User Needs and Challenges in Information Sharing between Pre-Hospital and Hospital Emergency Care Providers

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Abstract

Effective communication between pre-hospital and hospital providers is a critical first step towards ensuring efficient patient care. Despite many efforts in improving the communication process, inefficiencies persist. It is critical to understand user needs, work practices, and existing barriers to inform technology design for supporting pre-hospital communication. However, existing research examining the ways in which patient information is collected and shared by pre-hospital providers in the field has been limited. We conducted a series of ethnographic studies with both pre-hospital and hospital care providers to examine 1) the types of information that are commonly collected and shared by the pre-hospital providers in the field; 2) the types of pre-hospital information that are needed by hospital-based teams for ensuring appropriate preparation; and 3) the challenges in the pre-hospital communication process. We conclude by discussing technology opportunities for facilitating real-time information sharing in the field.

Introduction

In high-risk, time-sensitive medical domains, such as emergency care, medical professionals must provide rapid treatment and manage potentially life-threatening illnesses or injuries (e.g., trauma injuries, stroke, medication overdose). Effective and timely information sharing between pre-hospital and hospital providers (also known as *pre-hospital communication*) is a critical first step for achieving this goal[1]. Information collected in the field and en route to the hospital (*pre-hospital information*) can help the emergency care providers at the receiving hospital anticipate the severity of patient illness or injury, and make appropriate preparations and triage decisions[2]. Despite its critical role, information sharing between the field providers and those at the receiving hospital remains challenging[3, 4]. For example, verbal reports given by pre-hospital providers during patient transport often lack detail[5, 6] or accuracy[7, 8], making it difficult for hospital teams to appropriately prepare. The highly dynamic nature of out-of-hospital encounters is also characterized by frequent interruptions, posing challenges on real-time data collection and leading to delayed and incomplete information dissemination from the field[9, 10].

Previous research has developed information and communication technologies (ICTs) to support data transfer from the field to receiving hospitals[11, 12]. Key examples include mobile electronic documentation systems[10, 13] and ambulance-based telemedicine systems[14-19]. These systems, however, are rarely used in real-time due to portability and usability issues[15, 19, 20]. Pre-hospital providers have to perform hands-on examinations and treatments on patients while managing information from multiple sources in short time periods. This work practice limits their direct interaction with handheld systems[21]. Prior research has highlighted that the development of ICTs for healthcare professionals should not only focus on technological aspects but also account for user needs and current work practices[3, 12]. Although several studies have looked at information handover workflow between pre-hospital and hospital teams in the receiving care centers (e.g., emergency department)[5, 8, 9, 22], limited research exists on the ways in which pre-hospital information is collected and shared in the field.

The long-term goal of our research is to design and develop novel technologies to better support *real-time*, seamless data sharing between pre-hospital and hospital teams. To achieve this goal, we first need to answer several fundamental research questions (RQs):

RQ1: What types of information are commonly collected and shared by pre-hospital providers in the field?

RQ2: What types of pre-hospital information are needed by hospital teams for ensuring appropriate preparation?

RQ3: What challenges and barriers exist in the pre-hospital communication process?

In this paper, we describe a mixed-methods ethnographic research conducted with both pre-hospital and hospital providers to answer these research questions and inform technological interventions for facilitating the acquisition and dissemination of pre-hospital information in the field.

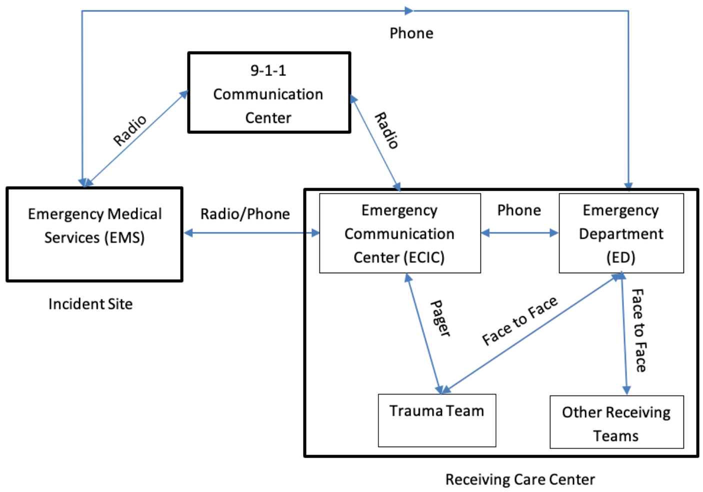

Figure 1. A typical pre-hospital communication process.

