Outside the Box: Contextualizing User Experience Challenges in Emergency Medical Technician (EMT) and Paramedic Workflows

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Abstract. Paramedics and Emergency Medical Technicians (EMTs) often serve dual roles in their communities as both emergency medical providers and firefighters. Therefore, the demands and needs of these providers are different than those working directly in a hospital emergency room or medical office. Medics are required to treat a patient in less than ideal conditions where seconds can mean the difference between life and death. The goal of this work is to better understand how research informing technology for the emergency room (ER) can be linked to improving the user experience of EMTs and paramedics in the field. Through a review of relevant literature, we capture lessons learned in conveying information quickly, linking necessary information from disparate sources, and giving these providers accurate information to successfully treat and transport patients during prehospital care.

Keywords: Human factors · Emergency medicine · Prehospital care · Electronic health records

1 Introduction

As technology in healthcare continues to advance, the field of health informatics shifted from a focus on simply managing patient medical records to the management of protected health information. The introduction of electronic medical records (EMRs) and electronic health records (EHRs) have changed the way providers and patients manage their care. However, some studies have demonstrated conflicting evidence regarding the successful implementation of EHRs in a variety of healthcare contexts [1].

One understudied area is the impact of these systems on prehospital emergency medical services (EMS). Prior to arriving at the emergency department, patients generally are transported in an ambulance. This portion of care, known as prehospital care, requires careful consideration. Prehospital care refers to the treatment patients receive prior to handoff at the hospital ED. Prehospital care varies depending on location, region, and funding. For example, in the US, prehospital care is generally performed by

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trained and certified EMTs and paramedics [2]. In Europe and in other countries, physicians or nurses may accompany paramedics on an ambulance to provide care [3]. The majority of modern prehospital care systems are equipped to provide advanced life support (ALS) [3]. Breyer [4] detailed the importance of understanding the effect of the Patient Protection and Affordable Care Act (PPACA) on the current prehospital fire-based EMS systems operating in the United States (U.S.). The PPACA created the opportunity for fire-based EMS systems to transition from emergency response and patient transport, to a more integrated part of the healthcare system. Despite this transition, the introduction of EHRs in fire-based EMS is relatively new and poses a variety of unique challenges [4]. For example, some studies have demonstrated that patient satisfaction is directly correlated with perceived paramedic response times [5–7]. Results from a meta-analysis suggest that the total average time for prehospital care is approximately thirty minutes in urban areas, demonstrating that paramedics and EMTs must gather information quickly [8]. The goal of this work is to better understand the role of EHRs in prehospital care, as well as to outline areas where more research is required to afford EMTs and paramedics the information needed to deliver quality patient care.

We conducted a conceptual review of the literature, emphasizing the importance of lessons learned in the transition of paper medical records to electronic in emergency medicine. These lessons are applied to emergency medical services (EMS) to translate how these practices map to the needs of paramedics and EMTs in the field. Additionally, we identified gaps where further information is necessary to recommend solutions. To do this, we interviewed EMTs and medics to better understand the practical impact of best practices and the link to their current information needs to existing solutions. Drawing from human-computer interaction (HCI) methods, we conducted interviews with two separate fire-based EMS departments. We contend that the current technologies provided to medics and EMTs do not meet provide a positive user experience. Instead, these rescue units often face *distractions, interruptions, and issues with technologies, creating deficits related to patient care and response times*. This not only impacts the patient, but also has negative outcomes for emergency medical personnel [9]. The goal of this work is to better understand the current tools and technologies rescue units rely upon in order to provide patient care and to better understand interdependencies where the human user is required to intervene or interact with inadequate systems in prehospital care.

By capturing the information requirements of these emergency medical personnel in the context of a sociotechnical framework, we can map these needs to current or future technological capabilities. Ultimately the use of technology has an impact on patient safety and the safety of the medical professionals providing patient care [10], creating an opportunity for the human-computer interaction (HCI) and human factors communities to better assist the prehospital emergency medical domain through further analysis of their direct user experiences and the extant literature.

