Simulating Teamwork for Better Decision Making in Pediatric Emergency Medical Services

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Abstract

Emergency Medical Services (EMS) are an essential component of health systems and are critical to the provision of pediatric emergency care. Challenges in this setting include fast pace, need for advanced teamwork, situational awareness and limited resources. The purpose of this study was to identify human factors-related obstacles during care delivery by EMS teams that could lead to inefficiencies and patient safety issues. We examined video recordings of 24 simulations of EMS teams (paramedics and EMTs) who were providing care to pediatric patients. Two reviewers documented a total of 262 efficiency and patient safety issues in 4.25 hours of videos. These issues were grouped into 28 categories. Reviewers also documented 19 decision support opportunities. These issues and decision support opportunities can inform the design of clinical decision support systems that can improve EMS related patient outcomes.

Introduction

Emergency Medical Services (EMS includes ambulance or paramedic services) are critical to the provision of pediatric emergency care. During a medical emergency, EMS teams provide initial medical care in the field and transport patients to a point of definitive care (e.g. hospital). They also gather patient information and communicate this information to the emergency department (ED) team at the receiving facility. Three major challenges to coordination between ED and EMS teams have been identified: ineffectiveness of current information and communication technologies; lack of common ground; and breakdowns in information flow[1].

Approximately 7% of pediatric patients arrive to EDs by ambulance[2]. Children presenting by EMS are more likely to have serious illness and require hospital admission[3]. However, these emergencies represent only a small portion of all EMS transports. For many EMS agencies, pediatric emergencies (compared to adults) are low frequency, but high-risk events. Pediatric prehospital care requires unique knowledge, skills and equipment that are distinct from adults. Decision making in EMS care is a challenge because of the fast pace, uncertainties and environment. Making and executing decisions require teamwork. Errors in pediatric EMS care are common. One study found approximately 70% of critical transports contained some form of adverse patient safety event; 20% of which were categorized as severe[4]. Little is known about the causes of error in this setting. Lack of computer aided decision support, single provider administering medications, challenging environments, and complex teams are theorized as potential contributors[5]. Interventions such as standardized teams, availability of standardized equipment, checklists, and implementation of "pit-crew" provider roles, have reduced errors and improved outcomes in the prehospital setting[6-8]. Further informatics research in this area is needed to understand the causes of prehospital pediatric management errors and identify targets for intervention.

Teamwork is an essential ingredient of EMS care. The core components of teamwork include five overarching constructs: team leadership, team orientation, mutual performance monitoring, backup behavior, and adaptability[9]. Closed-loop communication, shared mental models, and mutual trust are three mechanisms that help coordinate team constructs[9]. Poor teamwork behaviors are associated with negative patient outcomes[10, 11]. Teams in the EMS environment are unique and face challenges not often seen in other healthcare settings. EMS teams work in small groups, under conditions that change frequently, and in environments that are often unfamiliar or dangerous. Many EMS teammates are not accustomed to working with a steady partner[12], many are fatigued and under a great deal of stress, and many work in a poor organizational culture[13]. There is a limited body of research involving EMS teams[13, 14]. Decision support technologies along with other interventions such as training and technology have the potential to improve teamwork and improve patient outcomes in the EMS setting[15, 16].

Clinical decision support can be used to ensure patient safety and efficiency in all healthcare settings[17, 18]. However, it is even more important in fast-pace environments such as EMS[19, 20]. The success of clinical decision support depends on its fit with workflow, individual factors and the working context[21-23]. The use of clinical decision support for EMS can decrease "time to definitive care" and improve diagnostic accuracy among EMS personnel[24], thus, improving diagnostic accuracy and reducing medical errors in the care of children.