Background: Pre-Hospital Communication Process

A typical pre-hospital communication process involves multiple geographically distributed and heterogeneous emergency care teams[3, 23], including Emergency Medical Services (EMS), Emergency Communication and Information Center (ECIC), and Emergency Department (ED) (Figure 1). Depending on the patient needs, other care teams, such as trauma teams, neurology, and cardiology teams may also be activated and involved in the care process. Following an incident, EMS providers (e.g., paramedics and air-ambulance crews) are dispatched to the scene to provide urgent medical care and transport the patient to the nearest or most appropriate care center. EMS teams collect and manage a variety of information about the patient's status and clinical needs, which inform treatment decisions in the field. Under certain circumstances (e.g., trauma or burn injuries, cardiac arrest, stroke), EMS teams need to notify the receiving hospital about the patient's status. By protocol, EMS crews should provide a verbal report via radio (also known as *pre-arrival notification*) to the 9-1-1 communication center, where dispatchers collect the information and relay it to the ECIC teams—the first point of contact at the hospital for crews transporting patients to the hospital. In some cases, EMS providers would choose to contact ECIC or ED directly via phone. Upon receiving the pre-arrival notification, the ECIC staff (e.g., dispatchers or communication specialists) first call the ED charge nurse or physician on call to relay the reported information. If EMS providers request medical advice, ED physicians are added to the EMS-ECIC call to provide guidance and make decisions. If trauma team activation is needed, ECIC staff sends out a brief notification message to trauma team members via pagers. As the trauma team assembles in the resuscitation room, the ED physician relays known information about the patient and works with other trauma team members to prepare for the patient's arrival. For other critical cases (e.g., stroke or cardiac arrest), care specialists will also be summoned to the ED for consultation, and the receiving teams (e.g., neurology and cardiology teams) will be notified to get ready.

Methods

Data Collection

Data collection occurred in different time periods. Between 2016 and 2017, we conducted semi-structured interviews with three different care teams in an urban pediatric teaching hospital with a Level I trauma center in the east coast region. Participants included six ED physicians, eight ECIC team members, and 16 trauma team members (five emergency medicine physicians, eight senior surgical residents, one surgical fellow, one respiratory therapist, and one nurse practitioner). The interviews focused on their work practices, pre-hospital information needs, and concerns about receiving and using pre-hospital information. The length of interviews varied depending on their availability (ranging from 15 minutes to one hour). This interview study helped us uncover pre-hospital information types that are critical to the work of emergency care professionals at the point of care. We also gained an in-depth understanding of the challenges faced by hospital-based teams in acquiring and using pre-hospital information. These results informed our following studies with EMS teams.

To understand how pre-hospital information is collected and shared by EMS providers, we first reviewed video recordings of 25 simulations performed in an urban fire-based EMS agency in the mountain region. The simulations were conducted for training purposes. Participants in the simulations were paramedics and emergency medical technicians (EMTs) recruited from the EMS agency; all participants were experienced providers and met local and state authority requirements for staffing an Advanced Life Support (ALS) ambulance. Each simulation team consisted of 4-6 members with a designated team leader, carrying out three different scenarios over a period of 6 months in 2019. The scenarios involved a 15-month-old seizure, a 1-month-old with hypoglycemia, and a 4-year-old clonidine ingestion. The simulations were conducted in a mobile simulation laboratory resembling the back of an ambulance, using high-fidelity patient mannequins. All simulations were captured by three video cameras: 1) the patient's overhead view, 2) the foot side of the patient, and 3) a zoom-out view of the entire scene.

To augment the findings from video review, we conducted 45-90-minutes long semi-structured interviews with 13 EMS practitioners, 11 of whom are paramedics, and the other two are EMTs. The interviews were conducted via Zoom between 2020 and 2021. The participants were recruited from four hospital-based EMS agencies, which are part of the 9-1-1 system in an urban area in the US Northeast region. Years of experience range from 7 to 30 years, with two participants being EMS directors. The interviews focused on their work experience and backgrounds, job responsibilities, data collection in the field, communication process with physicians, and challenges in sharing data with the receiving hospital.

All interviews were audio-recorded and transcribed for further analysis. The videos were transcribed using excel sheets to provide a linear list of conversations and activities. Both the university and hospital Institutional Review Board (IRB) approved the studies.