2 Related Work

Electronic health records (EHRs) recently became more prevalent due to the introduction of the Health Information Technology for Economic and Clinical Health (HITECH) Act [11]. Generally, there has been a focus on EHRs in traditional medical offices and hospitals. However, much of the literature does not focus on the impact of EHR use in ambulances by paramedics and EMTs. Seminal work in this area includes a systematic review of prehospital emergency care in England that examined the tensions between systems and providers [12]. Additionally work emphasizes the importance of systematic reviews for understanding the changing landscape as more hospitals transition to EHRs [13, 14]. Relatively few articles from the extant literature examine the impact of EHRs on prehospital care providers, and even fewer articles focus on understanding the impact of these systems on the stress and workload levels of these providers [15, 16]. Some of the core research conducted in this area includes an analysis of reports and handoffs to better support EMTs [15, 16]. Additional research in this area has focused on the perception of eHealth systems more broadly, from the perspective of multiple healthcare stakeholders [9, 17].

This lack of empirical data creates a critical gap in the literature since the role of paramedics, EMTs, and prehospital care providers are typically not included in discussions of EHRs. However, they are considered important stakeholders in the overall electronic health system, since they perform care prior to arrival in the ED. Newgard et al. [18] studied the impact of electronic data processing, providing evidence that the implementation of EHRs in ambulances positively impacted care. The use of EHR systems in prehospital care has largely been driven by a need to improve systems for billing, consequently enhancing quality assurance practices [12, 19]. However, these decisions are typically driven by administrative requirements and the end-users of the systems are generally not involved in the process of adoption, meaning paramedics and EMTs often *do not have a voice* in the process of selection or implementation of the EHR systems they rely upon to complete their daily job tasks.

2.1 Transition from Paper Records to Electronic Health Records (EHRs)

The concept of electronic health, known as eHealth, was first introduced in the late 1990s [20]. Moving into the early 2000s, advancements in computing made the possibility of electronic medical systems and records much more viable [21]. This transition made it possible to avoid clinical documentation errors such as illegible writing and allowed for the collection of other types of health care data, saving practitioners time. It also contributed to better information for insurance companies to file claims [21]. Despite this, some studies have identified deficiencies in the use of EHRs due to a lack of data on patient outcomes or the actual cost-effectiveness of these systems [22, 23].

The emergency department (ED), also known as the emergency room (ER), in modern US hospitals is an acute care facility. Emergency departments adopted EHRs primarily as a means of improving patient care through decision-making support on scene, continuity of care and access to patient information [24]. Studies have demonstrated that physicians in U.S. EDs complete over 100 tasks an hour, requiring a system that supports their ability to complete these tasks as quickly as possible [25].

Consequently, the impact of EHRs on ED efficacy and efficiency has been studied for over a decade [26–29]. Most studies suggest that EHRs generally enhance ED productivity and efficiency; however, there have been some studies that uncovered some issues associated with the use of commercial EHR systems in emergency medicine, such as increased task switching [30–32]. Additionally, some studies have emphasized the importance of addressing the impact of EHRs on provider well-being [33] and the importance of meeting the technology needs of first responders through user-centered design [34, 35].

This study contributes to the literature by identifying areas where further research could enhance user experience for *prehospital* emergency medical professionals who rely upon systems that do not meet their current needs or the needs of the patient due to outdated and unreliable technologies. Additionally, this work contributes to better understanding the needs of prehospital emergency providers who often lack access to historical health information to provide patients with better continuity of care.

3 Methods

We conducted a literature review on peer-reviewed publications related the implementation of EHRs between the years of 2000 and 2018. The year 2000 was chosen as a starting point since eHealth and EHRs were first introduced and implemented as a potential solution in the late 1990s [20]. The process involved three iterations and was conducted between November 2018 and January 2019. We conducted our search via the ISI Web of Knowledge and Science Direct. The search terms were derived from key words used in combination such as: "EHR and paramedic," "technology and emergency department," "user experience paramedic," "eHeath and emergency medicine," and "electronic medical records emergency." For the purposes of our literature review, articles must have met three criteria to warrant inclusion:

1. Peer reviewed and published work
2. Published between the years 2000 and 2018
3. Involved discussion of technology or eHealth systems in the context of emergency medicine or prehospital care.