Simulation is a valid and efficient way to recreate high risk events in a low-stakes environment. High-fidelity simulation is commonplace in emergency medical training, for all levels of providers[25]. The observation of pediatric emergency simulations allows for the study of a large number of critical events that would otherwise be difficult (or impossible in a reasonable timeframe) to obtain in "real world" settings. The ability to use various scenarios improves the richness of the collected data. Video recorded simulation can be particularly useful to study care delivery that takes place in a small physical space, such as an ambulance, or in dynamic environments where multiple tasks occur simultaneously.

The value of field studies in informatics is essential for contextual inquiry and user centered design[26, 27]. EMS can particularly benefit from these studies given the changing and unpredictable effects of context in their care. High-fidelity simulations can provide an opportunity to conduct research in this field, where the presence of investigators in the field is not practical. This study should also provide insights about simulation studies in informatics research.

EMS care has been previously examined by informatics, human factors and design researchers who identified important themes that inform the design and implementation of safer and more efficient EMS care[28-31]. However, the design principles of services in EMS may still be predominantly based on principles developed in other settings (e.g. acute or inpatient)[32]. The novelty of this study is twofold. First, we collected data through a structured simulation study that was video-taped. Observers were able to simultaneously see EMS providers delivering care as well as obtaining vital signs and other clinical monitoring. Second, our simulation scenarios were based on pediatric patients. This study fills an important gap in care, by identifying decision support needs of a team in a specialized context that is otherwise challenging to study.

The purpose of this study was to identify human factors-related obstacles during care delivery by EMS teams in the pediatric setting, that could lead to inefficiencies and patient safety issues. Understanding these obstacles can inform the design of various interventions such as health information technologies that can support the teamwork, which is both critical and challenging for EMS systems. As the scope of practice of paramedics continues to expand, and the sophistication of EMS systems evolves, it is essential to assist their services with methods such as clinical decision support[33].

Methods

This is a secondary exploratory analysis of a collection of videos from simulations performed within a single EMS agency. Subjects were licensed EMS providers from one local EMS agency that served a population of 280,000 over 130 square miles. All participants (n=112) were trained and licensed with either Pediatric Advanced Life Support (PALS) or Pediatric Emergencies for Prehospital Providers (PEPP). Participants were all active EMS and fire professionals that routinely respond to emergencies. All participants attended mandatory quarterly education, designed to train on updated protocols and new clinical initiatives undertaken by the agency.

Simulations

Videotaped simulations conducted as part of an educational study were reviewed for this study. This serial simulation training was accomplished in an EMS agency to determine if there was a change in psychomotor and cognition skills and team-based care over 6 months. High-fidelity simulation scenarios were of a 15-month and a 1-month old with hypoglycemia, both with seizure activity and hypovolemic shock requiring intravenous (IV) fluid and medication administration. Both scenarios required airway management and treatment of hypotension. The scenarios were constructed with expected actions based on protocols with the actions representative of clinical practice. The content was identified to drive recognition and appropriate management of shock and respiratory failure. The "patient" was a pediatric manikin with real-time feedback. The simulation attempted to mirror standard paramedic practice. Equipment was organized and available to participants in the typical department configuration. The scenario took place in a mock ambulance interior. Events and scripts were standardized with changes in patient condition occurring at pre-determined intervals. All EMS professionals were oriented to the mannequins and then subsequently debriefed. Teams were asked to provide normal care (i.e. follow their protocols), as they would in the field. This included a primary assessment with vital signs, oxygen administration, ventilatory support, intravenous or intraosseous access, fluid and medication administration.

Data Collection

A total of 24 prerecorded videos (scenarios) were reviewed by two independent reviewers (CD, YD) for task analysis and scoring of team cognitive processes. The two reviewers had prior EMS experience and were trained on analysis by a study member (MO) with expertise in systems engineering and health informatics. The two reviewers were instructed to review the videos one by one, played backward as needed, and noted the following outcomes: time to task completion; number of providers involved in each task; scoring of cognitive processes utilizing the Anesthesiologists Non-Technical Skills (ANTS) instrument[34, 35]; identification of actions that did not contribute to the care of the patient; and identification of decision support opportunities (e.g. tools, approaches). The ANTS instrument is a validated tool that scores aspects of team-based care including task management, teamwork, situational awareness, team communication and decision making. Authors met twice to discuss issues during data collection. The scope of this paper included only efficiency, patient safety issues and decision support opportunities during EMS care delivery.