Data Analysis

In reviewing the videos, we used an open coding technique[24] to uncover common information types collected in the field and work practices related to data collection and sharing. Two researchers coded the video transcripts. They first reviewed four randomly selected videos to develop a codebook in an iterative manner (e.g., codes and codebook disagreements were discussed through regular meetings). The codebook defines a set of codes related to types of collected and shared information, types of verbal communication (e.g., inquiry, clarification), instances of non-verbal communication (e.g., note taking, gazing, pointing), and artifacts used. The codebook was then used by the researchers to standardize the coding process. The inter-rater reliability between the two researchers was substantial (Cohen's Kappa coefficient value is 0.7). We also compared the information collected in the field to the information reported to the hospital. Because EMS verbal reports were omitted in 3 simulation sessions, our analysis focused on the remaining 22 simulations. This video review helped answer the first research question (RQ1).

Data from semi-structured interviews were also analyzed using an open coding technique[24] to answer RQ2 and RQ3. The EMS interview analysis focused on the challenges faced by EMS practitioners in communicating patient data to the receiving facility, while the analysis of interviews with hospital teams focused on their needs and concerns in acquiring pre-hospital information from the fields. All the codes generated through the interview analysis were discussed among researchers to determine which codes to keep, merge, or discard. We then used affinity diagrams to generate high-level themes, followed by identifying representative quotes to support the claims.

Results

We report the results in three parts. First, we describe the information types that are collected and shared by EMS providers in the field. Second, we report the needs and challenges of acquiring pre-hospital information by emergency care professionals at the receiving hospital. Finally, we present the challenges and barriers that EMS providers face in communicating patient data to hospital teams.

Types of Information Collected and Shared by EMS providers in the Field

Of 25 simulations, EMS providers verbally reported the information via radio to the receiving hospital in 22 sessions. The analysis of these 22 simulations showed that EMS providers collected and shared about 18 types of information during pre-hospital care. We grouped these 18 information elements into five high-level categories: demographics, mechanism of injury, physical findings, injuries, and treatments (Table 1). Below we discuss each high-level information category in greater detail.

Demographics: Commonly collected demographic information included patient age, gender, name, weight, and medical history. In particular, age and medical history were inquired by EMS providers in all simulations (22/22), while gender and name were asked in 19 and 13 out of 22 sessions respectively. Because the simulations were situated in the context of pediatric emergency care, demographic information was mainly collected through verbal communications with the patient's parents or guardians. Among these demographic information types, patient age (22/22) was always included in the EMS pre-arrival notification. In contrast, medical history (1/22) and weight (1/8) were rarely shared with the hospital teams.

Mechanism of Injury (MOI): To come up with an appropriate patient management plan, it is critical for EMS providers to know how the patient got injured or what type of incident occurred. EMS providers specifically asked for this information from the patient's parents or guardians in almost all simulations (20/22): "*About 30 minutes ago I heard*

Table 1. Types and frequency of pre-hospital information collected and shared by EMS providers in 22 simulations.

	Collected in the field through explicit communication and physical examination	Shared with the hospital via radio		
		Fully Reported	Partially Reported	Not reported
Demographics				
Name	13	0	0	13
Age	22	22	0	0
Gender	19	14	0	5
Medical History	22	1	2	19
Weight	8	1	0	7
Mechanism of Injury				
Incident details	20	9	7	4
Physical Findings				
Vital Signs	22	7	12	3
Pulse	8	0	0	8
Neurological Status	22	14	2	6
Breathing	21	5	6	10
Airway	8	0	0	8
Symptoms	7	2	0	5
Change of Status	13	2	0	11
Injuries				
Signs of trauma	6	2	0	4
Treatments				
IV/IO	22	12	8	2
Oxygen	18	8	2	8
Outcomes	11	3	0	8
Medication	2	1	0	1

him kind of banging around, and then I walked in just a few minutes ago, and then he was just lying there." Of the 20 simulations where this type of information was collected, EMS crews shared injury mechanism with the receiving hospital in 16 sessions.

Injuries: Because the simulations were medical resuscitation cases, EMS providers only collected injury information in 6 out of 22 sessions. Their focus was primarily on whether the patient presented any signs of trauma (e.g., swelling, bruises, and lacerations). In the simulations, this information was identified either by talking to the patient's parents or when a certain injury was reported during physical examination. The injury information was reported to the hospital in two cases.

