Scenario-Based Evaluation of Team Health Information Technology to Support Pediatric Trauma Care Transitions

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Abstract

Background Clinicians need health information technology (IT) that better supports their work. Currently, most health IT is designed to support individuals; however, more and more often, clinicians work in cross-functional teams. Trauma is one of the leading preventable causes of children's death. Trauma care by its very nature is team based but due to the emergent nature of trauma, critical clinical information is often missed in the transition of these patients from one service or unit to another. Teamwork transition technology can help support these transitions and minimize information loss while enhancing information gathering and storage. In this study, we created a large screen technology to support shared situational awareness across multiple clinical roles and departments.

Objectives This study aimed to examine if the Teamwork Transition Technology (T^3) supports teams and team cognition.

Methods We used a scenario-based mock-up methodology with 36 clinicians and staff from the different units and departments who are involved in pediatric trauma to examine T^3.

Results Results of the evaluation show that most participants agreed that the technology helps achieve the goals set out in the design phase. Respondents thought that T^3 organizes and presents information in a different way that was helpful to them.

Conclusion In this study, we examined a health IT (T^3) that was designed to support teams and team cognition. The results of our evaluation show that participants agreed that T^3 does support them in their work and increases their situation awareness.

Keywords
- team health information technology
- team cognition
- scenario-based evaluation
- pediatric trauma
- care transitions

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Background and Significance

The design and implementation of usable and useful health information technology (IT) remains challenging.[1] Engaging end users in health IT development and evaluation is critical to ensure that these technologies don't have a negative impact on clinician workflow and lead to frustration and burnout.[2,3] In particular, user-centered approaches are needed to design and evaluate technologies before they are actually implemented. While such approaches have been used to develop health IT to support the work of individuals (e.g., individual clinician interactions with clinical decision support systems [4] and computerized medication alerts,[5] limited research has tackled the design of team-oriented health IT.[1] By team-oriented health IT, we mean the use of health IT to support the information needed by a team of people to care for a single patient.

Integrated displays are one type of health IT that can support the work of teams. These displays have been used to facilitate information sharing and improved team cognition during resuscitation in the emergency department (ED)[6,7] or the intensive care unit (ICU)[8] and to manage patient flow in the adult[9,10] or pediatric ED.[11] However, teams studied in previous research were restricted to a limited number of clinicians (primarily physicians and nurses) who cared for patients on a single service or unit (e.g., ED or ICU). As health care teams become larger and are increasingly required to work together across services and units,[12] there is a need to develop health IT to address the unique information needs of multiple team members across different roles and units (e.g., ED nurse, respiratory therapist, and pediatric intensive care unit [PICU] attending). Integrating the various needs of different end users represents a major challenge for team health IT design and implementation.

Large multidisciplinary clinical teams, such as pediatric trauma teams that include ED, operating room (OR), and ICU subteams, may particularly benefit from health IT to support team cognition, shared mental models, and situational awareness regarding a patient's past, current, and future status.[13–15] Using a collaborative design approach, a process that brings together team members with different ideas, roles, and backgrounds, we created health IT tool mockup aimed at supporting team cognition for the many clinicians involved in pediatric trauma care across units called the Teamwork Transition Technology or T^3.[16] In an ideal situation, T^3 is an integrated display projected on a very large screen, near the bed of the patient in the trauma bay, or in another central location, so that all trauma team members can see a summary of the information about the patient's status and next care transitions. The same information can also be displayed on monitors in the OR and PICU as to better prepare clinicians in those units. In this study, we used scenario-based evaluation to assess end-user perceptions of T^3.

Background

Pediatric Trauma Care

Trauma is the leading cause of injury and death in children and teenagers in the United States.[17–19] The most common unintentional injuries vary by age and gender and include burns, drowning, falls, fires, poisoning, suffocation, gunshot wounds, and motor vehicle, bicycle, and pedestrian-related accidents. The most severe injuries need treatment in the ED. There were more than 30 million pediatric ED visits in 2015.[18–21] More than 3% or nearly a million of those children are admitted to the hospital[20,21] to receive additional care such as surgery or for observation.

Patient care in the ED is characterized by high acuity patients, intense pressure, possible life-threatening situations, unpredictable patient arrivals, and many interruptions.[9,12,13,15,22] Care of pediatric trauma patients can be even more complex and often involves a very large care team as it is a complex process. Clinicians working in different units and services (e.g., ED, OR, and PICU) with multiple roles (e.g., nurses, surgeons, anesthesiologists, or intensivists) come together in the ED trauma bay to provide the best possible care for the injured child. Results of our prior research show that up to 50 clinical roles can be involved in the care of a single pediatric trauma patient, and that pediatric patients can be transferred up to 25 times between multiple units or services.[12,23] Pediatric trauma patients are particularly vulnerable during care transitions because children cannot always express themselves and information about patient care may not be available or accessible, not transferred, and transferred information may not be complete.[24] This suboptimal flow of information can lead to serious patient safety risks, such as delays in care or missed injuries.[25]

Design of the Teamwork Transition Technology

The development of T^3 relied on an extensive analysis of work system barriers and facilitators in the pediatric trauma care process. We first identified team cognition as a key barrier and patient safety risk during transitions of pediatric trauma patients.[12,14,15] We then used a collaborative design approach[26] to design T^3 with clinicians from the ED, OR (surgery and anesthesia), PICU, pediatric hospital medicine, and medical informatics who participated in a process led by human factors experts.