The 24 prerecorded videos contained the activities of 112 EMS providers. Among the 24 videos, 12 were of a 15-month old with hypotensive shock and seizure requiring intravenous fluid and medication administration and 12 were of a 1-month old with hypoglycemia that resulted in a seizure if not treated within 5 minutes of the scenario starting. Each scenario was approximately ten minutes in length. A total of 4.25 hours of scenario time was observed. Figure 1 is an example of a swimlane diagram developed for one of the scenarios.

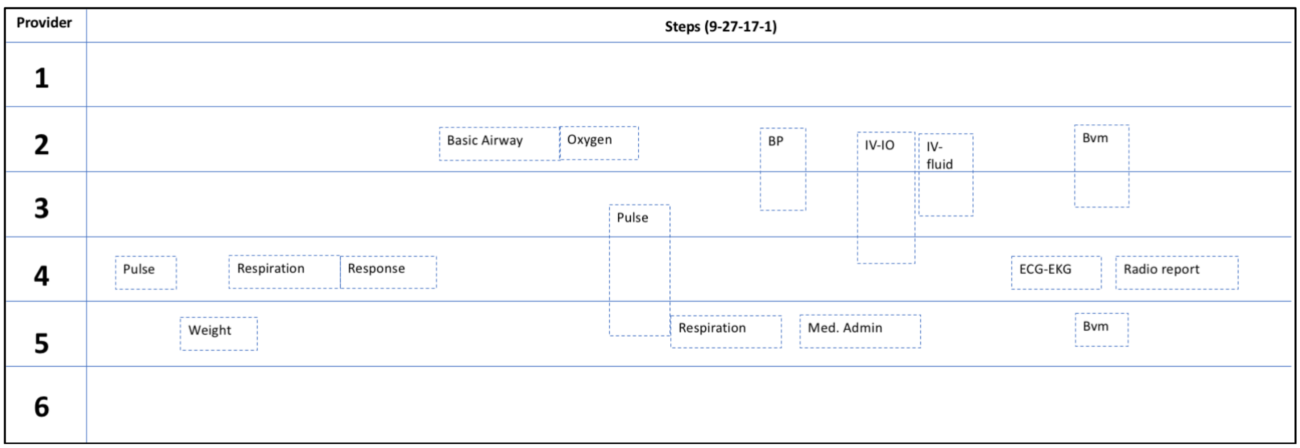

Figure 1. Swimlane diagram for one of the scenarios (X-axis shows time).

Results

Efficiency and Patient Safety Issues

The two reviewers created 349 notes in total. Each note was created independently by the reviewers while watching the videos to identify issues (e.g. an obstacle for teamwork or an efficiency or safety concern). Each note also was time-stamped. Twenty of the 349 notes were excluded from analysis because they were not considered an "issue". Excluded notes included notes on team conversation that did not reveal any issue, or notes that did not describe an issue. The remaining 329 notes referred to 262 unique efficiency or safety issues. Multiple notes were created for some issues. We identified unique issues by using the time stamp and description provided. A total of 329 notes were made, 189 by reviewer 1 and 140 by reviewer 2.

Of 262 total unique issues (152 by reviewer 1 and 129 by reviewer 2), only 19 were captured by both reviewers. The first author reviewed the notes of the two reviewers for efficiency and safety issues and grouped these issues into 28 broad categories (Table 1). Broader categorization was accomplished by bringing similar issues together such as explaining the same suboptimal performance or outcome. Therefore, some of the categories focused on cognitive components, workload or physical tasks. The research team then reviewed the categorizations for issues and decision support tools to reach a consensus. The issues and decision support categories were not mutually exclusive.

