Characteristics and Challenges of Clinical Documentation in Self-Organized Fast-Paced Medical Work

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Clinical documentation is a time-consuming and challenging task, especially in time-critical medical settings. Even with a dedicated scribe person, timely and accurate documentation under time constraints is never easy. In this work, we present a unique type of fast-paced medical team—emergency medical services (EMS)—which has no designated role for documentation while constantly working outside in the field to provide urgent patient care. Through interviews with 13 EMS practitioners, we reveal several interesting and prominent characteristics of EMS documentation practice as well as their associated challenges: EMS practitioners self-organize and collaborate on documentation while in the meantime being both physically and cognitively preoccupied with high-acuity patients, having limited capability to use handheld documentation systems in real-time, and being overwhelmed by strict documentation requirements and regulations. Lastly, we use our findings to discuss both technical and non-technical implications to support timely and collaborative documentation in dynamic medical contexts while accounting for care providers' physical and cognitive constraints in using computing devices.

CCS Concepts: • Human-centered computing • Collaborative and social computing • Empirical studies in collaborative and social computing

KEYWORDS

Documentation, teamwork, self-organized team, electronic health records, healthcare, emergency medical services

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1 INTRODUCTION

In the medical field, documentation has a critical role in supporting decision-making and work coordination because it provides a historical and temporal record of care team activities and patient care tasks [1]. As U.S. healthcare moves toward digitization, Electronic Health Records (EHRs) are being increasingly adopted by medical providers. Over the past two decades, seminal HCI and CSCW studies have examined the use of EHR in various medical settings and

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documented many challenges and limitations in EHR use, such as the gap between the formal EHR documentation and actual clinical workflow [2-4]. These limitations become more evident in time-critical medical settings because the documentation task in such settings is performed during a short and highly intense process, i.e., within a scale of minutes and even seconds, posing significant challenges in the timely and accurate creation of patient medical records [5-7].

Emergency medical services (EMS) is an example of time-critical medical domain with a highly dynamic and interruptive work context that often leads to extreme challenges in documentation, such as incomplete, delayed, or erroneous patient data entry [8]. For example, a study found that 28% of EMS records were missing physiologic data [9], while another study reported that almost 40% of the data fields on EMS records were either left blank or filled in erroneously [10]. What makes this medical domain even more interesting for the study of clinical documentation is that unlike other clinical teams which usually have a designated person (e.g., medical scribe, nurse recorder) in charge of documentation [11, 12], EMS teams do not have a dedicated role for data collection and documentation. Also, EMS teams work outside in the field and are constantly on the move while performing hands-on tasks to address patients' life-threatening illnesses and injuries, making the real-time use of the EHR system very challenging. Given those unique characteristics of EMS work, it is of utmost importance to understand how EMS documentation is performed and what challenges EMS practitioners face in recording time-critical patient data. These insights will inform technology implications for better supporting time-sensitive and highly dynamic documentation during EMS work. However, to date, there is limited research examining such challenging work practice that can provide important insights applicable to other similar dynamic environments.

In this paper, we report an interview study with 13 EMS practitioners conducted in the U.S. Northeast region. Based on our data analysis, we first describe the workflow of EMS and their specific tasks associated with data collection and documentation (Section 4). Then we report the key characteristics and challenges of EMS documentation work (Section 5). Specifically, we found that EMS documentation work is self-organized, and highly collaborative due to the dynamic and unstructured nature of the EMS work. The use of the handheld documentation system was affected by the time-sensitive and hands-busy nature of EMS work as well as strict documentation requirements. Based on the findings, we then conclude this paper by discussing both technical and non-technical implications that provide valuable insights for improving improvised, collaborative, and real-time data collection and documentation in time-critical medical settings.

Our contributions to the CSCW community are two-fold. First, we contribute insights on the characteristics, challenges, and strategies of documentation work in highly collaborative, time-critical, and dynamic patient care settings, such as EMS. Second, our study informs both technical and non-technical implications to support rapid and collaborative documentation in highly dynamic medical settings.

2 BACKGROUND AND RELATED WORK

2.1 Research Context: Emergency Medical Services

Following an incident that causes severe illness or injury, EMS teams are dispatched to the field to provide emergency care. Their primary goal is to quickly stabilize a patient's urgent health condition and transport the patient to the nearest or most appropriate care facility. In the United States, EMS services can be operated by a fire department, a hospital, a private agency, or a non-profit organization. There are two major types of EMS practitioners: *emergency medical technician (EMT)* and *paramedic*. They all undergo similar training in field data collection and documentation. However, there are significant differences between these two roles. For example, EMTs are trained to provide basic life support (BLS) such as cardiopulmonary resuscitation, oxygen administration, and wound treatment. While EMTs might work with paramedics, their scope and autonomy are limited. As compared to EMTs, paramedics have a higher level of education (e.g., 1,200 to 1,800 additional hours of training) so they can provide advanced life support (ALS) for patients, such as administering medication and fluids and providing advanced airway management (e.g., intubation). A typical EMS team has two practitioners, such as two paramedics or two EMTs. When a team has two paramedics, it is considered an ALS unit; in contrast, two EMTs can only form a BLS unit. In some cases, an EMS team is comprised of one paramedic and one EMT.

When an incident occurs, the ambulance dispatcher decides what level of EMS response is needed (BLS versus ALS) and how many ambulance units are needed. After arrive at the scene, EMS practitioners have to assess the patient and make decisions quickly. If a critical medical procedure is required or an ambiguous case presents, EMS practitioners can call remote experts, such as emergency department (ED) physicians at the receiving hospital, for decision support and online medical control. While performing patient care, EMS practitioners also need to collect, integrate, and document patient data from various sources. Depending on the agency, EMS practitioners may use paper forms or an electronic documentation system to record patient data.