The design goals of T^3 formulated at the start of the study were to:

- Provide a timely, up-to-date summary of clinical patient information and status to a broadly distributed care team during patient transition from the ED to OR or PICU.
- Help identify care team members involved in the ED to OR or to PICU transition.
- Support communication, coordination, and anticipation between sending (ED) and sending and receiving (OR and PICU) units such as when the OR is ready to receive the patient, if the patient is still in the ED, what medications need to be prepared, and others.

We created a mock-up of T^3 consisting of a patient information banner at the top resembling the electronic health record (EHR), three columns in the middle, and a timeline at the bottom of the screen (►Fig. 1). The three columns in the middle of represented past patient status (left), current status (middle), and future status (right hand column), thereby

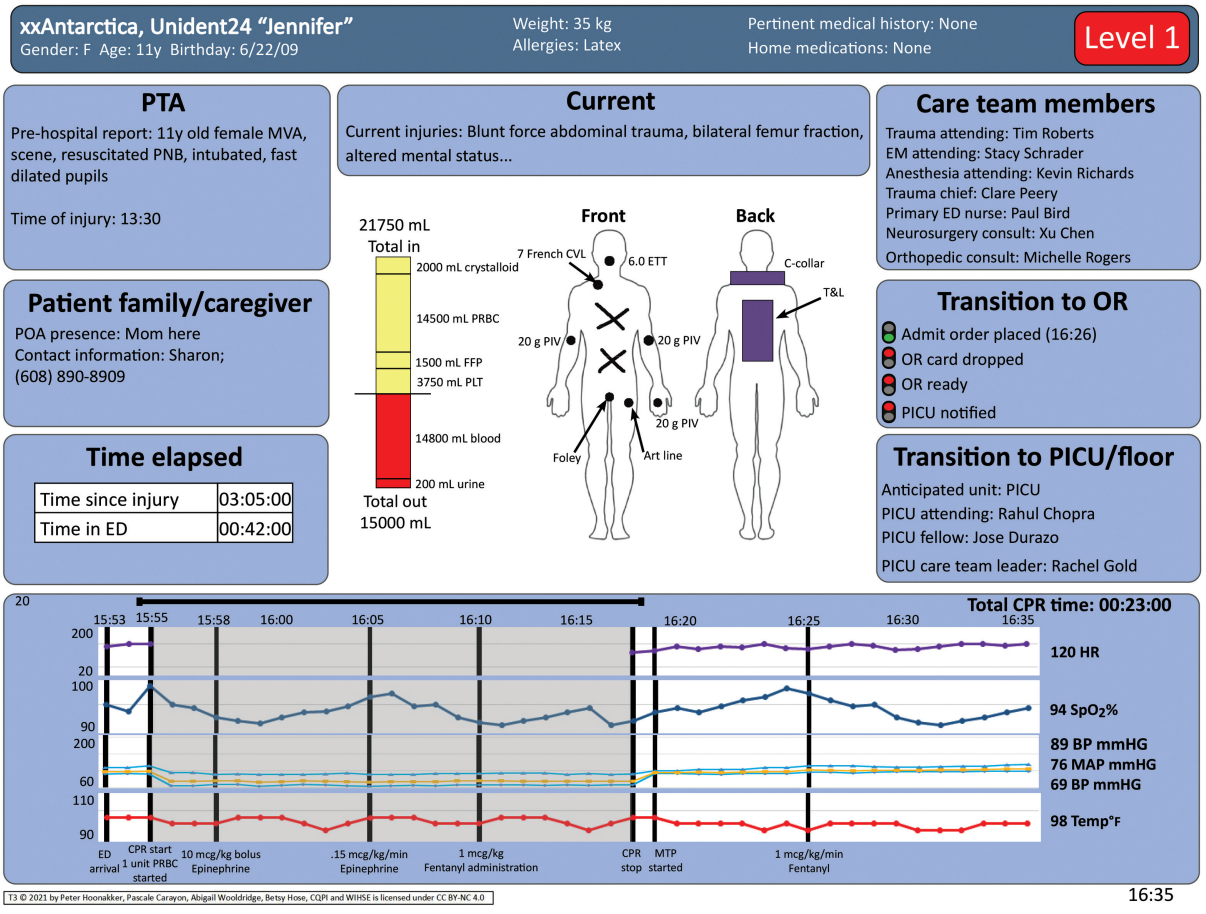

Fig. 1 Teamwork transition technology (T^3). BP, blood pressure; CPR, cardiopulmonary resuscitation; ED, emergency department; EM, emergency medicine; FFP, fresh frozen plasma; HR, heart rate; MAP, mean arterial pressure; OR, operating room; PICU, pediatric intensive care unit; PLT, platelets; PNB, pulseless non-beathing; POA, power of attorney; PTA, prior to arrival; PRBC, packed red blood cell.

supporting the three stages of situational awareness.[27] The left column had three boxes as follows: (1) the information received prior to arrival (PTA), (2) the presence of a caregiver, and (3) the time elapsed since the injury and in the ED. The middle column had a text box with current injuries and a figure that summarized the amount of fluids in and out and a mannequin. On the mannequin, the injuries are indicated as well where peripheral intravenous lines (PIV) are placed with gauge sizes (e.g., 22-ga PIV). The column on the right summarized that the care team members present in the ED, who may be involved in future care, and traffic lights for the transition to the OR or PICU. Finally, the timeline at the bottom of the screen summarized trends in vital signs and reactions to major events on the timeline such as administration of fentanyl (a strong opiate pain medication). An estimated 90% of all information on T^3 can be directly drawn from information in the EHR. The additional 10% of information can be provided by one of the ED nurses whose main task is to document during trauma cases. More details about the design of T^3 can be found in Hose et al and Carayon et al.[28,29]

The objective of this study was to examine team member experiences with and perceptions of a mock-up of the T^3, whether it met its design goals and its potential impact on team situational awareness during care transitions and patient safety (►Fig. 1).