The most frequent issue was the *lack of close-loop, directed communication* with 27 observations. Fourteen of the 24 videos (58%) included this issue. *Inappropriate or lack of task sharing and coordination*, *lack of situational awareness* and *suboptimal task performance* were also observed in 58% of the videos. *Unsafe medication administration* was observed in 54% of the cases. There were no videos in which no issue was observed. Table 2 provides excerpts from the reviewers' notes for some of the relatively implicit issues.

Situational awareness does not have a universal definition. For our purposes, we defined situational awareness as the EMS team's understanding of patient and environment related factors that affect (or could affect) what the team needs to do and that subsequently had an impact on overall performance.

Table 1. Efficiency and patient safety issue categories

Category	Times observed	Videos by category (n=24)
Lack of close-loop, directed communication	27	14
Inappropriate or lack of task sharing and coordination	24	14
Lack of situational awareness	22	14
Suboptimal task performance	19	14
Unsafe medication administration	19	13
Cannot locate a tool, equipment or medication	14	8
Delay in fluid/medication/dextrose administration	12	7
Idle personnel	11	11
Inappropriate use of tools	11	6
Missing details in radio report	10	10
Missing tasks	10	8
Miscommunication between team members	10	7
Incorrect radio communication	8	8
Leadership Issues	8	6
Delay in oxygen administration	8	6
Informal/inappropriate communication	7	6
Provider confusion	6	5
Delay in IV/IO access	5	5
Delay in ventilation	5	5
Unnecessary/repeat task	5	5
Delay in recognizing hypoxia/apnea	3	2
Distraction	3	3
Delay in obtaining vital signs	3	3
Disagreement between team members	2	2
Delay in treatment	2	2
Lack of documentation	2	2
Delay in serum/glucose measurement	2	2
Other	4	4

Decision Support Opportunities

The two reviewers were also asked to develop a list of decision support opportunities (i.e. tool/approach/needs) based on the issues that they identified. We did not provide the reviewers a specific definition for decision support. The reviewers identified any mechanism that would allow EMS providers to make better decisions with less cognitive resources and could potentially prevent the issues listed in Table 2. The research team grouped these opportunities into 19 broad categories (Table 3). The most frequently reported decision support opportunities were delegation (Task), vital signs checklist (Artifact), closed loop communication (Task) and orientation for equipment (Training).

Table 2. Select quotations for efficiency and safety issues

Category	Quotes from reviewers' notes
Idle personnel	"Group member 1 not doing anything"
Inappropriate use of tools	"Attempted to inject saline into IO catheter, but could not do it because cap was on"
Informal/inappropriate communication	"Leader states to crew member 'you know that right' referring to versed as the treatment and crew member seemed to be offended."
Lack of situational awareness	"Failure to recognize sepsis, shock and did not give fluids" "Leader asks for someone to listen to breath sounds, but it was already done he just doesn't know, person who did it earlier doesn't say anything."
Leadership issues	"Team lead does not speak up to resolve team dispute/confusion" "No clear team leader" "Asked the group to start a line and prepare versed, but did not indicate who he would like to do that, team had to delegate themselves"
Missing tasks	"No blood pressure obtained" "Did not check respiratory rate at any point" "Member 1 stopped giving O_2 to see if monitor was broken, as opposed to taking [respiratory rate] manually"
Suboptimal task performance	"Left tourniquet on for too long" "Ventilating 40-50, too fast. Leader confirms this rate with ventilator, doesn't catch it's too fast"
Unsafe medication administration	"Unsafe fluid admin (bag to IO, blood pressure cuff attached to IV bag for increased flow wide open)" "Error: protocol says benzos must be 5 min between doses, they gave 2 doses in 2.5 minutes"