2.2 EHR Use and Documentation Practices in Time-Critical Medical Settings

With the widespread adoption of EHRs in various clinical settings, the recording of patient encounters using this computerized system and its associated challenges have been the focus of many CSCW and HCI studies. For instance, a considerable challenge reported by prior work is the gap between the formal EHR documentation and actual clinical workflow—the current design of many EHR systems was found to have inherent limitations in capturing procedural and temporal information according to the actual clinical workflow [2]. In addition, recording patient data using EHRs is time-consuming and often results in clinician burnout [13]. To work around these barriers, clinicians and nurses often use paper charts and personalized report tools [14], as well as informal documentation mechanisms such as "working records" [15], "scraps" [16], and "provisional information" [17], to summarize patient situations and facilitate information sharing among team members during shift meetings.

The challenges in clinical documentation are exacerbated in time-critical medical settings, leading to ineffective and even limited use of EHRs. For example, one study examined the use of EHR in intensive care unit (ICU) settings and reported that the EHR system decreased the time ICU nurses spent on patient care compared to using paper records [4]. Another study examined

the use of an EHR system in trauma resuscitation and found that using EHR often led to incomplete or delayed data capture [5]. In a similar vein, Park and her colleagues examined the deployment of an EHR system in ED and its effects on ED clinicians' work practices [6, 7]. They found that the introduction of EHR in the ED has both direct and indirect effects, including increased documentation time and cognitive burden, decreased patient care time, shifted documentation responsibilities from attending physicians to residents, and temporary use of paper notes to transfer information. Altogether, these studies highlighted the significant challenges in clinicians' use of EHR systems due to the gap between the EHR system design and the clinicians' actual workflow in dynamic, fast-paced, and interruptive medical settings.

In our research domain, EMS teams face similar issues in the use of EHR systems for real-time charting. For example, a recent study [18] reported several key challenges in using an electronic record system by EMS teams, such as time-consuming and complicated data entry across screens, integration issues with existing hospital systems, and delays in addressing recurring technical problems. As such, it is not surprising to see that EHRs are rarely used in real-time by EMS practitioners who are already busy with unpredictable care situations and cognitive-consuming tasks. Literature suggests that the workflow and challenges of EMS documentation need to be thoroughly investigated to determine how to design or re-design electronic documentation tools for EMS practitioners [19]. However, limited research has investigated the specifics of EMS data collection and documentation in the field. Our work contributes to bridging this knowledge gap.

2.3 Role-Based Clinical Documentation

Roles in work and their impact on team coordination and communication have been extensively studied by CSCW researchers, especially in high-stake settings, such as underground control [20], air traffic control [21], search and rescue [22, 23], emergency preparedness [24], trauma resuscitation [25], and emergency medical dispatch [26]. In those settings, team members relied on clearly defined roles and responsibilities or division of labor to distribute cognition, assign or self-assign tasks, and coordinate work. For example, nurses are usually charged with collecting and documenting patient data so that physicians can attend to patients.

With the rising interest to offset the burdens of EHRs and improve documentation quality, new roles and occupations have started emerging in medical teams in recent years [12]. A typical example of such new roles is a clinical documentation specialist whose primary responsibility is to monitor the charting of physicians in real-time to make sure the data entry is accurate and complete [27]. Prior work has examined the work practices of scribe roles during patient encounters and their impacts on teamwork and patient care efficiency (e.g., [11, 28-30]). However, how fast-response medical teams with no designated role for documentation, such as EMS, complete documentation under extreme time pressure remains understudied in the CSCW community [31]. Thus, our work presents an important case that could contribute new knowledge and insights to the body of research in clinical documentation and role-based coordination in dynamic medical settings. Identifying key characteristics of teamwork when members cannot rely on clearly defined roles and specifications of who works on what to distribute workload and cognition is critical for understanding how to design (or re-design) EHRs and other computerized support for data collection and recording in highly dynamic clinical work environments.

3 METHODOLOGY

3.1 Data Collection

We conducted semi-structured interviews with 13 EMS practitioners recruited from four hospital-based EMS agencies in the U.S. Northeast region. The study was approved by the first author's University Institutional Review Board (IRB). Among our participants, 11 are paramedics while the other two are EMTs (see Table 1). Five of them "wear multiple hats" by serving other roles in their agency, such as an EMS director, an operation manager, and a quality assurance coordinator (e.g., being a field practitioner, P2 also does EMS training in his agency).

Table 1. Participant demographics

ID	Gender	Occupation(s)	Years of Experience
P1	Male	Paramedic	28 years
P2	Male	Paramedic & EMS Educator	15 years
P3	Male	Paramedic & EMS Director	25 years
P4	Male	Paramedic	18 years
P5	Male	Paramedic & Quality Assurance Coordinator	30 years
P6	Male	Paramedic & EMS Director	30+ years
P7	Female	EMT	11 years
P8	Male	Paramedic	23 years
P9	Male	Paramedic	14 years
P10	Male	EMT	4 years
P11	Male	Paramedic & EMS Operation Manager	21 years
P12	Male	Paramedic	11 years
P13	Male	Paramedic	7 years

The interviews were remotely conducted by two trained researchers in early 2021. Each interview lasted between 45 and 90 minutes. At the beginning of each interview, we started with questionnaires related to the participant's demographics, work experiences, and training backgrounds. To help us better understand their workflow, we asked them to describe one of their typical days, such as tasks they complete during a shift and who/which organization they communicate and collaborate with. The researchers then asked a series of questions regarding work practices, technologies and tools used, and challenges they faced concerning documentation, communication, and care coordination. All interviews were audio-recorded and transcribed verbatim.

In addition to the interviews, two EMS agencies also shared several samples of digital patient records (which were originally created with dummy data for training purposes) with the researchers and provided access to their web-based electronic documentation system, called electronic Patient Care Report (*ePCR*). The ePCR system has several tabs (e.g., incident, patient, vitals, treatments, assessments, narrative, and billing), with each tab detailing different types of information. For example, the assessments section contains data fields related to head-to-toe examination, mental status, chest, abdomen, pelvis, back, etc. (Figure 1). By exploring these artifacts, the researchers got an in-depth understanding of the documentation system our participants have been using.

