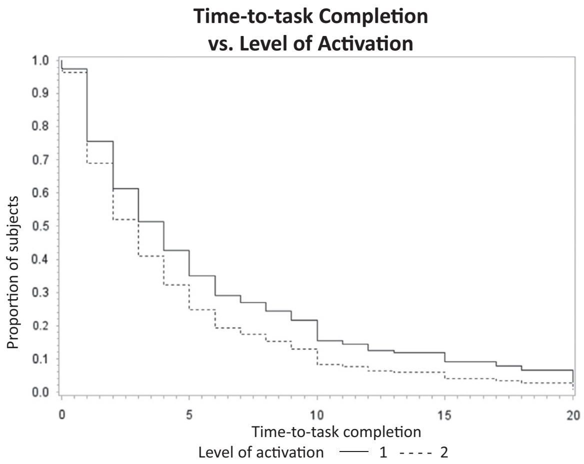

FIGURE 4. Time-to-task completion vs. level of activation. A Cox proportional hazard model comparing the proportion of team leader orders based on level of activation I (solid line) vs. II (dash line) and time required to complete each order. Trauma activation level did not have a significant effect on time-to-task completion.

respectively, $p < 0.7862$). Level of activation (level 1 vs. level 2) did not show a significant difference in the rate of closed-loop communication usage (33.8% vs. 23.2%, respectively, $p < 0.2344$).

Closed-Loop Communication Made a Significant Difference in Time-to-Task Completion for Medication Orders, Placement of Intravenous Lines, and Obtaining Laboratory Test Results

Out of the total call outs observed during video review ($n = 387$), 4.1% ($n = 16$) were medication orders, and 38% ($n = 6$) of those orders were completed with closed-loop communication. Medication orders completed via closed-loop communication had a mean time to completion of 1 minute compared to 4.5 minutes for orders without closed-loop communication ($p < 0.00221$). Intravenous line placement was ordered 22 times by the trauma team leader, 13.6% of which ($n = 3$) used closed-loop communication. Placement of an intravenous line on average required 3.5 minutes when not using closed-loop communication vs. 1 minute with closed-loop ($p < 0.00968$). Laboratory test results were ordered by the trauma team leader 34 times, 20.5% ($n = 7$) completed using closed-loop communication in 1.9 minutes compared to the 5.7 minutes when closed-loop was not used ($p < 0.00286$). Administration of intravenous fluids did not show a significant difference in time-to-task completion for closed-loop communication with a total of 15 orders for intravenous fluids and only 1 using closed-loop communication as shown in the Table.

Trauma Team Leader Type Showed a Significant Difference in Time-to-Task Completion

There was a significant difference in time-to-task completion with respect to trauma team leader status ($p < 0.0001$). Out of the total 387 orders articulated: 178 were by the pediatric surgery fellow, 110 by the ER attending, 50 by the surgery resident, 32 by the ER fellow, 10 by surgery attending, and 7 by ER residents. Using ER attending as the reference, pediatric surgery fellows were 1.4 times more likely to complete the task sooner (HR=1.4 [95% CI: 1.1–1.8]), ER Fellows were 1.3 times more likely to complete the task sooner (HR=1.3 [95% CI: 0.8–2.0]), and surgery residents were roughly the same as ER attending with respect to time-to-task completion [HR=1.0 (95% CI: 0.7–1.4)]. Pediatric surgery attending and ER resident data were not included for this analysis because of the small sample size (Fig. 5).

There Was Not a Statistically Significant Difference in the Rate of Closed-Loop Communication Among the Trauma Team Leaders

When evaluating the rate of closed-loop communication between different categories of trauma team leaders using type III tests of fixed effects, we found no significant difference ($p < 0.2786$). Pediatric surgery fellows were the most likely to use closed-loop communication with a 30% rate.

DISCUSSION

Our study used a review of trauma resuscitation videos to demonstrate a reduction in the time required for task

TABLE. Comparison of Closed-Loop Communication by Task

Task Description	Total Number	% Completed by Closed-Loop	Time-to-Task Completion (Min)		Mann-Whitney *U* Test (p Value)
			Closed-Loop	Open-Loop	
Medication	16	37.5	1	4.5	0.0022
IV placement	22	13.6	1	3.5	0.0097
Laboratory test results	34	18.9	1.9	5.7	0.0029
Intravenous fluids	15	6.7	1	3.7	0.287

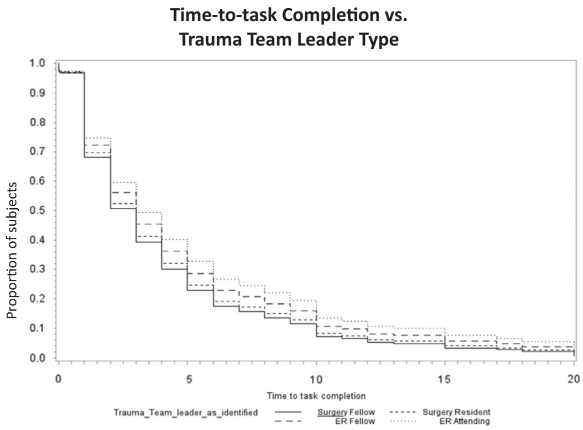

FIGURE 5. Time-to-task completion vs. trauma team leader type. Using adjusted Cox models we compared trauma team leader type and time-to-task completion. We found a significant association with trauma team leader and time-to-task completion with surgery fellows having tasks completed 1.6 times faster than other team leaders while using emergency room attending as the baseline.