Table 3. Decision support opportunities

Decision Support Opportunities	Number of Videos that can benefit from reported decision support(n=24)
Delegation	17
Vital signs checklist	15
Closed loop communication	12
Orientation to equipment	11
Role Clarity	9
Leadership	6
More feedback on ventilation	5
Easier documentation	5
Radio report checklist	5
Primary survey checklist	4
Guideline/support for streamlined dosing	3
Orientation to procedure	3
More positive/respectful group dynamic	3
Use of standardized terminology	2
Team awareness	2
Questioning family	2
Procedure checklist	1
More feedback on blood pressure and cardiovascular outputs	1
Clear and specific plan for unexpected situations	1

Discussion

Informatics opportunities in EMS settings are understudied[36]. Our analysis revealed a wide variety of patient safety and efficiency issues but also design opportunities for decision support systems in EMS. We should note that these categories may not be mutually exclusive. The most commonly observed issues were lack of closed-loop and directed communication, inappropriate task sharing and coordination, lack of situational awareness, suboptimal task performance, and unsafe medication administration. Our analysis also revealed various delayed activities. These issues can significantly undermine patient outcomes.

We directly observed several medication errors in the simulations. Medication errors are the most commonly documented source of significant error in hospitalized patients[5], and are frequent in the out-of-hospital environment as well[37]. Our data support this claim for the prehospital environment. We recorded 19 instances of unsafe medication administration in 13 scenarios (Table 1). These represent a high risk for patient safety. Provider confusion (6 instances), distractions (3 instances), and communication issues (44 instances; 27 lack of closed-loop, directed communication, 10 miscommunication instances between team members and 7 Informal/inappropriate communication) are possible contributors. These errors occurred even with the use of medication decision support. All teams used a smartphone application with medication dosages and many teams used a pediatric length-based weight guide. EMS providers had the correct medication dose from the decision support tools, but succumbed to challenges in equipment, communication or distraction that led to the errors.

Both simulations included the need for time sensitive, complex interventions which involve individual and team-based decision making. For example, consider the administration of IV fluid in hypovolemic shock. IV fluid is the standard of care for pediatric hypovolemic shock and early administration has been shown to reduce mortality[38]. EMS teams that are able to intervene early by delivering IV fluids have a positive impact on patients. However, to perform the task of IV fluid administration, EMS providers must a) recognize the patient is in shock, b) collect the correct equipment, c) calculate and d) administer the correct volume of IV fluid, and e) in the correct manner. We observed team challenges at every step. Recognition of shock is done by assessing vital signs and observing the patient's condition during the primary survey (i.e. initial assessment). We observed 22 instances of teams that lacked situational awareness and 3 instances where teams were delayed in obtaining vital signs. Although their equipment was arranged and prepared in bags that were identical to their "real world" counterparts, many teams struggled to find and use the correct equipment. We observed 14 instances where teams could not find required equipment and 11 instances of inappropriate use of equipment (e.g. the use of adult equipment on pediatric patients). Challenges to both the recognition of shock and the collection of the correct equipment can accumulate to produce significant delays in needed emergency care.

There was great variation in the way teams collected vital sign information. For example, some teams missed taking a blood pressure that would have alerted them the patient was in shock. Other teams checked for respirations first, put the patient on the monitor or checked for pulses first. The use of a checklist to standardize the initial approach to a patient could reduce missing crucial information in the primary survey that would indicate the patient needs immediate care.

Communication is a critical aspect of EMS care[39], and in our study communication represented a large portion of the teamworking challenges. Communication training has been used to improve medical teamwork in other settings[40]. All participants were trained in either Pediatric Advanced Life Support (PALS) or Pediatric Emergencies for Prehospital Providers (PEPP), which include modules on closed-loop communication. Despite this, we observed many instances where closed-loop communication was not used. Further practice and drilling on these principals of closed-loop communication would be beneficial. Core concepts of team communication are standard curriculum for hospital-based teams. EMS training and should also include the practice of standardized communication. We observed many opportunities where closed-loop communication and verbalization would have improved teamwork. EMS managers, leaders and educators should continue efforts to train EMS providers in efficient communication.