Methods

Study Design

We assessed the experience and perceptions of various clinicians regarding the mock-up of T^3 in a scenario-based evaluation. Clinician members of the multifunctional trauma teams who were not involved in the design of T^3 were invited to participate. They provided information about their perceptions of the different elements and usability of T^3, the extent to which T^3 supported a shared mental model, and the potential impact of T^3 on care transitions and patient safety.

We used a scenario-based methodology to evaluate the T^3 mock-up. This methodology consisted of three parts: a realistic patient scenario based on several real pediatric trauma cases, a participant survey and debriefing interview. The scenario described an injured child arriving in the ED and receiving care from the multidisciplinary trauma team until the decision to transfer the child to the OR and subsequently to the PICU. A researcher read the scenario and showed participants how the information on T^3 would change during these points of time. After completing the while scenario, the researcher administered a survey to capture participant perceptions of T^3 and conducted a debriefing interview which provided illustrative quotes to support quantitative survey data.

Before implementing the scenario-based methodology, we first tested it in a pilot study with seven subject matter experts (SMEs). Based on the results, we made minor changes to the methodology. For example, we changed the team composition in the scenario. We removed neurosurgery because, in this case, the child did not suffer from neurological complaints. Before filling out the survey, we emphasized that we were not testing participants' clinical knowledge, but how they would use T^3 in practice. We did not make any changes to the survey or the debriefing interview.

Sample and Setting

The study took place in an academic hospital in the Mid-West United States. The participating hospital is an American College of Surgeons–certified level-1 pediatric and adult trauma center[30,31] with an 87-bed children's hospital, 8 pediatric ORs, a 21-bed PICU, and an 11-bed pediatric ED. Health care professionals, that is, nurses, physicians, and support staff, in the ED, OR, and PICU were involved in the study, as they are most frequently involved in the care of these patients. Pediatric trauma care is initiated in the ED where a specialized pediatric trauma team cares for the patient. After care is provided in the ED, the patient may be transferred to another unit or be discharged. Data collection occurred between August 2019 and October 2019. We used purposive sampling, a form of nonprobability sampling in which researchers rely on their own judgment when choosing members of the population to participate in their study (Campbell, no. 240)[32] to interview 12 groups of clinicians which represented the 12 roles primarily involved in pediatric trauma care starting in the ED, all the way to the PICU. Potential participants, who were not involved in the design of T^3, were suggested by clinicians on the research team and nursing leaders and recruited over e-mail. Participation was voluntary, and all participants provided verbal consent. Thirty-six clinicians took part in the study (►Table 1).

Table 1 Study participants characteristics ($n = 36$)

Service/unit	Role	Number of participants
Emergency department (ED)	ED attending physician	3
	ED resident	3
	ED nurse	3
Operating room (OR)	Anesthesiology attending	3
	Anesthesia resident	3
	Anesthetist	3
	OR nurse	3
	Surgery attending	3
	Surgery resident (trauma chief)	3
	Surgical technician	3
Pediatric intensive care unit (PICU)	PICU attending physician	3
	PICU nurse	3
Age (y)		
	<30	6 (16.7%)
	30–39	16 (44.4%)
	40–49	9 (25.0%)
	50–59	4 (11.1%)
	≥60	1 (2.8%)
Gender	Female	18 (50%)

Procedure

The researcher first gave a short introduction to the study and then, using a figure of T^3, explained the different aspects of T^3 (e.g., different sections of T^3 such as past, current, and future state, timeline, and others). Then she read out loud the patient scenario. The patient scenario described six different stages of a pediatric trauma case as follows: (1) prior to ED assessment, (2) 10 minutes (13:09) after arrival to the ED, (3) 15 minutes after arrival (13:14), (4) 21 minutes after arrival (13:20), (5) 32 minutes after arrival (13:31), and (6) 38 minutes after arrival and just before transfer to the OR (13:41). Each stage of the scenario was associated with descriptive text (e.g., "The trauma attending requests the primary ED nurse to grab 1 unit of packed red blood cells and 1 unit of fresh frozen plasma (FFP) from the emergent blood refrigerator due to hypotension and tachycardia") and a picture of what T^3 would look like at that moment. When reading the text for each stage, the researcher would point out different aspects of the scenario in the picture. For example, when reading this part of the script, "The ED tech places a PIV in the girl's left antecubital," the researcher would point to mannequin in the picture of T^3 where a black dot would indicate the access point (PIV) in the girl's left arm. After finishing the scenario part of the evaluation, the researcher administered a survey and conducted a short debriefing interview about things that the participant liked and disliked about T^3. The pediatric trauma case scenario can be found in ►Appendix A. The University's Institutional Review Board (IRB) approved the study protocol.