completion, during pediatric trauma activations when closed-loop communication is used. We further demonstrate a significant difference in the time required to complete medication orders, placement of intravenous lines, and obtaining blood for laboratory evaluation. No significant change was seen in orders requesting the administration of intravenous fluids likely owing to the limited number of intravenous fluids ordered by closed-loop communication during the study period. Taken together, our study highlights the potential to increase the speed and efficiency with which tasks are completed in the setting of pediatric trauma resuscitations.

We used trauma team activation level as a surrogate for urgency and stress, with level I as the highest activation response at our facility. With potential life threatening injuries, the importance of completing orders and tasks accurately and expeditiously might be amplified. Interestingly, the level of activation did not have a significant effect on either time-to-task completion or frequency of tasks completed using closed-loop communication. We would like to suggest that how you communicate is more important than the urgency of the event, but this current study might be underpowered for level I trauma team activations having only 8 of these activations out of the total 89.

Prenotification of the trauma team by EMS personnel facilitates preparation and organization in a busy trauma center.[32] Direct benefits of prenotification have been published in stroke and cardiac events.[33,34] EMS teams report a great deal of information from the field, often providing accurate and required information to the trauma team.[35] Prenotification did not have a significant effect on either time-to-task completion or frequency of orders completed using closed-loop communication in our study. Other studies have found an indirect effect of prenotification on time-to-task completion.[36] Prenotification and level of trauma urgency may affect the team size and impact the time to-task-completion. It has been suggested that the optimal team size of 7 during pediatric traumas shows the greatest efficiency in completing tasks.[36] We did not measure team size in our study and focused our analysis on the role of the team leader that could be viewed as a limitation. Another potential limitation of this study was the usage of trauma video review as opposed to live evaluation of activations. Our video system uses 3 cameras and a highly sensitive microphone, but there is still a potential for missing a communication owing to room noise level and camera obstruction.

Trauma team leader as categorized by training and specialty was associated with time-to-task completion. Interestingly, the pediatric surgical fellow and emergency medicine fellow categories had a significantly shorter time to time-to-task completion when compared to the ER attending role. Although the use of closed-loop communication when compared to team leader category was not significant, the pediatric surgery fellows did demonstrate the highest rate of closed-loop communication of all the groups. In a Swedish simulation study evaluating trauma communication, education level and experience were both factors in the usage of closed-loop communication.[39] Taken together, our current study suggests that the level of training is not as important as the method of communication. Given the differences in language, culture, educational models, and systems of trauma care between the United States and European centers, additional studies would be required to further clarify the optimal trauma team leader's level of training and education.

Studies of team resuscitation dynamics show an understanding of the need for closed-loop communication by using it in training sessions, but a contradictory failure to implement closed-loop communication in real resuscitations.[37] The trauma team leaders in this study only used closed-loop communication in 26% of their orders. Future efforts focus on drilling the use of closed-loop communication and highlighting the benefits of this approach to trauma team members. Perhaps some individuals believe that closed-loop communication will decrease team efficiency by team hindering their ability to complete tasks by requiring added communication steps.[37] Our trauma team leaders were identified as they entered into the trauma bay with a color-coded name tag. Additional providers verbally initiating orders during resuscitation and the effect of multiple conflicting orders were not included in this study. Other studies have used the nontechnical skills adapted for trauma system modified from the aviation community and the operating room to evaluate all team members during trauma activations.[38] Trauma nontechnical skills uses a point system to look at leadership, cooperation, communication, assessment, and situational awareness, but does not directly evaluate the use of closed-loop communication and time-to-task completion.[38]

Closed-loop communication can systematically prevent errors, improving patient safety and outcomes. This study further highlights the importance of closed-loop communication by demonstrating a significant improvement in the efficiency of completing many tasks. We plan to increase usage of closed-loop communication at our institution by highlighting the benefits to patient care. One approach to achieve increased closed-loop communication might be an even greater emphasis within Advance Trauma Life Support training to include the communication aspects used with in Team Strategies and Tools to Enhance Performance and Patient Safety. We suggest that trauma drills and systems of communication that emphasize the use of closed-loop communication should be further incorporated into the training of trauma team leaders.

AUTHOR'S CONTRIBUTION

Ibrahim Abd El-Shafy, the primary author, was involved in all aspects of the study from data collection, data analysis, and compiling of manuscript. Jennifer Delgado assisted in data collection and preparation for statistical analysis. Meredith Akerman was integral in advising on study design and conducting all statistical analysis. Francesca Bullaro advised on study design and manuscript revision. Nathan A. M. Christopherson and Jose M. Prince were integral in reviewing and advising on all aspects of the study including development, data collection, and manuscript preparation.

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