We excluded articles and works that covered topics outside the scope of the emergency room care, such as disease genomics. We also excluded papers that used EHRs or EMRs as a source of archival analysis for a particular injury or condition. For example, some papers leveraged health records as a data source to identify whether emergency admissions generally peak at a certain period of time or on certain days of the year. Since this did not directly involve the use of technology for patient care, these papers were excluded from the review. Our search terms identified over 2,000 papers that were initially reviewed for relevance based on the criteria above. Two hundred articles were excluded due to the fact they were not peer-reviewed. Of the remaining articles, all were reviewed for relevancy, and 108 papers were included in this review. A representative sample of these articles are included in the reference list. We aggregated findings to communicate general trends related to the effective use of EMRs in an emergency medical setting, drawing from the sociotechnical framework originally

proposed by Sittig and Singh [36] to guide our discussion. This framework conceptualizes key issues in the sociotechnical system that prehospital care providers operate in, providing the key dimensions of interest and scaffolding the coding scheme for understanding the cognitive and physical needs and demands placed upon prehospital emergency medical providers.

In addition to the literature review, we conducted interviews with four paramedics and two EMTs, (n = 6) from separate agencies that service different metropolitan areas in the Southeastern region of the United States. This process of data collection supplements the existing gaps in the literature with data from prehospital care providers who are not well-represented in the literature. To do this, we conducted interviews via phone and online conferencing systems. Our approach was grounded in the Applied Cognitive Task Analysis (ACTA) framework, a well-known method in the field of human factors that consists of three interview methods [37]. ACTA is designed to help inform HCI work for interface design and applied product development. The participants age (M = 33.67, SD = 4.32) and years of EMS job experience (M = 13, SD = 2.90) are captured in the table below (Table 1).

Table 1. Participant demographics

Participant	Age	Experience in EMS (in years)
1	36	17
2	27	9
3	34	15
4	40	14
5	33	12
6	32	11

4 Results

The Safety Assurance Factors for EHR Resilience (SAFER) guidelines were originally developed to help understand the importance of measurement and monitoring in the case of eHealth systems more broadly [38]. However, this framework emphasizes *self-assessment of risk*, allowing departments and organizations to take ownership of improving the safety and effectiveness of EHRs with the goal of improving the quality of patient care. These guidelines provide evidence that self-assessment of EHRs is an important component of ensuring that quality of care and satisfaction are not compromised in the implementation or use of EHRs. Despite the benefits, these guidelines generally apply to settings other than prehospital care. To better frame the risk to both patients and prehospital care providers, we categorized the results of our literature and interviews below in terms of the dimensions outlined in the sociotechnical model originally proposed by Sittig and Singh [36]. The table below is adapted from their original model [36]. We leveraged this model to create an *a priori* framework in order

to analyze the qualitative data from interviews and to categorize the literature evaluated in our review. See Table 2 below for the code book that guided our analysis.

Table 2. Sociotechnical Model Proposed by Sittig and Singh for self-risk assessment of EHRs to improve the quality of patient care, adapted to prehospital care.

Sociotechnical dimension	Definition
Hardware and software	Computing foundation for applications and systems used in patient care
Clinical content	Data (text, images, etc.) contained in clinical documentation
Human-computer interface	How clinicians or other stakeholders interact with a computer system (including inputs and outputs)
People	All stakeholders involved in prehospital care
Workflow and communication	Procedures and protocols that ensure patient is being cared for
Internal organization features	The work environment surrounding the prehospital care provider
External rules and regulations	External limitations and regulations (e.g., accreditation, laws, etc.)
Measurement and monitoring	Evaluation methods used to determine the impact of computer systems on the provider and patient safety

4.1 Hardware and Software: Case Studies and Prototype Testing

A majority of studies focused on understanding the impact of new systems in specific locations or applied settings. Two studies in Crete, Greece demonstrated the importance of applying theoretical models, such as the Task-Technology Fit Model to better understand the role of EHRs in delivering better quality care and assisting prehospital care providers with technology to meet their needs [39, 40]. Additional work in this area evaluated a mobile system architecture for assisting emergency medical personnel rendering aid to victims of motor vehicle accidents and systems for triaging patients in the midst of a disaster or mass casualty incident [41–43]. These new systems have focused on understanding the impact of information availability on patient care, ultimately paving the way for future systems.