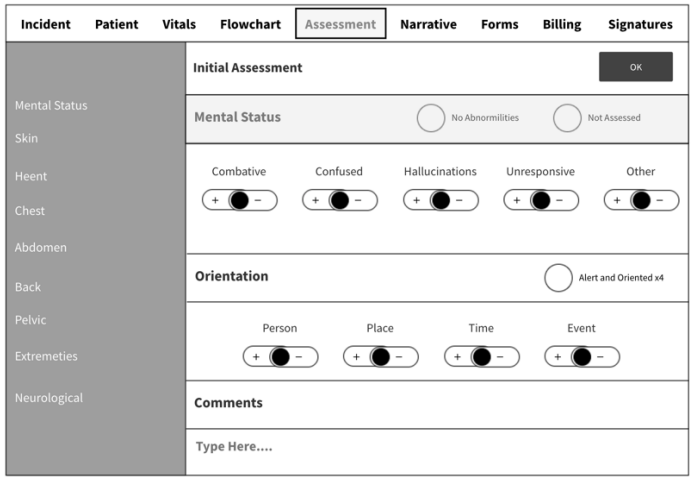

Figure 1: The mockup of the "Assessment" section of the ePCR system.

3.2 Data Analysis

We used an open coding technique [33] to analyze the interview transcripts. The codes were generated and discussed by two researchers in an iterative manner to determine which codes to keep, merge, or discard. Once consensus on the codes was reached, the researchers then used affinity diagrams [34]—a common approach for finding patterns in the qualitative data—to group all the codes under themes. This step allowed the researchers to identify high-level themes describing the characteristics and practices of EMS documentation work and the challenges faced by EMS practitioners in collecting, integrating, recording, and sharing patient data in the field.

In the next section, we describe our first finding—the EMS workflow—that emerged through our data analysis. This finding will help contextualize our subsequent findings about the key characteristics and challenges of EMS documentation work.

4 EMS WORKFLOW

Our analysis of the interviews with EMS participants showed that the entire EMS workflow could be roughly divided into five phases, and each phase has some unique information-gathering and documentation practices (Figure 2). Below we describe each phase in greater detail.

Phase 1: To be dispatched. The first phase is between dropping off a previous patient and getting a next patient assignment. During this period, the ambulance crews perform different tasks: they might still stay at the hospital or inside the ambulance finishing up the documentation for the previous patient who was handed off at the hospital, get back to their station to restock the ambulance, or do other things like getting meals. When a new task is assigned by the ambulance dispatcher, their second phase starts off immediately until they arrive at the new patient's location.

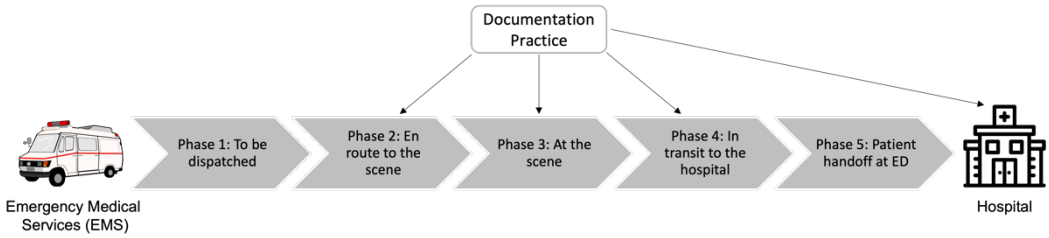

Figure 2: An illustration of the EMS workflow and the phases where documentation practice could occur.

Phase 2: En route to the scene. During this phase, EMS practitioners use the information relayed by the dispatcher to anticipate the patient's status and needs. The information is usually communicated via radio first and then sent to the Computer Aided Dispatching (CAD) system in the ambulance. As CAD is well integrated with the ePCR system, the patient's address, mechanism of incident, and some basic information (e.g., age, gender), if available, are automatically transferred from CAD to ePCR: "*They married their program [ePCR] to the CAD system. So now what ends up happening is when the unit receives an assignment, it will actually auto-populate the address and the call type into their documentation program*" [P2]. At that point, EMS practitioners only need to manually enter a few pieces of information into ePCR while they are en route to the scene: "*There are different sections of the documentation system. So, the first section is the incident information. We try to get that done before getting to the scene. Like where did we go? How did we go? How long did it take us to get there? Were there any weather issues?*" [P4].

Phase 3: Stabilizing patient at the scene. The third phase is from the moment of arriving at the scene until moving the patient to the ambulance. During this phase, EMS practitioners closely coordinate to assess, treat, and stabilize the patient, and collect the patient's information. Depending on the patient acuity, they may also document patient information into ePCR, such as demographics, medical history, mechanism of illness, and chief of complaints. If any treatment or initial assessment is performed at the scene, that information also needs to be captured and recorded. As one participant explained this process: "*What type of place did we find the patient, an apartment or a street corner or a hospital or a subway? How many patients are on the scene? [...] Then the patient information, so, the demographics where the patient lives, age, sex, and the insurance. [...] And the history of present illness. So that's where we document what happened to the patient, how long they've been feeling sick, the mechanism of injury, etc. And the next section [on ePCR] is known as the event log. So, the event log is where we do a line-by-line breakdown of every treatment record. So, you gave a medication that goes on one line, gave a second medication, goes on the second line, you did a splint, you started an IV, you gave oxygen. All of those interventions, whether they're clinical or not, or even assessment goes on a separate line. So, if you take a pulse ox, if you check their blood sugar, all of those go on a separate line. So, for a high acuity patient, you may have had 15 or 20 separate entries in an event log*" [P4].