An important expectation of EMS teams is to communicate information on the patient's situation and other relevant information to the receiving hospital ED[41]. This communication can affect the quality of care the patient will receive at the ED. Our study revealed 18 incidents (10 missing details in radio report and 8 incorrect radio communication) where communication between EMS team and hospital is problematic. Time pressure, memory issues, and lack of situational awareness are potential causes for these observed miscommunications.

Our analysis revealed the following decision support opportunities in more than ten scenarios: delegation, vital sign checklist, closed loop communication and orientation to equipment. A direct mapping between some of these opportunities and previously reported issues is possible. For example, providing a "orientation to equipment" may directly remedy the issue of "Cannot locate a tool, equipment or medication." Such intervention would also expect to rectify/resolve some of the delays reported in Table 2. The mechanisms of how decision support opportunities overcome issues are probably complex and require employing a holistic systems perspective during design and implementation to avoid unintended consequences that were reported in many informatics implementations.

Many of the decision support opportunities can improve teamwork in EMS by providing better situational team awareness. Such awareness can allow for mutual performance monitoring, backup behavior, and adaptability. These decision support opportunities should also (1) help with providers' short-term memory; (2) augment team and individual cognition; and (3) prepare clinicians about upcoming activities that should be accomplished in a short time. These decision support systems would improve communication among team members, support situational awareness, inform delegation and prevent delays. The design of these interventions can be accomplished by multidisciplinary teams and novel approaches. Any new intervention should be congruent with the unique physical environment, individual characteristics of EMS teams and team dynamics.

This study highlights the need for decision support that is specifically designed for EMS teams. Some of the decision support needs can be mainly fulfilled with new or improved tools and technologies (e.g. checklists, documentation tools). Augmented reality based on technologies can also provide needed decision support to EMS teams[42, 43]. Other needs mainly require rigorous training (e.g. orientation to equipment and leadership) and policy interventions (e.g. use of standardized terminology, role clarity). A combination of these interventions can be even more effective.

Clinical decision support is essential in health care settings. However, for EMS, their success depends on integration into the clinical workflow of a mobile unit with a team that changes composition over the course of a single encounter, that often lasts less than one hour[36]. We suggest the following design guidelines for decision support system for EMS:

1. Applying User-Centered Approaches: Decision support must be adaptable to both electronic and paper-based systems and work across both analog and digital communication systems. It must integrate different protocols and be modifiable, i.e., it must be able to adjust to changing medication formularies, EMS provider scope of practice, and varied patient age and physiology. User-centered design approaches help understand not only the user's needs and desires but the holistic context of the user's social, technical, and cultural environments, and, as necessary, engage users as designers of the technology they will use. Users of EMS for pediatric services include EMS providers, patient families and receiving staff in the EDs. Participatory design approaches can be useful to involve these users to ensure that decision support is developed to fully meet needs.

2. Workflow considerations: EMS related activities at the broad level include dispatch, arrival to scene, assessment, loading to an ambulance and changing composition of teams. Some of the activities directly related to patient care are illustrated in Figure 1. Although the broad level activities are more sequential, patient care activities are loosely coupled temporally and many variations are possible. Decision support systems should be flexible so that they are adaptable to all situations. EMS can occur in challenging physical places, and dealing with patients with various conditions. Decision support systems should be able to accommodate to a wide range of situations. Decision support systems can be adaptive if they are fed with all the relevant information (e.g. EMS technicians' speech[15]). Organizational routines framework can provide a guideline to examine both codified and tacit workflows[44].

3. Context sensitive systems: EMS may take place in various physical places and surrounded by diverse social context. EMS providers may have different training and experience. Moreover, values, preferences and the ability of a patient's family to provide assistance can differ in different cases. Patient confidentiality should be considered. System level context such as billing and financial considerations, or policies such as HIPAA may affect care. Decision support systems should be sensitive to all these context factors. Contextual inquiry approaches can serve as a starting point for designing context sensitive decision support systems for EMS[26].