Some studies focused on the testing and evaluation of new software prototypes or architectures to better support both patients and healthcare providers [44–48]. For example, a large-scale project funded by the European Union demonstrated the efficacy of video-based information exchange to support prehospital care [49]. There have also been systems that use RFID technology to track care [50]. Majeed [51] introduced a new architecture for prehospital care reporting. Although these studies have demonstrated the efficacy of EHRs on prehospital care, it is important to note that the majority of them took place outside the United States, which may represent a different model of emergency care [52]. There is a paucity of literature on existing implementation of

EHRs in prehospital care, of those that do exist, most of them focus on ED physicians or other stakeholders rather than prehospital care providers [9, 53].

This dimension is difficult to measure due to the lack of consistency between departments and agencies. It is critical to note that each agency may have different requirements or interoperability standards, making it sometimes unfeasible or impractical for the paramedics or EMTs to have any input or influence on the system.

4.2 Clinical Content

Historically, fire-based EMS systems did not have access to hospital-based EHR systems [6]. However, this dynamic is changing. A number of papers we reviewed addressed the clinical data or content of charts to better understand trends in diagnosis and care of patients in the ED [54, 55]. Some recent studies have revealed negative provider perceptions on the use of EHRs for documentation of specific life-saving interventions, such as resuscitation in the ED [29]. This focus on clinical content is important for understanding some of the interaction design decisions that can negatively impact provider perceptions.

Continuity of Care. In our review, preliminary work focused on better understanding how information exchange leads to better clinical outcomes. Lammers et al. [56] demonstrated the importance of timely information exchange on the reduction of redundant imaging orders in the ED, saving both the patient and provider frustration, time, and unnecessary costs. Detailed work has been conducted on identifying some of the sociotechnical factors that contribute to the improvement of patient handover to [57]. Additionally work has focused on understanding how to more effectively chart patient information prior to conducting patient handover, also known as patient handoff [58–60]. However, it is important to note that paramedics do not typically have access to detailed health information or EHRs that are integrated with the patient's primary care doctor, resulting in potential information losses and reduced efficiency of care.

During an interview session, one paramedic succinctly captured the idea that while having access to prior emergency runs can be important in the case of opioid abuse or chronic health conditions, it also may bias prehospital care providers towards a particular treatment plan, as illustrated below:

> *"Sometimes you have a patient that calls us frequently. While it's important to understand that they most likely have a chronic condition or require treatment for a specific problem repeatedly, that is not always the case. You can go on several calls that don't necessarily give you the full history, but then they really do have an emergency. It's important to know and recognize when this happens. We can be biased without even recognizing it because we see them all the time for the same things over and over." -P2*

From this comment, it is important to note that patient outcomes can be inadvertently influenced by the existing information that is available to the provider, usually from previous hospital runs. Paramedics and EMTs are limited in the information provided to them and often have to make critical decisions about interventions in order to save a patient's life *without access to information about prior medical conditions or treatments plans*. However, for certain patients, this may not be the case as a department may run calls on a single patient multiple times per day depending upon their

health and living conditions, etc. Balancing what little information is available with their own assessments can present challenges and increase paramedic workload. Moreover, research in this area has demonstrated that frequent users of urban EMS systems are typically treated for recurring health conditions that could be better managed outside the EMS system [61]. The accessibility of this information across providers has also been investigated as a means to improve patient care [62].

Managing Patient Engagement and Education. One area of emerging interest involves the use of mobile applications and technology to enhance patient engagement and education in their own treatment process [63]. For example, a mobile health application involving a text-based intervention seemed to demonstrate positive clinical outcomes and decreased the number of ER visits for patients with Type II Diabetes [64]. These applications of mobile health provide a more convenient way for patients and providers to interact. However, these solutions are often focused on longer term care and involve follow up with the patient's network of doctors, which is outside the scope of the prehospital care they receive in the rescue unit. However, in order to realize the goal of integrating fire-based EMS systems within the total healthcare ecosystem of a patient, this introduction of technology for education and outreach may have positive outcomes.