Data Collection

We designed a survey to measure clinician perceptions of whether T^3 achieved its design goals and its potential impact on situational awareness and patient safety. The seven questions about goal achievement (e.g., support a shared mental model between care team members) were designed by the researchers and were based on a (single) question in the Canada Health Infoway Survey.[33] Internal consistency of this 7-item goal achievement scale that we created was 0.92. The 10 questions assessing situational awareness were inspired by a (single) question in the Post-Electronic Health Record Implementation Survey, developed by the New York City Department of Health and Mental Hygiene[34] and were applied to measure the macrostructure of T^3. Cronbach's α of this 10-item

situational awareness scale that we created was 0.92. Three items on patient risks were proposed to be included in the Agency for Healthcare Research and Quality (AHRQ) patient survey[35] but were not included in the final version of the AHRQ survey. Cronbach's α of this patient safety scale was 0.89. The survey also included items assessing clinician age, gender, role, and service/unit. The survey was programmed in Qualtrics (Version 112020 of Qualtrics. Copyright [2020] Qualtrics and administered on a tablet right after the researcher presented the patient scenario (the full survey can be found here: *https://cqpi.wisc.edu/wp-content/uploads/sites/599/2019/11/T3-Evaluation-Mock-Up-Survey-Tool-Physicians.pdf*).

After participants completed the survey, we conducted a short, semistructured debriefing interview with the following three main questions: (1) what do you like about T^3?, (2) what do you dislike about T^3?, and (3) how does T^3 fit in the work system? (the full interview guide can be found here: *https://cqpi.wisc.edu/wp-content/uploads/sites/599/2019/11/Teamwork-Transitions-Technology-T3-for-Pediatric-Trauma-Patients-Interview-Guide.pdf*).

Data Analysis

We imported survey data in SPSS (Version 25.0. IBM SPSS Statistics for Windows, Armonk, New York, United States) for quantitative analyses and computed descriptive statistics. We tested internal consistency of the scales we created. The scales in the survey were used to compare different clinician types (attending physicians, resident physicians, and other clinicians) and respondents working on different units and services (i.e., ED, OR surgery, OR anesthesia, and PICU). Analysis of variances (ANOVAs) were used to test for statistically significant differences between job titles and units/services. The debriefing interviews were transcribed and data were imported into Dedoose, a web-based qualitative analysis software (Los Angeles, California, United States: SocioCultural Research Consultants, LLC, version 8.3.43). Debriefing data were coded to a predetermined coding scheme listed below:

1. Whether participants liked or disliked aspects of T^3 made suggestions for improvement.
2. The design goal that was addressed (e.g., provide timely summary, support communication, and others).
3. The specific part of T^3 that they addressed (e.g., mannequin, banner, timeline, and others).

Two HFE researchers independently coded one transcript, and then met to review and resolve discrepancies. The same researchers then independently coded a second transcript, and met to review discrepancies; at this point, there were minimal differences, and one researcher coded the remaining interview transcripts.

Results

Study Participants

►Table 1 summarizes the characteristics of the 36 clinicians who participated in the study. Fifty percent of the participants were female, all were native English speaking.

Teamwork Transition Technology and Design Goals

Overall, respondents agreed that T^3 helped achieve the goals that set out to support (►Fig. 2). Most respondents agreed with the statement that T^3 helped achieve a shared mental model between care team members (92%). A smaller percentage (64%) agreed that T^3 helped them make patient care decisions or recommendations in a timely manner. There were no statistically significant differences between respondents working in different job titles or services and units.

As one of the interviewees said, "I think the things that are really important are have kind of a way of unifying information distribution amongst all the parties on the team so that everybody has the same information available to them during a trauma resuscitation …." (ED resident)

Teamwork Transition Technology and Situational Awareness

Results in ►Fig. 3 show that, overall, participants agreed that the design elements of T^3 helped them quickly identify different aspects of the patient's past and current medical condition, as well as the next steps in the patient's care.

There were no statistically significant differences between respondents working in different job titles or services and units in how they perceived that T^3 supported situational awareness.

During the interviews, participants mentioned several elements of T^3 that contributed to situational awareness, including prior-to-arrival, on the mannequin and in the timeline.

Prior to arrival: "Because oftentimes, the conversation in the trauma bay before a patient comes in is, does anybody know what's going on? Has anybody heard anything? And then there's all this kind of conjecture like, you know, people just say stuff. Oh, I heard this or that or the other. It would be nice to have a, three or four sentences just written down that the things we know for sure." (ED resident physician)

Mannequin: "I like the mock-up of the patient that shows the access points. I think that's often something that is not well communicated. And especially in more emergency situations, you might now always know what good access the patient has, so having a visual of it is helpful." (Anesthesiologist)

Vitals: "I like the vital trends because that's a snapshot of everything. And why it's important is that I can both see how an intervention affected what we're seeing, as well as, from start to finish, more or less, are we getting better, or are we getting worse? Because I think it's easy amongst the hecticness of it that you could see the heart rate is going down and not realize that the oxygen saturation was 100% here and 93% at the end. And though that like one snapshot, 93%, doesn't jump out to me, if I see, that's actually really going down a decent amount, might trigger me to do an additional intervention." (ED attending physician)

Teamwork Transition Technology and Patient Safety

Most respondents anticipated that T^3 would have a positive impact on patient safety and help them provide higher quality care to patients (81%; ►Table 2). Two-thirds of