Physical Findings: The information types collected in this category included vital signs (e.g., heart rate, blood pressure, and respiratory rate) (22/22), breathing (21/22), patient neurological status (e.g., alertness, consciousness) (22/22), pulse (8/22), airway status (8/22), symptoms (7/22), and change of status (13/22). Some physical findings were almost always reported in the notification to the hospital, such as vital signs (19/22) and neurological status (16/22). However, other physical findings were rarely shared with the hospital, e.g., such as breathing (11/21), pulse (0/8), airway (0/8), and change of status (2/13).

Treatments: Commonly collected information related to treatments included IV (intravenous) or IO (intraosseous) access and administration (22/22), oxygen (18/22), and treatment outcome (11/22). But only IV/IO administration (20/22) was consistently reported by EMS providers to the hospital.

Our analysis also showed that the collected information was only reported briefly or partially in many cases (Table 1). For example, vital signs information was only fully reported in 7 sessions, but partially reported in 12 sessions. In those partial reporting cases, only one or two physiological data points (e.g., blood pressure) were shared with the

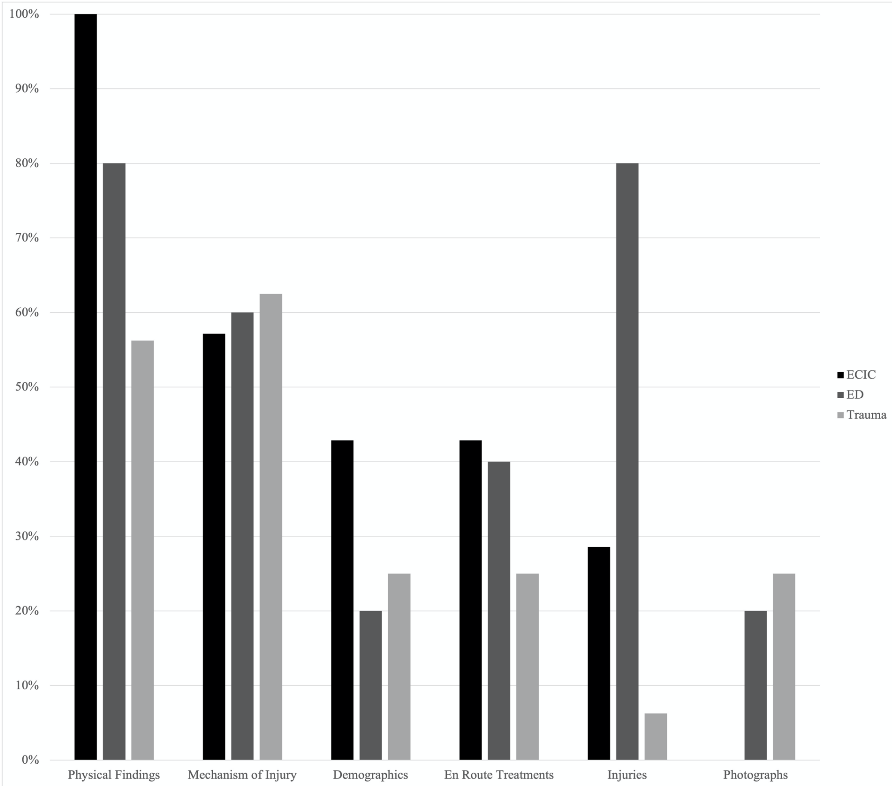

Figure 2. Comparison of pre-hospital information needs across ECIC, ED, and trauma teams. The X-axis represents different high-level categories of pre-hospital information, and the y-axis indicates the percentage of medical professionals within each team who expressed the needs for specific information.

hospital while other vital signs were excluded from the verbal report. Another example of partial reporting is related to the mechanism of injury, with many details missing from the pre-arrival notification.

During the interviews, we asked EMS practitioners to explain why the information was only partially shared with the receiving hospital. They stated that the purpose of pre-arrival notifications is to "*let the hospital know you are coming, not just give them very comprehensive report*" [EMS-P1]. Also, they are concerned that the notification receiver (e.g., dispatcher or ED nurse) could get overwhelmed if they report too much information: "*I try to keep it super tight because usually if you give too much information, the person who's taking the call might not remember all of it. So, we just try to keep it to about 30 to 45 seconds if we can*" [EMS-P11].