While stabilizing the patient and deciding treatment options, EMS practitioners also need to make other decisions. For example, they have to determine the destination for the patient based

on various factors, such as the distance to the hospital, traffic, whether special care (e.g., trauma or neurology) is needed or not, and the patient's preference.

Phase 4: In transit to the hospital. This phase is where the EMS team and the patient are in transit to the receiving hospital. When the patient is stabilized, EMS practitioners move the patient to the ambulance and start transporting him/her to the nearest or most appropriate care facility they have decided. During the transit, only one practitioner stays with the patient while the other drives the vehicle. If the patient is in stable condition, the practitioner in the back starts documenting the patient's record. But if the patient's acuity is high and demands full attention, the practitioner usually relies on short-term memory or quickly jots down notes on temporary artifacts to preserve information for later use. One participant mentioned that although he primarily relied on his memory, he also used any convenient artifact to aid his memory: "*We pretty much know what we have done with the patient, so we just usually remember it, but if we need to write anything down like specific things, we can write it on a piece of paper, on our gloves and things like that*" [P1].

Another essential task in this phase is to give a brief verbal notification to the receiving hospital. This task is usually done by the ambulance driver who summarizes the patient's history and the last status on the scene. While doing so, the driver usually cannot communicate with the practitioner in the back of the ambulance regarding the current patient's status due to various reasons, such as the noisy environment of the ambulance, limited communication channel, and high cognitive load because of multitasking of navigating direction, driving, and contacting the hospital.

Phase 5: Patient handoff. Upon arriving at the hospital, EMS practitioners hand over the patient to ED providers. In addition to giving a comprehensive verbal report to the ED care team, EMS practitioners work with an ED nurse to register the patient. This registering process is usually followed by completing patient documentation, transferring the patient record to the receiving ED, and then getting a sign-off by the ED nurse. If EMS practitioners need more time to complete the patient record, they may stay in the ED or go back to the ambulance to focus on completing their documentation, particularly for the "Narrative" section in their ePCR system that requires a detailed description about the patient care trajectory: "*The last piece is a narrative history. So even if you do the event log, you still need to write a narrative that can be read in plain language of what occurred. [...] That's where you're going to have to write a whole lot*" [P4].

5 KEY CHARACTERISTICS AND CHALLENGES OF EMS DOCUMENTATION

In this section, we describe four unique, prominent characteristics of EMS documentation work, which provide important insights for designing appropriate documentation technology for urgent and dynamic care settings like EMS. While describing those characteristics, we also illustrate the challenges associated with each characteristic, and the workarounds (if any) EMS practitioners employed.

5.1 Self-Organized and Collaborative Nature of EMS Documentation

A typical EMS team consists of two members who usually decide and perform their tasks based on their own experience and in-situ situations, rather than having a certain structure in assigning their tasks, roles, and responsibilities. Moreover, unlike other clinical teams that have a dedicated documenting role (e.g., a scribe) who mainly documents patient records, EMS teams do not have a specific or designated role for documentation. As a result, EMS team members self-organize documentation tasks and, more broadly, patient care activities. For example, EMS team members might explicitly discuss who will work on what right before their shift starts: "*So typically, they [EMS team members] would talk it out. The way that I like to say in the beginning of the shift is that 'are you wheeling or are you healing?' You know, which one are you doing today? So, we kind of decide on our own who is driving and who is doing patient care*" [P9]. A long-term partnership could help two EMS team members form a routine of work distribution, so that each of them could assume an implicit "role" over a certain time. For example, one person works on documentation as well as driving while the other takes the lead on patient care work for a week, and then they may switch their primary task and responsibilities in the following week, as one of our participants explained: "*When I had a steady partner one week I would drive, and he would do all the patient care sitting in the back of the ambulance and the next week we'd switch*" [P11]. This self-organized nature of EMS work could lead to an experienced-based, informal team hierarchy—a non-bureaucratic, informal structure among team members who had equivalent roles and shared identical responsibilities, with a more experienced worker emerging as an informal leader [21]—which could affect the work distribution. For example, one participant explained how his work could be shifted and coordinated differently based on the partner for the shift: "*If I'm a senior guy, if I'm working with someone who's brand new, you're doing all the patient care because you need to learn. I'll do the documentation stuff in real-time*" [P8].

Due to the self-organized nature of EMS documentation, we found that this task was carried out in a highly collaborative effort between two EMS members. That is, two EMS practitioners usually contribute to documenting a single patient's information using the same ePCR system. This collaborative work practice is enabled by similar training in documentation and shared responsibilities of practitioners in an EMS team. Our participants explained that the collaboration between EMS team members was very dynamic and improvised, so that the documentation task could be taken over by any EMS practitioner at any time. In a typical case, the ambulance driver (who is also a practitioner) often starts collecting a patient's basic demographics and the chief complaint when they get to the scene, while the other EMS practitioner assesses and takes care of the patient's condition (phase 3, Figure 2). After the patient is moved to the ambulance for transportation, the driver hands over the documentation system to the EMS practitioner who sits in the back of the ambulance to take care of the patient. When time permits, the practitioner in the back of the ambulance may continue documenting the patient assessment and treatment information during the transit (phase 4, Figure 2). As EMS work is dynamic, switching documentation work between two practitioners could occur more often than in the typical case described above. One participant explained this dynamic, collaborative nature of their documentation practice: "*So, like if my partner is the one who is writing the final ePCR and I'm the driver, I might start by writing in the patient demographics, maybe if I have time, if I can, I'll document procedures in real-time, kind of like a scribe type person. And then when we get going*

during transportation, my partner can go through [my notes], and just double check and then they will write the narrative and fill in the missing pieces" [P8].