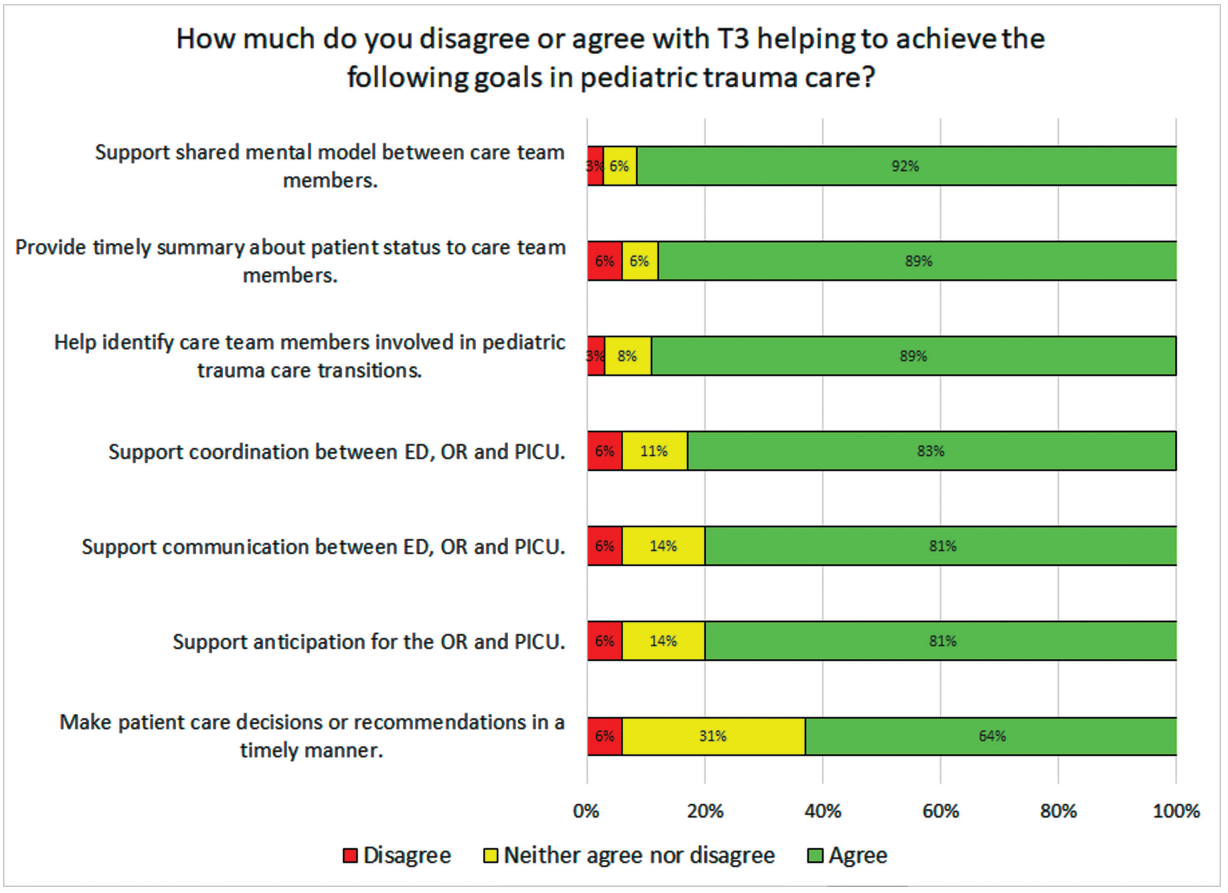

Fig. 2 Percentage of agreement with the design goals of teamwork transition technology (T^3), sorted by highest percentage of agreement. ED, emergency department; OR, operating room; PICU, pediatric intensive care unit.

respondents also thought T^3 would lower the risk of preventable harm to patients and lead to better decision-making. There were no statistically significant differences between respondents working in different job titles or services and units. One study participant summarized the potential impact of T^3 on patient safety, "Just so information is not lost. I think, to that idea, for example, we gave antibiotics on arrival, but I forgot to pass that along to the team that we did. And we just pulled it out of the downstairs pharmacy, and by the time we get to the OR, it hasn't been entered into the computer system yet, and so to be safe, they just decided to give another dose of antibiotics. Whereas, this would be a way to completely integrate in that they would quick look up and run through the list of the meds that they see there and see, antibiotics, already been given." (ED attending).

Overall Impression of Teamwork Transition Technology

Overall, clinician participants had a positive impression of T3 and could "see" how T3 could support them in their work and possibly help prevent patient safety issues. This was described by one clinician:

"… I think one thing that I definitely experienced on trauma is that there is so much going on, and there is so much data coming at you, and we often assume that the things that I know you also know, and so we don't necessarily talk about it. But if it's up there, and we all can just see, yes, this is the access that the patient has right now. I don't have to like search around the patient or ask somebody.

And like here are the injuries. And if I wasn't listening when the junior resident called out that, you know, had they had this injury, then we sometimes will come in in the morning after a patient came in at night, and there's a, like a laceration or some cut that wasn't closed, because it just got lost. People forgot about it. And that we didn't have a shared, like we all know that, yes, there is like a laceration on the knee that needs to be closed, like it was up here and on the mannequin, we would all know. We have to address that before they go. That I think helps to create this shared mental model about what is happening with the patient." (Trauma chief)

Discussion

Health care transitions can be problematic. The literature shows that patients are particularly vulnerable during transitions, and that important information often gets lost.[15,25] During pediatric trauma cases, on the one hand, sometimes very little information is available because the patient is not conscious or because they are children and thus not able to express themselves, while, on the other hand, an enormous amount of information is shared between trauma team members who are physically present. It is difficult to organize all this information in such a hectic environment, to