4.3 Human-Computer Interface

This dimension resulted in one of the most frequently discussed and rich areas of research in our review.

In describing the impact of interfaces and information systems on providers, we often conceptualize their functionality as something of importance. That is, without a fully functioning system, their job tasks are impeded. One paramedic we interviewed described the initial process of obtaining better devices. They were provided with tablets that featured a removable keyboard, as outlined below:

> *"We received these fancy new tablets last year with a detachable keyboard. When we need to get an elderly patient to provide a signature, the tablet is much less burdensome and less heavy than a Toughbook. However, now the problem is that the keyboard attachment has become loose and the keyboard will unsnap in the middle of typing up a report. It is frustrating and often just makes our tasking more difficult." -E1*

On one hand, this participant could name the benefits of the newly implemented system: lighter weight, easier for patients to hold, and the convenience of using a tablet in the rescue unit. However, the use of improperly functioning devices challenges providers who are already dealing with time-sensitive and critical patients. Clinical documentation and reporting are key features of many EHRs, but without a properly functioning system, EMTs and paramedics experience more stress and frustration than necessary. Some work in this area has also demonstrated the efficacy of an approach focusing on *non-acceptance* to better inform the design of new systems in disaster and emergency response [65]. The participant quote below illustrates the perspective of the end-user who sees impacts to productivity and time as critical:

"The system was not user friendly. Several features never worked such as populating patient information from prior runs or bring over CAD (Computer-Aided Dispatch) system information like addresses or times. Little things like that make a big difference for us in time management." -PM6

In the literature, clinician perceptions of EHRs were measured, but it was often in the context of the ED, thus excluding prehospital care [66–68]. More importantly, not all departments have swiftly transitioned from paper to electronic patient care reporting systems (ePCRs). Subsequently, there are challenges in the transition of paper to electronic health records. Studies comparing paper to electronic records demonstrated that more data elements were captured in the electronic documents. However, paper records were more likely to contain information about the amount of intravenous fluids administered before arrival to the ED [69]. Although this study did not highlight the role of prehospital care EMS, it did point to the idea that nurses were able to leverage existing EMS reports to better support patient care, thus improving the dialogue between paramedics and the hospital ED.

4.4 People

Along this dimension, our participants indicated that often they were required to complete tasks that may be outside their written job description. Additionally, although it was not directly captured in a participant quote, some of our participants indicated that their shift partner could make or break their performance.

Unclear or Ad-hoc Roles. One participant captured this issue well in his description of his daily job tasks. In addition to his duties as a firefighter/paramedic, he acknowledged the impact of budget cuts on department funds and operations. Two firefighters were appointed to order supplies and manage inventory. Instead of providing dedicated support or consultation personnel, they were required to learn this on the job. This added frustration and stress to the simple process of ordering supplies:

"Ordering supplies is an extremely frustrating process. I have to navigate to an internal website, download a form, fill out the form, save the form as a PDF, attach it to an email, and send it, just to get supplies. So instead of hiring a designated IT (information technology) person to handle this, they "promote" two firemen and expect them to just figure it out." -P1

Teammate Familiarity. Studies have demonstrated the importance of team composition and familiarity in reducing workplace injuries, increasing performance, and creating safer work environments, specifically in the context of EMS [70]. In considering what factors influence patient care, internal factors such as the composition of shifts and teams are critical. Although this is often not brought up in discussions of internal factors, this idea of teammate familiarity may also play a role in preventing unsafe practices, may enhance adherence to protocols, and could potentially impact the ability for providers to respond quickly to escalating situations, which we highlight in the discussion portion of this paper.