Similar to previous work[1], we also found that EMS providers already follow a relatively stable structure to construct the pre-arrival notification: "*The first thing that I share is usually what I'm rolling in—what the diagnosis is that necessitated us calling ahead of time. And then the patient's demographics, age, gender, their associated medical history, usually any interventions that I've performed, and things that are out of the ordinary. And lastly what the ETA [estimated time of arrival] is to the hospital*" [EMS-P12].

Types of Pre-Hospital Information Needed by the Hospital Teams

The semi-structured interviews with three different hospital-based teams (ECIC, ED, and trauma teams) helped us identify commonly needed pre-hospital information types by emergency care providers at the point of care (Figure 2). Based on these data, findings from the physical examination were considered the most critical type of pre-hospital information. For example, patient neurological status (e.g., loss of consciousness) and vital signs were viewed as critical by most emergency care professionals because this information helped them anticipate the level of patient acuity. Hospital teams also considered mechanism of injury as an important pre-hospital information type because this information helped them "picture" what happened to the patient: "*In addition to vital signs, getting an impression about the patient [is also important]. So, impression could be respiratory distress, or motor vehicle crash. I would like to know what happened first*" [ED-P5]. Many care providers also wanted to know what treatments were completed en route, and if any medications were administered. As an ECIC staff explained: *"So, like, if they have started a [IV] line, and gave morphine, and if they gave other treatments, I would definitely let ED nurse know, so it does not overlap with ED work. In that way, the ED doctor knows at what time they gave morphine […] If they just gave morphine 5 minutes ago, you don't want to give it once again*" [ECIC-P5].

Information needs, however, could also vary across different professions (Figure 2). For example, ED physicians expressed more interest in knowing details about patient injuries (e.g., the type, severity, and location of the injuries) than other teams. We also observed differences in information needs even among the members of the same team. For example, several ED physicians expressed the needs to know injury mechanism, however, it is interesting to see that one ED physician had different opinion on the importance of the mechanism: "*Mechanism doesn't matter. Mechanism increases risk about certain injuries, if you use seat belt, if you get hit by a car, but it is still a matter of what. It just increases your risk, but it doesn't mean any injury. I've seen a kid fell from 70 feet from an apartment building, and he is fine; and I've seen kids fell from 10 feet, lay on concrete, then he has major head injury. So, mechanism is useful information but it doesn't really help you*" [ED-P4].

Even though the hospital teams may have different opinions on the importance of different types of pre-hospital information, they all expect a well-structured and clearly articulated EMS report: "*I want a short, sweet assessment of three criteria that I need. I need to know is there a physiological change in the patient, is there an obvious fracture, and is there a mechanism. They are pretty objective assessments. [...] I don't need that 'live in the home,' all that nuanced information. Give me what I need, and I don't know if EMS really knows what it is we are looking for. [...] As you may see, I am rolling my eyes over and over again, I am like just give me the information*" [ED-P3].

Our results also showed several concerns and unmet information needs related to receiving the pre-hospital information from EMS providers. First, four ED physicians and trauma team members indicated the desire to receive more contextual information from the accident scene (e.g., photos and videos) to better anticipate the patient's needs. They considered visual information such as photographs and videos as a helpful addition to the summary of the patient's status because they visually augmented the brief EMS reports. However, this information need is not well supported by current communication mechanisms. Second, not all information types considered necessary were available at all times; even when available, information was not always accurate. Third, the level of detail about certain information needed by the hospital-based teams was not clearly established between pre-hospital and hospital teams, leading to some tensions. EMS teams sometimes did not know how important certain types of information about patients were to the hospital teams. It was therefore challenging for them to prioritize these information items in communicating with hospital teams, causing EMS reports to be either too short or overwhelmingly detailed.

Challenges Faced by EMS Teams in Sharing Information with the Receiving Hospital

EMS teams are well aware of the importance of communicating accurate and essential patient information with the receiving hospital: "*We are sometimes the only eyes and ears for the physician and the hospital. So, the story that we provide may sometimes be the only story that the clinicians at the hospital have to take care of the patient*" [EMS-P4]. However, EMS providers face many challenges in accomplishing this important task, including limitations on collecting and reporting patient data in the field, ineffective communication mechanisms, overloaded EMS systems, and intermediary communication links. Below we describe each challenge in greater detail.