Challenges: Despite the benefits of collaborative documentation practice, there were challenges found to be associated with this collaborative documentation process. First, we found that the individual's preference and style in documentation could vary significantly between EMS practitioners: some of them lean toward a succinct narrative, whereas others prefer documenting as many details as possible. Also, each practitioner develops and uses his/her own style and format to follow when writing the narrative section. For instance, P8 described how his way of documenting patient information in ePCR was different from some other EMS members, in terms of what information should be entered, which section should be completed first and which can be left toward the end to complete, whether using abbreviations or not, and how much information needs to be documented and repeated: "*I see a lot of people repeating what they wrote in the flow in their narrative. Whereas me, if it's in my flow and the flow covers it, I don't write it in my narrative. If I have to emphasize something on the flow, I'll write a little bit more detail in the narrative. But otherwise, if it's in there [the flow], I don't rewrite medications, I don't rewrite IV because that is in the flow already*" [P8]. Such individual differences in documentation styles could lead to problems in their collaboration when both EMS practitioners work on the same documentation. For example, it is challenging for each EMS practitioner to quickly get a sense of where to read and what information their partner has documented or missed. In particular, when working with a new partner, it requires some time to be familiar with each other's documentation style.

Second, issues related to quality assurance could arise. For every submitted patient record by EMS, quality assurance staff reviews the quality, correctness, and comprehensiveness of the report. For the reports with missing or incorrect values, they will be sent back to the EMS practitioners for corrections; however, because of multiple EMS practitioners contributing to one patient record, it is difficult to track and identify who has completed which information and whom to ask questions about a specific data entry.

5.2 Highly Time-Constrained and Time-Sensitive EMS Documentation

Unlike other clinical settings where the patient encounters span hours, days, or months [35], the work pace in EMS is very rapid and usually situated within a highly condensed time frame (i.e., minutes and even seconds) [36]. During such a short amount of time, EMS practitioners are required to capture and record time-sensitive information, such as timestamps of vital signs and treatments. Such temporal information is crucial for EMS practitioners to plan next activities, maintain awareness of the patient's condition, and coordinate patient care across members or teams. For example, for some time-sensitive medications that may lose effect after a certain amount of time, EMS practitioners need to rely on accurate timestamps to calculate how much time had passed since the medication was administered. Our participants confirmed the importance of documenting temporal information in a timely and critical manner: "*[They] need to be timestamped appropriately so that you can communicate what type of care you've given to the patient*" [P12].

Challenges: Not surprisingly, the fast-paced EMS work left providers with very limited time to properly collect, integrate, and document patient information, especially time-sensitive information: "*It's actually kind of hard to collect and document patient data in real-time. A lot of times, you know, a whole call might be finished within 45 minutes or even shorter from responding to the call to meeting up with the patient and then going to the hospital. You could just imagine trying to get all information documented with evaluating the patient within that short period of time is a little hard*" [P5].

Workarounds: To cope with challenges with fast and accurate information documentation, EMS practitioners used several strategies. For example, they typed some bullet points in the narrative section of ePCR and used them to recall information: "*What I ended up doing now is just going straight into the narrative part of the ePCR and briefly jotting down certain bullet points, like chief complaint, medications, things like that. And then I go back and edit it once I hand off patient care*" [P9]. Also, EMS practitioners used other devices to help them keep track of some temporal information. For example, one participant explained that he would use a unique feature of the vital signs monitor to record the timestamps of medication administration: "*I personally like to use the event stamp on our heart monitor for medication giving. I think a lot of people don't necessarily know that that function even exists. But I will use that and then I can do a printout and go back after the patient handoff, and say, okay, this is the time stamps I did everything*" [P8]. Lastly, a common practice cited by many participants was that they tended to just rely on their short-term memory to remember when each procedure was done and then estimate the timestamp for each procedure after handing the patient off: "*As far as [documenting] treatment and medications are concerned, a lot of that you'll tend to do after you drop off the patient because sometimes, let's say a cardiac arrest, you're heavily involved. You might be using 10 to 20 medications throughout that whole process, and you're not going to have time to punch everything in. So, you do your best to estimate the time after the call is over. Usually, you look at what time you actually arrived on the scene, and then you sort of guesstimate [guess and estimate], okay, I probably gave X at this time, and Y at that time. So, it's not a perfect science, but it is how we do our work in the real world*" [P2].

5.3 Hands-Busy Nature of EMS Care and Documentation

Due to the lack of dedicated documentation role, EMS practitioners need to multitask during pre-hospital encounters—collecting and integrating vast amounts of information from multiple sources, communicating with partners, remote experts (e.g., an ED physician), or patient's family, and observing the scene, while performing hands-on patient care tasks. This multitasking practice is more prominent in phases 3 (stabilizing patient at the scene) and 4 (in transit to the hospital) where patient care demands a lot of care providers' cognitive attention and physical involvement. Such hands-busy nature of EMS work poses challenges in using the ePCR system to document numerous patient information in real-time, as described below.

Challenges: EMS practitioners had limited cognitive and physical capability to use the handheld ePCR system in real time to document all necessary information related to the patient's condition, treatment, and relevant contextual information. In particular, when patient severity was high, EMS practitioners had to focus on patient care tasks rather than documenting tasks and therefore, often neglecting documentation until the patient handoff. In such cases, the documentation work often became a secondary task, as one of our participants elaborated: "*EMS*

is situation specific. If the patient is a lower acuity patient who doesn't necessarily need immediate care, we'll usually spend some time on the scene detailing demographics. But if it's a high acute patient and they need constant monitoring, changing of their medications, the person in the back performing patient care is not going to be doing any documentation. I would wait until the end of the job to document, because obviously it's really difficult to document, and give them medications or perform the intervention while moving in the ambulance" [P12]. Also, performing hands-on patient care while interacting with handheld medical as well as computing devices could lead to concerns about cross-contamination and patient infections: "*If we're both working on patient care at the same time, we only have two sets of hands and we're both needed on taking care of the patient and can't really document in real time. Infection control also comes to mind where if I'm wearing gloves, I don't necessarily want to touch my ePCR with it because I don't want to get that all contaminated*" [P8].