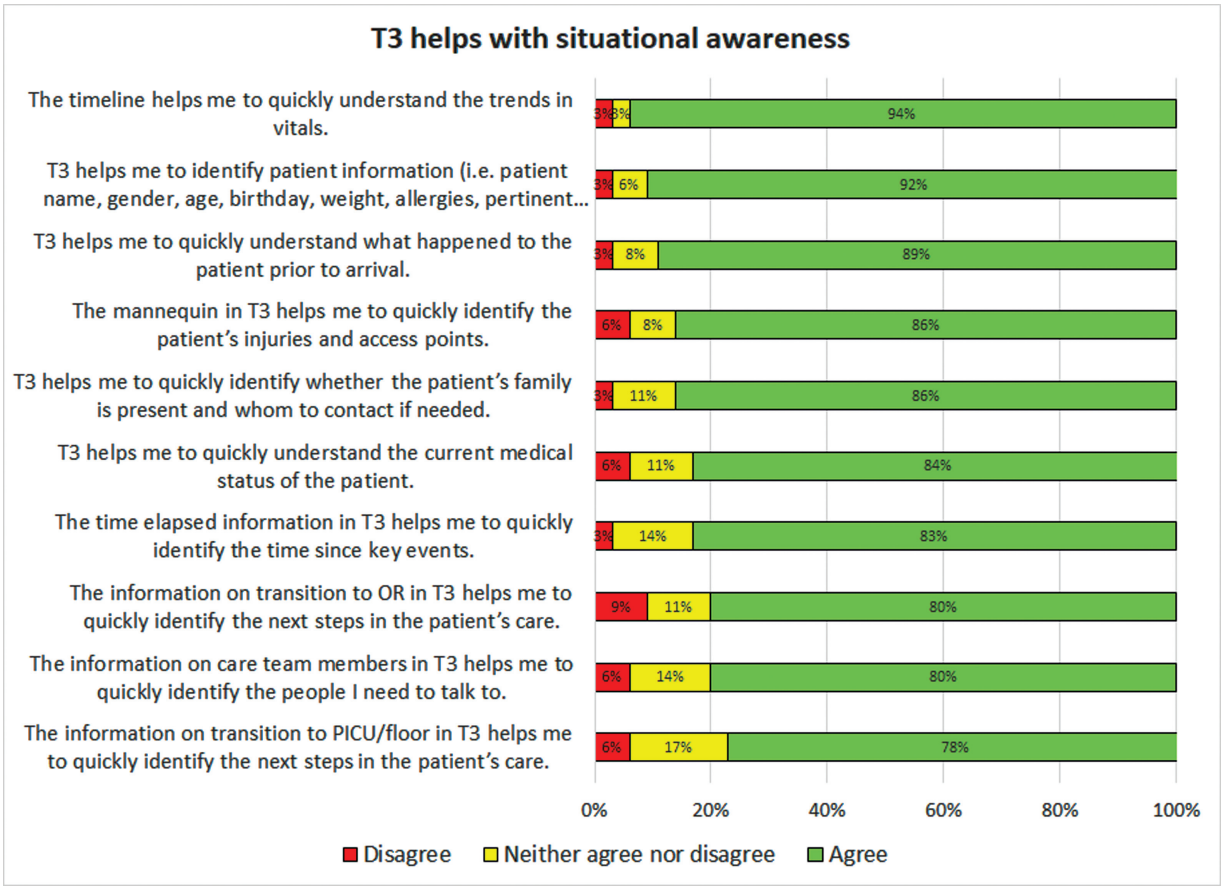

Fig. 3 Teamwork transition technology (T^3) and situational awareness. OR, operating room; PICU, pediatric intensive care unit.

Table 2 Perceived impact of teamwork transition technology (T^3) on patient safety, sorted by largest percent agreement

The next questions ask about the extent to which T3 helps with patient safety risks	Disagree (%)	Neither agree nor disagree (%)	Agree (%)
T^3 helps us provide better quality care to patients	2.8	16.7	80.6
T^3 lowers the risk for patient harm	2.8	27.8	69.4
Information from T^3 enables me to make better decisions about patient care	5.6	30.6	63.9

make sure that none of the essential information gets lost and to communicate to other invested units in the hospital.

Designing health IT that supports all members of multifunctional trauma teams in their work is challenging. Different team members have different information needs, based on their role and location in the pediatric trauma process; however, not all information could be presented at once. If too much information was included, the display would not provide a timely, up-to-date summary of the patient's information and status. The process of choosing what information to display (and what not) was long and difficult. Results of this study show that, using a collaborative design approach, it is possible to design team health IT that supports most, if not all, multifunctional team members. Results of our study also support findings of the few other published studies on team-oriented health IT. Specifically, Calder et al and Parush et al showed that situational awareness displays can improve health care providers' perceptions of situational awareness. However, the (resuscitation) teams in the studies by Calder et al and Parsush et al were relatively small and the displays did not include information about care transitions.[6,7] Our study uniquely demonstrated that you can design team health IT for larger teams across units and provide information beyond the current (patient) status.

Study participants thought that T^3 organized and presented information in a different, better way. Results of the mockup evaluation showed that participants agreed that T^3 supported its design goals and anticipated that it could increase situational awareness and improve patient safety. Overall, participants seemed to particularly like the middle part of T^3 which included both the mannequin and timeline. Many of them thought the left column also provided useful information, particularly, the prior-to-arrival information but also the clock that kept track of the time. Information

in the right column (care team members, transition to OR, and PICU) were mentioned less often. However, it was not the individual sources of information but the fact that T^3 combined all kinds of key information that would otherwise be "buried" in different silos of the EHR.