Limitations on Collecting and Reporting Patient Data in the Field. It is common that EMS providers cannot always obtain sufficient information in the field due to time pressure or the patient status (e.g., unconscious), limiting their ability to report the needed information to the hospital teams. In those situations, they announce their arrival to the hospital teams with only a fraction of the patient information. As one participant explained: "*If the patient is unconscious or the patient might be too critical to be able to answer questions, and there might be nobody with the patient, we can't get their name or any information on demographics. […] We may just guesstimate [guess and estimate] the patient's age*" [EMS-P1]. In other cases, EMS crews may not even have the capability to notify the hospital as their hands are occupied with stabilizing a critically injured or ill patient: "*In some critical cases, like if I'm doing CPR to patient, I can't take out my phone and start calling the charge nurse*" [EMS-P10].

Ineffective Communication Mechanisms. EMS providers primarily rely on radio or cellular link to communicate with dispatchers and hospital teams. However, the radio signal is often unstable and fails to work in many areas, causing challenges for efficient and accurate pre-hospital communication: "*There are dead zones in the city where your signal is poor, so you might not be able to get through in a timely fashion where you might have to move somewhere, either away from the patient or move the patient to somewhere where you have a stronger signal*" [EMS-P8]. The COVID-19 pandemic has exacerbated this challenge, as explained by another EMS participant: "*What comes to my mind first is that because it's a different world right now with COVID. We are wearing N95 respirators, and it's really, really difficult to speak to anyone over the phone, let alone that you have to request orders from that*" [EMS-P12].

Due to the system integration issues, the portable radio carried by EMS providers on the scene cannot be used for pre-arrival notification, forcing the EMS crews to use the radio inside the ambulance. Because of this limitation, the EMS provider driving the vehicle is usually the one giving the notification to the hospital. The driver may not necessarily know the most current patient status since they have difficulty communicating with the co-workers in the back of the ambulance: "*If you have a real serious patient and you have two paramedics in the back and an EMT who doesn't* *necessarily know what's going on is driving. And then that EMT has given the notification, they might not get the right information because they don't know what's going on or they might forget something*" [EMS-P8].

The limitations of the current communication mechanisms also pose significant challenges in communicating contextual information from the field to the receiving hospital, leading to not only time-consuming verbal descriptions but also misinterpretations of the patient status: "*I think the biggest issue is the fact that it's all verbal and they can't generally see the patient*" [EMS-P4]. To work around this issue, a few participants mentioned that they would take a picture of the accident scene for trauma cases to help ED and trauma teams understand the severity of the accident and consider potential internal injuries: "*When I showed up to the scene of a really bad accident, I would take pictures of the accident, and then when I got to the hospital, I would show the trauma doctors because they can see if it was a head-on collision, then they know what kind of injuries they're expecting and what could be wrong with the patient. […] I find that could be relevant information to doctors and assisting them*" [EMS-P11].

Overloaded EMS Systems. An organizational-level challenge is that the EMS system is usually overloaded. The entire system could become extremely busy in peak hours, especially in large cities. For example, EMS providers need to call the emergency communication center to give the pre-arrival notification, but establishing connection with the dispatcher is sometimes challenging: "*It's only one dispatcher. So, if two ambulances are trying to give notification at the same time, one is stuck in limbo. And they might not ever get through because he's hung up on details on one call. I can't even talk to him yet about my call and I'm going to get to the hospital before I get through*" [EMS-P8]. To address this challenge, EMS practitioners sometimes call the receiving hospital directly using their personal phones: "*Because I'm working in a hospital-based EMS system, I have the phone number for the ER, if I have to give a notification to the specific ER that we work at, I will call them on my phone personally, rather than having to go through the dispatcher*" [EMS-P12]. Another participant confirmed this "unofficial" yet effective work practice: "*There are times where I can't get over the radio to the dispatcher. So, I do have to call the hospital notification line directly and speak with the nurse in the ED and let them know we're coming. That's like more unofficial way of getting a notification. Meaning it's not technically the correct way to do it, but I think it's more efficient*" [EMS-P9].

EMS practitioners may also need to consult a physician about treatment plans en route or patient destination. Almost all of our EMS participants have experienced difficulties reaching out to ED physicians: "*Common problem that has occurred is that there is a long delay to actually speak to the physician sometimes. Sometimes, it can take anywhere between 15 minutes to half an hour, and that can be frustrating. And obviously it delays patient care. […] What you're supposed to do is just wait, because otherwise you get in trouble for doing something without speaking to the physician*" [EMS-P1].