4.5 Workflow and Communication

Several studies focused on better understanding portions of workflow and communications within the ED are impacted by the use of EHRs [71, 72]. This is also critical for understanding the work environment of paramedics. One participant was able to capture his frustration with his current system's workflow in the excerpt from his interview below:

> *"There is so much repetitive information. You would document the same complaint in several different areas of the report. They tried to make everything "black and white" is [sic] the aspect of click boxes with predefined answers. This is not a "black and white" field." -PM1*

> *"Many of the options in the click boxes made no sense and did not fit the dynamic of the call we were documenting. All we wanted was a box to type in the exact issue. Not to have to find something that was the closest match which felt like lying on a report." -PM6*

Work in this area extended from understanding workflow more broadly, to more specific instances of workflow interruptions. For example, Madathil et al. [73] leveraged unified modeling language (UML) to demonstrate bottlenecks associated with patient consent processes. Interestingly, studies also indicated correlations between dissatisfaction of EHR usability and disruptions to clinical workflow [74]. Although these studies would need to be replicated in a prehospital care environment, this work does demonstrate that EHR user experience affected clinical workflow and direct patient care time. Further investigation is necessary to determine if this would have an impact on prehospital care perception as well. However, based upon limited study data, we contend that clinical workflow is interrupted in the case of the EMTs and paramedics interviewed during this study. More objective analysis is required to determine the magnitude and direction of the effect.

Ergonomics and Physical Environment. Paramedics identified that assessment and understanding of their work environment was one of the more critical areas requiring further analysis of needs. As illustrated in the quote below, some providers feel that there is little concern for the environment they work in when it comes to choosing EHR and information systems.

> *"I think the biggest thing people get wrong is the complexity of the situation. Sometimes I have to intubate a patient and he is lodged in between the bed and the wall because he fell. Sometimes I have a patient who is trying to jump out the back of the ambulance. The work we do is not always in a sterile operating room. It's uglier. We are given imperfect conditions and it's our job to do our best despite the circumstances." -PM1*

> *"The Phillips Monitor is so heavy it impedes my ability to do my job when I'm trying to hold it and take care of a patient." -PM2*

Because current systems place so many physical demands on the user, getting through a call efficiently can present a problem. This also creates additional strain on responding units who are running calls frequently during their shifts and frequently has implications for EMS-based standards. Despite the existing gaps in technology, EMS providers are still required to meet the demands of the department credentials and accreditation standards.

4.6 Internal Organization Factors

Training on EHR Systems. Studies have demonstrated evidence that peer-based instruction seemed to increase proficiency and satisfaction related to use of EHR systems for physicians [75]. When asked about the training received, most of the participants in our study indicated they were taught on the job or through "train the trainer courses." This is captured in the participant quote below:

> *"Most of it really is a learned on the job deal. The 10 rides with a seasoned preceptor give plenty of opportunity to learn the system and ask questions. There is no renewal or certification procedure for the EHR system. Once you got it, you got it for life." -PM6*

This lack of formalized training can create user frustration since this creates additional demands on the paramedics or EMTs who are training new staff. More importantly, there are no continuing training courses, so if providers struggle to pick up the system, they are typically required to manage any additional training on their own time.

4.7 External Organization Factors

Seminal work in the area of prehospital EMS focused on identifying measurable indicators of quality [76]. Since the late 1990 s, the landscape of prehospital care has vastly changed. Now more than ever, this changing landscape impacts EMS providers both directly and indirectly. Financial reimbursement, medical policy, insurance policy, and government legislation all contribute to the effectiveness of fire-based EMS, in addition to quality assurance measures of performance. Although paramedics and EMTs may not be directly involved in these processes, they are impacted by these changes. For example, as mentioned earlier in this paper, EMS response times are important for both patient satisfaction and quality assurance [77]. Paramedics are increasingly facing pressure to respond as fast as possible, despite the additional concerns outlined throughout this portion of our review.

Additionally, work in this area has focused on reviewing adherence to national and international prehospital emergency medical protocols [78]. Adherence to protocols is also correlated with quality assurance and performance measurements, directly connecting to the discussion of the Measurement and Monitoring dimension below.