The challenges of using ePCR were further exacerbated by its usability issues: First, many of the data fields on the ePCR system interface that were rarely used made practitioners feel overwhelmed and frustrated without having an option to customize the interface like hiding the unnecessary fields: "*There are some annoying parts about it. I think it has to do with what information can or can't be hidden on the interface. Like the information fields that we'd never use, and they are just kind of there all the time, and that really annoys me. [...] It seems like it's a very universal document, and it's not specifically tailored to our work. Our supervisors not knowing how to adjust it or if it's just not able to be done*" [P13]. Another usability issue with the ePCR system was no physical keyboard available for documenting on the mobile platform since typing on the touch screen could be cumbersome and require much more EMS practitioners' visual attention compared to typing on physical keyboards. Several participants commented that the lack of a physical keyboard decreases their documentation efficiency: "*At my organization, we're using iPads that don't even have keyboards. Not having a physical keyboard to fill out a lot of fields could be a little bit difficult to submit your paperwork in a timely fashion*" [P12]. Lastly, although many usability issues with ePCR were apparent to EMS practitioners and their agencies, they found that the underlying issue lied on the system's vendor and their interests, because one of the primary purposes of the system design was to streamline the billing process, rather than improving EMS work: "*I think one of the biggest issues is they [ePCR vendors] solely look at it for NEMSIS*[2] *and as a billing document and they forget that it's still a patient care document. So, if NEMSIS doesn't require it, they don't want to add it because it has nothing to do with NEMSIS, even if it were beneficial to us. So, I find that maybe these ePCR companies just build a system around NEMSIS, and they didn't talk to the people who would be using it and what they're looking for on top of it*" [P8].

Workarounds: To work around these limitations in using ePCR, our participants mentioned that they would use temporary artifacts (e.g., notepad, glove, thick tape, etc.) to quickly jot down notes to help themselves remember critical and easy-to-forget information. P12 explained how he used various artifacts based on the situation at that moment as a memory aid: "*If it's a high acuity, I'll usually write something on my glove. If it's something like a cardiac arrest where I'm going to*

[2] NEMSIS is an acronym of the National Emergency Medical Services Information System, which is a universal standard for how patient care information resulting from an emergency 911 call for assistance is collected.

be in one place for a long period of time, honestly, what I'll do is I'll take like a couple of different pieces of a two-inch tape and then put it on my pants. And then, I'll write on the tape that's on my pants" [P12].

5.4 Highly Regulated EMS Documentation

The EMS documentation is highly regulated by policies and standards with an aim to improve patient care through the standardization of EMS data collection and documentation. For example, EMS practitioners should follow the guidelines and requirements to complete a great number of required data fields: "*There are data elements that are required by state. There are fields and information that must be input for every call, no matter what call it is*" [P3]. If a piece of particular required information was not documented, the ePCR system would alert the user to complete that data element: "*It [ePCR] will be in red and telling you, 'hey, you left something out'. Sometimes they leave out the respiratory rate or they leave out a time or something, the software puts these red marks on those areas*" [P6].

Challenges: Despite the needs and the benefits of such EMS data standardization, EMS practitioners have expressed concerns about the challenges imposed by these regulations, which introduce strict requirements for EMS practitioners to comply: "*There's a lot of extraneous check boxes that are required. So that just adds unnecessary time. For example, if I put on a pulse-ox, I have to write, was it successful? How did it affect the patient? Positively or negatively? And were there any bad side effects to it? It's putting on a piece of plastic on a finger. It's not going to have any of that, it's not pertinent, but it's required documentation. And, you know, it's for every single procedure, even if those procedures have no real potential to cause that [harm] to happen*" [P8]. Also, different organizations have slightly different standards and requirements, creating confusion and complexity to EMS practitioners: "*We have to figure out a way to make NEMSIS happy, because they have their own requirements on how to do it. Our agency has its own requirements on how to do it, and then the state EMS council and the city EMS council have their own requirements on how to do it. All of those requirements create such a complex thing*" [P2].

Given the complex requirements and varying standards, all of our participants shared that completing their documentation in the field was nearly impossible, and the documentation task became a huge burden on their time-sensitive patient care work. P12 expressed his concern that extensive documentation work required for EMS practitioners could take their time and attention away from the patient care, which should be the most important task: "*There are so many data fields that need to be filled out. [...] What somebody was saying to me the other day I agree with is you almost feel like you're being penalized for performing more patient care, because the more patient care you perform, you have to document all of it. And the more you have to document, it becomes a little bit more complex, and it takes a lot more time because of all the fields in ePCR that you have to fill out*" [P12].

6 DISCUSSIONS

In this study, we present an interesting yet understudied case of clinical documentation in the context of EMS that could contribute new knowledge and insights about fast-paced, collaborative documentation practices and opportunities for enhancing real-time documentation in dynamic medical settings. Below, we discuss the technical and non-technical implications of our findings.

6.1 Technical Implications

6.1.1 Supporting collaborative documentation practice

As described in section 5.1, EMS documentation is highly collaborative in its nature with more than one practitioner contributing to recording patient data. This flexible work practice is enabled by similar training in documentation and self-organized, unstructured, and improvised teamwork. This unique team dynamic allows EMS practitioners to collaborate to focus and complete pressing tasks, including documentation, in a timely and efficient manner. Despite the benefits of collaborative documentation, our analysis has shown that there are critical challenges in this work practice that could cause potential problems in the completion and review of documentation. For example, individual EMS practitioners may have different documentation styles and preferences, which may lead to collaboration barriers when both EMS practitioners work on the same documentation, since it is challenging to quickly get a sense of where to read and what information their partner has documented or missed. To mitigate the gap in different documentation styles and support the collaborative documentation process, it might be useful to provide an *"at-a-glance" overview of the documentation progress* on each section of ePCR (e.g., displaying a progress bar). By doing so, EMS practitioners can quickly get a sense of how much required documentation is left and which specific part is missing, when taking over the documentation from their partner.