Intermediary Communication Links. When giving a notification, EMS practitioners have to communicate with a 9-1-1 or ECIC dispatcher who takes the information and relays it to the next recipient in the communication chain. Our results showed several issues in the EMS-dispatcher communication process. First, some information could get miscommunicated or lost during this transition process, as described by an EMS participant: "*A lot of information gets lost in translation. I've had plenty of times where we show up and the hospital's ready for a patient in 'cardiac arrest.' And we're like, 'wait, we did not say that.' Or we show up and they're like, 'we didn't get a notification about what you're talking about.' So, the game of telephone, I think, is a big hindrance in getting notifications. […] The dispatcher has to understand 100% when you say over the radio and then they have to say it again to a person [ER nurse or physician] on the other end of the phone. And they don't really have the opportunity to call you back and ask further information. Because as soon as they're done with that one, there's another ambulance who's on the radio waiting to get connected*" [EMS-P13].

Second, the dispatchers often asked the EMS practitioners about unnecessary information, which delayed the notification process. An EMS crew member explained: "*They [dispatchers] tend to follow a protocol. […] It's ingrained in them that they need this and that information or they can't continue on, even if the information really isn't going to make a difference. If you call about a stroke patient, they will ask if it is the left side or the right side. It doesn't matter. Or exact numbers on a set of vitals. […] If it's normal, it doesn't matter. It's not going to affect the main goal for a notification, which is to have a team ready and the right sources. […] But they'll get hung up on those details and that'll just delay them*" [EMS-P8].

Given those challenges, EMS participants expressed their interest in sharing original patient data directly with the receiving ED department: "*It'd be great if we are able to send our notes to the hospital, so they could know what's going on even before we get there*" [EMS-P10]. However, this need is not fully supported by the current system architecture and communication mechanisms.

Discussion

We found that EMS providers collected a variety of information from multiple sources in a short time period, including patient demographics, mechanism of injury, physical exam findings, injuries, and treatments. Due to the time pressure, EMS providers were only able to provide a very brief verbal report to the receiving hospital. Our results showed that only a few information types (e.g., patient age, neurological status, vital signs, and IV/IO administration) were always shared by EMS providers, while other types (e.g., details of mechanism of injury, airway, breathing, and change of status) were rarely reported. Even when available, much information, including the essential parts such as vital signs, was often partially reported. A possible reason for this limited or partial reporting may lie in the purpose of the EMS verbal report, which is to quickly announce the patient arrival to get the hospital teams and resources ready. However, these limited or partial reports could also lead to challenges in establishing common understandings between the pre-hospital and hospital teams[3, 23].

Interviews with different hospital-based teams uncovered information types that are critical to their work. We found that the pre-hospital information needs of hospital teams match what is typically reported by EMS teams. However, hospital teams need contextual information from the accident scene (e.g., photos, videos) to better anticipate the patient's needs. The challenge, however, is that EMS teams currently lack effective mechanisms by which context-specific information is accrued to allow for rapid integration and sharing[8]. Even in this era of modern communications, EMS providers still rely on radio or phone to communicate with hospital teams. Theses outdated mechanisms make it challenging for EMS providers to not only describe complex patient cases in words but also for hospital teams to understand the symptoms and status of the patient. The limitations of current communication mechanisms pose challenges to efficient information sharing between pre-hospital and hospital teams, requiring further studies[3].

Despite being aware of the importance of pre-hospital communication, EMS teams face many challenges in delivering accurate information to the receiving hospital in a timely manner. One prominent barrier is related to the limited ability to notify hospitals when dealing with a critical patient in the field, as EMS providers need to perform hands-on examination and treatments on patients. As a result, they often experience high physical and cognitive workload, limiting their abilities to use handheld radio or phone for notification. Another significant challenge is the difficulty of communicating with the dispatchers at the emergency communication centers. Sometimes dispatchers are overloaded, forcing EMS providers to wait in a queue to get connected. This challenge could severely delay the notification process and ultimately patient care. In other cases, miscommunication or information loss could occur in the notification process due to various reasons, such as unstable radio signal or inaccurate interpretation. Because of this issue, the information delivered to ED physicians is not always accurate, hindering their decision-making process (e.g., which specialist to call, what resources and equipment to prepare, and what labs to order).