4. Complementing technology interventions with needed policies and trainings: Any intervention that aims to provide decision support in EMS should include all technology, training and policy components. A technology-based decision support would be incomplete if it is not complemented with needed policies and providers' trainings. In this study, teams were observed committing errors despite the presence of decision support tools providing information such as the medication dosages, medication and fluid volumes based on patient weight. Implementing decision support tools could also include training and practice with teams in simulated environments to ensure its best integration to practice.

Simulations provide unique opportunities for design and informatics research[45]. Given the infrequent presentation of pediatric patients in the out-of-hospital environment, simulations offer an environment to explore workflow in a safe and controlled manner, allowing for review of the performance of a high volume of teams over a short period of time.

The design of any potentially effective technology, training, staffing, or policy intervention can be more accurately evaluated in a simulation environment. Video recordings and analysis of simulations can be superior to direct observations of simulation without video recording[46].

An advantage of video recording is the ability to create a permanent record that can be analyzed offline as often as necessary and at a pace different than real life. The ability to pause, reflect on the content and then continue with the video, is important to study fast paced teamwork such as EMS.

In this study, capturing a small number of issues that were observed by both reviewers can be a result of different perspectives, background and training of the reviewers. However, the qualitative foundations of this study allowed us to leverage the different perspectives of the reviewers and revealed further actual or potential patient safety and efficiency problems.

The limitations of this study included reviewer bias, difficulty in observing team work through video monitoring and the inability to fully understand the team member's motivation. Reviewers are biased in their observations and definitions of challenges. We attempted to limit this bias by having two reviewers. However, having two reviewers reporting different issues and reporting only a small number of common issues deserve further research. Because the scenarios were observed via video recordings, that presented some limited challenges as team tasks may have occurred outside the visual field of the cameras and audio recordings may not have captured all verbal communication clearly. In addition, body language or non-verbal communication was more difficult to detect. Team member motivation is difficult to determine without audible cues. Teams and individuals performed tasks on occasion without verbalizing their plan of care. In some cases, we made estimates based on our experience of what tasks the teams were performing.

Despite the great potential of simulations, de-contextualizing collaborative work by performing it in a laboratory setting, may affect not only the primary work activities, but also the background work that enable these activities. Within healthcare, the importance of, for instance, articulation work has been found to be critical to take into account in coordination of medical settings[47]. This often subtle and highly contingent background work may be difficult to recreate in a simulated setting, which introduces the uncertainty that the problems observed may in fact be caused by the absence of normal routine.

Another limitation was the description of the sample in this study. The included a sample of videos (n=24) from a broader study (n=135) which included 313 participants, 212 of those included in our study. 179 (%59, 8 missing) of the 313 participants were older than 40 years old, 292 (98%, 14 missing) of them were male, 283 (93%, 9 missing) of them were white, 235 (77%, 6 missing) of them were parent, 298 (99%, 12 missing) of them were full time employed, 198 (65%, 6 missing) of them were certificated at EMT-Paramedic level. We believe that the participants in our sample videos represent the participants of the broader study.

Future research includes designing participatory or non-participatory field studies to confirm these findings, gain more insights on the reasons of the identified patient safety and efficiency issues and the development and evaluation of decision support tools for EMS in light of these findings.

Conclusion

The unique contribution that this study makes to informatics research is two-fold. First, we demonstrated the efficacy of simulation to identify performance deficiencies in situations that are impractical to observe in the field. Second, we revealed design considerations for decision support of EMS teams for the care of pediatric emergencies. We then summarized our design recommendations in a four-item guideline (1. Applying User-Centered Approaches; 2. Workflow considerations; 3. Context sensitive systems; 4. Complementing technology interventions with needed policies and trainings). In studying EMS, a challenging health care delivery setting, our findings can be extended to benefit similar health care teamwork scenarios in which the team members are not fully familiar with each other, decisions need to be made in quick succession and resources are limited.

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