Most study participants thought that T3 would enhance patient safety during pediatric trauma cases and transitions (►Table 2). We conducted a separate study to examine the potential impact of T^3 on patient safety.[16] One of the interesting results of that study was that participants thought that showing clinical information and patient status on a large display somehow increased the chance that the information is unreliable.[16] However, an estimated 90% of information on T^3 is directly drawn from the EHR. The additional information can be drawn from other sources of information, such as the ED documentation nurse who documents all actions and decisions during a pediatric trauma case in real time in a trauma flowsheet, or by an electronic badge reader who keeps track of who is present during a pediatric trauma case. If needed, other information could be collected in the ED (e.g., is a parent present?). The fact that most of the information is already electronically available also means that T^3 does not cause much additional burden to the clinicians on the trauma team.

Study Limitations and Strengths

One of the most important study limitation is that we did not evaluate the actual technology but a mock-up. Because it is expensive to develop, program, and test new technology, mock-ups are commonly employed to evaluate β versions before spending considerable time and effort on designing technology that may not fit end users. Another limitation is that the study took place in a trauma center in one large hospital in the Mid-West United States which makes it difficult to generalize results to other trauma centers and hospitals. The United States had 1,154 trauma centers in 2002 (MacKenzie, no. 244).[36] In many of these trauma centers, there are multidisciplinary trauma teams (Soto, no. 245) that potentially could benefit from T^3.[37] A final limitation is that we did not include patients or caregivers in the design (and testing) of the technology. While pediatric trauma patients are typically too critically ill to be "users" of the display and/or not old enough to provide usable input, asking their caregivers for input on the design of T^3 may be a next step for investigation.

Study strengths include that all team members of the multifunctional pediatric trauma team were included in this study, which allowed us to examine differences in job types, services and units. Results of our analysis shows that there are no differences in job types, units or departments in their support for T^3.

Conclusion

In this study, we examined a team health IT that was designed to better support clinical teamwork, in this case pediatric trauma. Results of this study show that clinicians working in different units and departments really appreciated the integrated, large screen technology, thought that it supported situational awareness and had the potential to improve patient safety.

Multiple Choice Questions

1. The Teamwork Transition Technology (T^3) that was examined in this study has potentially the following advantages:
   a. it can help identify team members involved in care transitions
   b. it can improve coordination between the different units and services involved in care transitions
   c. it can support a shared mental model between care team members
   d. all the above

   Correct Answer: The correct answer is option d. T^3 has the potentially al of the advantages above.

2. What is a scenario-based evaluation?
   a. a scenario-based evaluation is an evaluation were everything is planned with all details considered and according to a specific scenario (first we do this, then the next step will be that, etc.)
   b. in a scenario-based evaluation a clinical scenario (a case study) is used to demonstrate and evaluate a technology
   c. a scenario-based evaluation is a method to test whether a certain scenario leads to previously defined outcomes.

   Correct Answer: The correct answer is option b. A scenario-based evaluation is an evaluation in which a case study is used to demonstrate and evaluate a technology.

Clinical Relevance Statement

Health information technology (IT) is developed to support the work of clinicians. However, most current health IT is designed to support the *individual* user. Few health IT applications are designed to support teams and teamwork in clinical settings, despite the fact that more and more often clinicians work in multifunctional teams. A few studies have shown that team health IT can support teamwork for example in patient resurrection.[7,8] In this study, we evaluated a large screen technology that was designed using a collaborative design approach, using a scenario-based evaluation. Results show that it is possible to design team health IT that supports team cognition and situation awareness. Most participants in this study were satisfied with the technology. In the future, more health IT needs to be designed that can support clinical teamwork. This study can contribute to that.

Authors' Contributions

P.H. reports support from Agency for Healthcare Research and Quality (AHRQ; grant no.: R01 HS023837, site PI: P.C.) for grant. P.C. reports support from AHRQ, grant no.: R01 HS023837. B.-Z. H. reports grants from the AHRQ (grant

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Protection of Human and Animal Subjects

This study was performed in compliance with the World Medical Association Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects, and, was approved by the University of Wisconsin-Madison Institutional Review Board.

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Conflict of Interest

None declared.

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Appendix A: Pediatric trauma patient scenario

(A list of acronyms can be found at the end of the appendix. Time is indicated in military time, for example 13:09 is 1:09 p.m.).

Relevant Information Prior to Trauma Assessment in Emergency Department

A level-1 activation page was received for a 5-year-old girl in a motor vehicle accident coming from the scene. She was an unrestrained passenger with a right upper extremity crush injury and prolonged extrication. EMS placed a tourniquet, just proximal to the right elbow, for a near amputation. The emergency department (ED) coordinator registered the girl as a Unident into HealthLink entering in her name (xx Aruba, Unident13 "Sally"), gender (female), birthday (January 1, 2018), and age (16 months) based on the current naming convention for unidentified children (name being XX country, Unident and assumed name in quotations, date of birth being January 1 last year and a calculated age between 13 and 23 months old). The ED care team leader entered the prehospital report note and estimated that 35 minutes elapsed since the accident (at 12:34 p.m.), including a 25-minute extrication. EMT placed a peripheral intravenous lines (PIV; 1, 24 g) in the girl's right foot. Upon arrival to the ED (at 12:59 p.m.), the girl showed signs of life: she was awake, alert, oriented, spontaneous breathing, and CV intact. A triage nurse took her blood pressure (BP) which was 74/49 and 57 MAP; her heart rate (HR) was 125. The EM attending (Stacy Schrader), EM resident, primary ED nurse (Paul Bird), pediatric trauma program manager, ED technician, and ED coordinator were waiting for the girl in trauma bay number 3. The girl arrived to the trauma bay with EMS; she was crying as the EM attending (S.S.) completed an initial assessment for life-threatening injuries. The primary ED nurse (P.B.) used a temporal scanner to take the girl's temperature, which was 98.8°F; he placed the girl on the CR monitor; her oxygen saturation was 99% on RA; a C-collar was placed in the field, in spinal immobilization.