In addition, as shown in our findings the retrospective reviews on the patient records for quality assurance purposes (e.g., who documented what) could trigger potential issues when multiple practitioners work on the same patient record. Inspired by prior research on emergency response [37], the ePCR design needs to *support accountability to make documentation and information sources attributable* [38]. This can be achieved by enabling multiple authorship, color-coding, and tracking the history of edits and changes within ePCR, similar to the design requirements for many collaborative authoring tools [39, 40].

6.1.2 Semi-automated recording of micro-temporal information

Temporality is one of the most important aspects of EMS work. Although temporality in medical work has been discussed extensively in the existing CSCW literature (e.g., [35, 36, 41-45]), the level of temporality in the EMS practice is much more micro at scale (i.e., within a scale of minutes or even seconds), compared to other patient care settings. As described in section 5.2, many key data that the EMS team must collect and record (i.e., timestamps of the patient's vital sign information, medication administration, treatment, etc.) are time-sensitive and ephemeral. As such information provides medical providers with the necessary evidence and awareness about the timing of past and present medical activities [36, 42, 46] for appropriate clinical decision-making, timely and accurate collecting and recording of temporal information are essential in the EMS work practice.

However, the temporal information is hard to be recorded during such an extremely short time of patient encounters. Even more concerning fact is that our study has shown that EMS practitioners may not have the capability to use their electronic documentation system in real-time and lack other effective mechanisms to record temporal information in a timely fashion. To work around this issue, our practitioners often took a retrospective approach to complete the information record after the patient handoff, such as thinking backward to estimate the past

timestamps of each activity like vital signs and medication administration based on their arrival time at the scene. However, this workaround has been found to be problematic because such micro-temporal information is difficult to be accurately recalled purely from memory given the high-intense EMS care setting [47].

To alleviate this problem, *semi-automated recording of time-sensitive information* can be a viable solution. Existing research has explored different technologies to accomplish automated patient data collection. For example, a recent study leveraged a combination of sensors (e.g., gesture control armbands) to passively collect data, such as the sequence of patient care procedures performed, medication timing and dosage, and specific vital sign ranges, to create an abbreviated care record [48]. Another proven approach is utilizing a barcode-enabled medication administration application to scan medication barcodes to extract and record the medication information and administration timestamps rapidly with fewer errors [49]. According to the literature, these technologies, coupled with the EMS documentation system, may enable more accurate and timely capture of key temporal information and events while reducing practitioners' cognitive burden on remembering them.

6.1.3 Enabling hands-free documentation

Recording patient data in real-time using a handheld electronic documentation system is a challenging task cognitively as well as physically for EMS practitioners since they have to constantly move around and manage various information, while performing hands-on patient care tasks. To deal with this challenge, our participants mentioned that they sometimes had to postpone the documentation tasks till they became available (e.g., after the patient handoff). EMS practitioners also commonly used temporary artifacts, such as gloves or tapes, to preserve easy-to-forget information (e.g., baseline of vital signs, dosage, and time of medication administration) and aid their memory. However, these workarounds used by our participants have inherent limitations. For example, the temporary artifacts are vulnerable to getting lost, contaminated, or torn, as experienced by our participants and also reported in prior work [19]. It is, therefore, not surprising to have incomplete, delayed, and erroneous EMS patient records, hindering real-time information processing and decision support as well as timely information sharing between care team members [50].

To help their real-time documentation while accounting for the constraints in using handheld computing devices in such hands-busy settings, it would be worthwhile considering means to *enable hands-free data collection and documentation*. In recent years, researchers have explored, developed, and evaluated new technology solutions for EMS teams to use in the field to reduce their need to use physical handling of computing devices. For example, a wireless biomonitoring system with sensors was tested in a massive casualty incidents scenario to help EMS practitioners continuously measure, record, and monitor the vital signs of multiple patients and make triage decisions at the field site [51]. Despite their advantage in the auto collection of vital signs, EMS practitioners still needed to use a separate handheld device (e.g., a tablet) to manually record other types of patient data (e.g., treatments, assessments, etc.).

Another promising technology is wearable technologies, such as smart glasses, since they offer hands-free interactions via voice controls and hand gestures [52]. While researchers have mainly tested its usefulness and affordance as a telemedicine tool (e.g., [53, 54]), its potential in facilitating clinical documentation has begun drawing attention recently. For example, in the context of wound care management, Aldaz, et al. [55] developed and evaluated a smart glass application to

enable hands-free digital image capture and transfer to the EHR system through gestural and voice commands. However, to date, limited research has investigated its application in time-critical medical settings. Future work will need to examine the feasibility of leveraging smart glass technology to offset the burden required for dynamic real-time documentation. For example, EMS practitioners can 1) capture images and videos to preserve time-sensitive contextual information and 2) dictate directly to smart glasses to automatically populate the data fields on ePCR.

6.1.4 Summary

Given the prominent challenges in the current EMS work practice, it is urging to consider what existing technologies are available or what kinds of new technologies are needed to better support this dynamic and challenging documentation task. Prior research in time-critical domains has explored and proposed different technology solutions, ranging from sensors to mobile and wearable applications. Even though these technologies are all very promising, it is important for technology designers and researchers to keep in their mind that EMS is a fast-paced, dynamic, and hands-busy environment, which could create tensions between technology use and the temporal aspects of the actual work practice. Researchers have argued that introducing new information technology in time-critical settings should avoid features that could lead to delays in clinical workflow and patient care [56]. In line with this argument, we believe that technology support for EMS should be as unobtrusive, hands-free, and minimal as possible. If new technology needs to be introduced, it needs to be seamlessly integrated with the current workflows and technologies (e.g., EHR) without causing any extra burden on emergency care providers.