Given these challenges, it is critical to consider novel technology interventions to support seamless, real-time pre-hospital information sharing in the field. For example, Schooley et al.[13] reported the design and evaluation of an Android-based smartphone application to support the communication of patient information from the field to the receiving hospital. EMS providers can use this application to take photographs, record digital audio notes, and capture video of the patient and scene. Such data can be relayed to and reviewed by ED physicians via a web application. An ambulance-based telemedicine system is another key example of technology being tested over the past decade to enable real-time, audio-video pre-hospital communication. The system is installed in the ambulance with video cameras to capture a designated area's view (e.g., patient body) and transfer data to the hospital. Despite the benefits, various challenges hinder the effective use of these technologies[15, 19, 20]. For example, given the size and weight of the ambulance-based telemedicine unit, this system is not portable enough to be used outside of the ambulance where a great portion of urgent patient care occurs[15]. As a result, these handheld systems have rarely been used in real time, becoming a hindrance to the user[12].

Recent work has shown that "smart glasses" have a high potential for supporting pre-hospital information transfer[25], because this novel technology offers touchless interaction mechanisms, such as voice control, to minimize the obtrusiveness of these tools[26]. These head-mounted, wearable devices with a transparent screen and a video camera that can project first person, point-of-view data to a remote viewer are *hands-free*, allowing care providers to focus on patients in many hands- and eyes-busy medical contexts. This novel technology could also reduce the likelihood of cross-contamination and patient infections since care providers do not have to handle the device physically.

Smart glasses also allow EMS providers to capture and share videos and pictures in real time, which are considered useful by emergency care professionals in the hospital. By doing so, EMS providers can easily share specific information about a patient (e.g., injury location and severity, symptoms) instead of spending a significant amount of time describing the patient situation with words. In addition, pre-hospital and hospital providers can connect via videoconferencing applications within the smart glass for more effective care coordination[27]. In this case, ED physicians can see and hear what the EMS providers see and hear through the smart glass application, allowing them to offer medical advice as EMS crews manage and stabilize a severe patient during patient transport. All these promising features of smart glasses make this technology of interest to EMS professionals, allowing them to have faster access to expert advice anywhere (e.g., outside of the ambulance)[28]. In our future work, we will look into how to design and develop smart glasses and hands-free interaction mechanisms to support real-time and effective pre-hospital information collection and sharing in the field. As prior work pointed out[29], smart glasses may introduce cognitive burden and human factor issues. These limitations require considering how smart glasses could be designed for seamless integration into the workflow of pre-hospital care while accounting for physical and cognitive limitations of emergency care providers. Also, social, organizational, and policy factors that can facilitate or impede the use and uptake of smart glasses will be explored in our future studies with various stakeholders.

This study has several limitations. First, we mainly relied on video review of simulated EMS interventions to understand the types of pre-hospital information being collected and shared in the field. It is possible that video recordings of simulations may not have clearly captured all work practices. Despite this limitation, this video review allowed us to analyze the data offline and capture detailed communication and work practices. Also, simulations provide a safe environment without the risk of loss of patient confidentiality. Second, the video recordings we analyzed were simulations with only 3 medical resuscitation scenarios. This limitation might affect the generalizability of the results to other domains (e.g., stroke or trauma). In our future work, we will conduct additional field studies with EMS providers to cover as many patient scenarios as possible for a more comprehensive understanding of the pre-hospital data collection and sharing practices in real world situations. Third, there is a five-year gap between the interviews with hospital teams and EMS teams. However, since the work practices and communication technologies (e.g., radio signal) haven't changed during this time period, we believe the impact of this gap on our findings is limited. Lastly, the video data and interview data were collected from different EMS agencies in different regions. However, these EMS agencies follow similar protocol and regulation, making the results generalizable. In addition, their different characteristics (e.g., fire-based vs. hospital-based EMS agency, east coast region vs. mountain region) can further strengthen the generalizability of the results.

Conclusion

In this study, we conducted a series of mixed-methods ethnographic studies with both pre-hospital and hospital care providers to examine user needs, work practices, and existing barriers in the pre-hospital communication process. We described the types of pre-hospital information commonly collected and shared in the field and whether the shared data meet the information needs of emergency care providers in the receiving hospital. We also discussed the issues and challenges related to real-time information sharing during pre-hospital encounters from both pre-hospital and hospital teams' perspectives. Finally, we used these findings to discuss potential technology solutions that could address the identified challenges and support seamless information sharing between pre-hospital and hospital teams.

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