13:09

The trauma attending (Tim Roberts) expeditiously responds to the trauma and performs a primary survey; he notices the PIV (1, 24), on the girl's right foot, placed by EMT. The anesthesia attending (Kevin Richards) arrives and talks to the trauma attending (T.R.) before assessing the girl. The pharmacist estimates the girl's weight to be 22 kg and tells the ED nurse (P.B.) who is currently documenting. The ED care team leader requests a child-life specialist. The girl's mother (Sharon) arrives to the ED and tells the trauma chief (Clare Peery), outside the trauma bay, that her daughter has known drug allergies to penicillin (rash) and vancomycin (red man); her past medical history is significant for well controlled asthma and she is on Advair, a controller medication with PRN albuterol (every 4–6 hours as needed for a wheeze), last taken greater than 1 month prior. The girl's mother (Sharon) also gives the trauma chief (C.P.) her cell phone number. The trauma chief (C.P.) decides not to let the girl's mother (Sharon) in the trauma bay and directs her to the ED waiting room. The trauma chief (C.P.) interrupts the primary ED nurse (P.B.), who is documenting to tell him the girl's drug allergies. Then the trauma chief (C.P.) talks to the trauma attending (T.R.) before going to the computer to place initial orders for monitoring, laboratories, and radiology studies. The CR monitor shows that the girl's BP is 71/47 and 55 MAP; HR is 135; oxygen saturation is 96% on RA. The girl continues to cry, so the trauma chief (C.P.) decides to order an analgesic to manage her pain. The primary ED nurse (P.B.) administers the analgesic, Fentanyl 25 µg (~1 µg/kg/dose) by IV.

13:14

The trauma attending (T.R.) requests the primary ED nurse (P.B.) to grab 1 unit of packed red blood cells and 1 unit of FFP from the emergent blood refrigerator due to hypotension and tachycardia. The ED technician places a PIV (1, 18 g) in the girl's left antecubital and draws the following laboratories, ordered earlier by the trauma chief (C.P.): complete blood count (CBC), PT-INR, PTT, and venous blood gas. The neurosurgery consultant (Xu Chen) arrives and assesses the girl; he then stands by the door to talk to the trauma attending (T.R.) about doing the operation at the adult operating room (OR). The orthopaedic consultant (Michelle Rogers) arrives, assessed the girl and walks to the door to join the discussion between the trauma attending (T.R.) and the neurosurgery consultant (Xu Chen). The trauma attending (T.R.) leaves the conversation and contacts vascular and plastics to consult emergently due to threatened limb. The CR monitor shows that the girl's BP is 70/45 and 53 MAP; HR is 140; and oxygen saturation is 97% on RA.

13:20

The primary ED nurse (P.B.) administers the emergent blood (retrieved from the emergency refrigerator), including 1 unit (330 mL) packed red blood cell (PRBC) and 1 unit (250 mL) of FFP via Belmont through PIV (1, 18 g) in the girl's left antecubital. The vascular consultant, plastics consultant and the pediatric intensive care unit (PICU) attending (Jose Durazo) arrive and assess the girl. The trauma attending (T.R.) instructs the trauma chief (C.P.) to complete orders for emergent OR card drop and bed request order placed for ICU level of care. The primary ED nurse (P.B.) tells the ED coordinator to admit the girl in HealthLink. The CR monitor shows that the girl's BP is 75/50 and 58 MAP; HR is 125; and oxygen saturation is 97% on RA. The PICU attending (J.D.) stands by the door as he notifies the PICU care team leader (Rachel Gold) of admission following the OR. The trauma attending (T.R.) leaves the room as he is calling the OR charge nurse to notify her about the emergent operation request. The anesthesia attending (K.R.) notifies OR staff of impending emergent OR. The primary ED nurse (P.B.) estimates blood loss in the ED to be 200 mL. The Child Life Specialist arrives and stands at the head of the bed; she is soothing the girl (who stops crying) by explaining what is happening. The X-ray technician arrives, signaling everyone else to leave the room

apart from the primary ED nurse (P.B.) and the Child Life Specialist. The X-ray technician performs a chest and pelvic X-ray. The trauma attending (T.R.) and orthopaedic consultant (M.R.) stand outside the trauma bay discussing details about the girl's impending operation.

13:31

The girl's emergent blood transfusions are complete. The trauma attending (T.R.) contacts the orthopaedic consultant (M.R.) while reviewing the girl's imaging. The girl's HR decreases to 105 and her BP increases to 89/53 and 65 MAP; and oxygen saturation is 95% on RA. The OR charge nurse indicates in HealthLink that the OR is ready. The primary ED nurse (P.B.) prepares the girl for transport and removes the CR monitors.

13:41

The ED nurse directs the girl's mother (Sharon) to the OR waiting room because her daughter has left the ED (at 13:37 p.m.) and is being transported to the adult OR. The trauma chief (C.P.), ED technician, and Child Life Specialist are with the girl, in the hallway, on their way to the OR.