4.8 Measurement and Monitoring

Due to a need for assessment and quality assurance, measurement and monitoring represent a key component of understanding the impact of EHRs on efficiency and improvement of patient care. However, because EHRs are relatively new to prehospital care, there is little information that exists on how to assess, maintain, monitor, and measure the impact of EHR systems on prehospital care providers, as well as patients [1, 79]. In looking at the literature reviewed, very few studies captured the importance of developing more robust or generalized frameworks for understanding the impact of these EHRs on emergency medical care outside of the hospital emergency department. Several papers emphasized a human-factors approach, but even these were targeted

towards the clinicians in the hospital and not necessarily created to measure the workload of paramedics or EMTs [53].

5 Discussion

Based upon the findings of our literature review and study, we have identified areas where more empirical research is necessary to better understand the needs of prehospital care providers. From our literature review and our interview data, we found that paramedics and EMTs often deal with issues related to interoperability of systems, problems with functionality, and interface design. Towards this end we have identified key areas where immediate intervention could better support fire-based EMS providers. We recognize that this is not an exhaustive list of potential future research directions, but we have identified areas where the HCI community has the opportunity to better support medics and EMTs.

5.1 Recommendations for Improving End-User Experience

Designing for Multiple Users. Interestingly, in medicine it is not uncommon for a patient to use the same interface as the provider to provide consent for medical care, educational or discharge instructions, etc. However, through our study, we found that this challenge of designing for multiple stakeholders emphasized the idea that the current systems used in prehospital emergency medicine may require patient input, such as a signature, on the same computers prehospital care providers use to draft reports and retrieve health information. Due to the complexity and the nature of emergency prehospital care, we found that providers, in our study, struggled with systems that did not necessarily fit their long-term needs. While the introduction of the tablets outlined above solved one problem, it created several more. It is our hope that with this data as a foundation, agencies and departments can look to this research as a way to understand and mitigate similar technology risks, while also selecting and implementing technologies that support EMS personnel.

3D User Interfaces. Due to increasing workload and call volumes, many fire-based EMS systems are facing issues related to meeting EMS-based standards while also providing the best patient care possible. Based upon some of the literature we identified, it is possible that there may be opportunities for EMS providers to adopt solutions that other healthcare providers current use. For example, dictation software packages and voice-activated inputs could help reduce paramedic workload when drafting patient care reports. Although the data is limited to emergency physicians, previous work demonstrated that voice-input charting could also potentially reduce the workload and number of interruptions, thus this may be a solution for EMS preceptors who may be observing and monitoring the clinical work of interns and students while also providing patient care [80]. Furthermore, work has also focused on the use of biometrics to create a safe and more accessible method of obtaining patient records on the scene of an emergency [81]. More objective data is necessary to determine whether these systems would provide viable solutions for prehospital care providers, but from our data and the

extant literature, further analysis is required to determine which configurations of interfaces best support fire-based EMS providers.

Potentially Violent Situations. Additionally, there is also the growing concern of potentially violent situations (PVS). Paramedics and EMTs may encounter belligerent patients or they may be ambushed while on the job. Recent studies have demonstrated that this risk has increased in the last four years and the risk of violence extends to international emergency care providers as well [82, 83]. This growing concern has created a need for these providers to be able to document situations, to call additional units and law enforcement for support, and to complete these calls for support without the need for another user interface or additional workload. This is where the need for interoperability and reliable communication systems becomes of utmost importance [84]. By providing support through interface design, we can assist prehospital care providers in keeping both themselves and their patients safer.

5.2 Approaches to Future Work

Although we found results consistent with previous studies, we must use caution when generalizing this information to other departments or agencies. In addition, some departments are moving towards alternative EMS models where non-emergency calls are handled differently to reduce call load [85]. For example, one department in Washington D.C. is implementing a new triage program in which first responders will assess the severity of calls to determine whether a patient needs routine care from a clinic or requires care from the emergency room [38]. The goal is to reduce the number of routine calls that do not require emergency medical attention to give rescue units the opportunity to treat the most critical patients. Similar programs have demonstrated success in other areas of the United States [39]. Additionally, some other work has focused on leveraging telemedicine and related solutions to better understand how to support paramedics as call loads increase [45].

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