6.2 Non-Technical Implications

6.2.1 Enhancing self-organized work and supporting informal team hierarchy in EMS

Clearly defined roles or division of labor have an important function in organizations and teams because they affect how work is organized and coordinated [57]. However, unlike other typical work settings where collaboration is carried out based on clearly defined work boundaries, distinguished roles, and explicit responsibilities, in our study on EMS there is no specific role or responsibility assigned to each team member. Moreover, the EMS team does not have any formal hierarchical structure.

As shown in our analysis, this unstructured and informal characteristic of EMS teams has allowed the EMS practitioners to actively self-organize their tasks and improvise their work routines based on varying situations. This flexible, self-formed practice has helped them better prioritize the time-pressing patient care tasks, effectively assist each other, and coordinate tasks to address urgent needs of different situations. Such self-organized, less structured work practice is found to be beneficial and efficient and should be sustained. However, as pointed out by prior work, self-organized work practice can be vulnerable to teamwork and collaboration problems; for example, without the organizational-level procedures and policies about who does what, some tasks may become "no-ones-tasks", blurring the boundaries of task ownership [58]. In addition, a lack of clear division of labor can lead to redundant task performance or even tensions in work distribution between team members, creating more challenges in teamwork [7, 32].

Thus, by acknowledging both the benefit and potential downside of the self-formed, unstructured team practice, we suggest that simply using computerized solutions may not be an

appropriate approach to support the EMS practice. Instead, we believe enhanced training that particularly focuses on non-medical skills, such as communication and care coordination, will be useful and necessary to quickly develop and improve self-organized teamwork [59, 60]. Also, gathering various experiences and knowledge from the experienced EMS practitioners (e.g., tips, guidance, and suggestions based on various EMS situations) and sharing them among inexperienced or incoming practitioners can help build conventions and team dynamics collectively over time [61].

6.2.2 Encouraging the use and creation of workarounds

Even though there are exciting technology opportunities for improving EMS documentation, we as system designers and researchers need to bear in mind that technology is not perfect, and it is inevitable for care providers to encounter unseen technical issues or unintended problems in reality. In addition, EMS is a tough environment that can easily cause damage or loss of computing devices. As such, EMS system designers, organizations, and policymakers should consider and prepare alternatives and support EMS practitioners' use and creation of workarounds. For example, a popular tool adopted by some EMS practitioners is a special glove with a pre-printed template of vital signs to assist in the capture of baseline vital information of the patient. Even though using a printed vital sign template on a glove is not part of the formal documentation process, EMS practitioners may find it useful and easy for rapid data collection compared to using technologies. Another possible approach for supporting the use of workarounds is to combine the formal and the transitional artifacts [62], such as digital tools and papers. Since EMS practitioners frequently jot down notes on gloves or notepads, it would be useful to provide them with a digital pen—an ordinary ink pen with a digital camera that digitally records the writing actions of the user—which can allow EMS practitioners to continue working with a familiar environment using pen and paper without any disruption to their current workflow. Several studies in time-critical medical settings have demonstrated the usefulness and feasibility of the digital pen-paper tool in supporting clinical documentation in real-time [63, 64], and others have reported the need of incorporating physical paper notes along with the EHR-based electronic charts to support the dynamic nature of clinicians' documentation and workflow in emergency care settings [2, 6].

6.2.3 Addressing the tension between documentation requirements and patient care needs

Our study has revealed the challenges brought by various levels of strict regulations and requirements for EMS work. Such regulations and requirements have shaped the design of ePCR, such as the creation of numerous text fields, checkboxes, and other data elements required to be completed for billing purposes. However, the time-critical and hands-busy nature of EMS poses constraints on the use of ePCR in real-time, leading to the tension between accomplishing documentation requirements and meeting patient care needs. Literature in the health informatics field has pointed out that such documentation tools have become "*a bloated repository of repetitive and redundant information*" [65]; they produce limited clinical value but add more time to the documentation process and lead to clinician burnout [66].

This common and long-lasting problem in healthcare practice is too complicated and not easy to solve. However, recently researchers have been exploring approaches to tackle this issue. For example, they suggested that the U.S. healthcare system should emphasize the need to transition from 'pay-for-transactions' to 'pay-for-value' so that the focus of documentation could return to supporting high-quality patient care delivery and care team communication [65]. Our study also

calls for a need for essential players and stakeholders, such as the Centers for Medicare and Medicaid Services (CMS), to consider re-examining and deemphasizing documentation requirements as a condition of payment for health care services.

6.2.4 Summary

Our study also offers organizational and policy implications: 1) increasing training opportunities for EMS practitioners to enhance self-organized and collaborative team dynamics, 2) supporting the use and creation of workarounds to cope with barriers and potential failures in using necessary technology, and 3) deemphasizing and phasing out the granular documentation requirements over time at the national level. We believe that these non-technical solutions are equally important as technical solutions to solve the complex EMS documentation challenges.

7 CONCLUSIONS AND FUTURE WORK

In this paper, we report an interview study with EMS practitioners to present the characteristics of EMS documentation work, challenges in real-time data collection as well as challenges in documentation using currently available technology and artifacts. We found that EMS teams self-organize and collaborate on documentation while being affected by time constraints, technology use constraints, and strict regulations and documentation requirements in the EMS context. We finally use these findings to discuss both technical and non-technical implications.

It is worth noting several limitations of this study. First, we solely relied on interviews in this study and lacked other types of data (e.g., observations) to corroborate our findings. In our future work, we will conduct additional user studies, including in-situ observations and design workshops, to further investigate how to design technology support to address challenges of real-time EMS documentation while taking unique characteristics of EMS teamwork into consideration. Second, our work was conducted in only one area (U.S. northeast region). The results thus may not be fully generalizable to other regions or countries. Future studies including other regions are needed to compare with and generalize the findings reported in the present work. Lastly, our study participants were mostly male with only one female EMS practitioner. Although EMS is a male-dominant work practice, female participants may have different opinions and preferences. Thus, future work needs to be done by including more female EMS practitioners.

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