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Challenges to effective crisis management: Using information and communication technologies to coordinate emergency medical services and emergency department teams

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ABSTRACT

Objective: The purpose of this study is to identify the major challenges to coordination between emergency department (ED) teams and emergency medical services (EMS) teams.
Design: We conducted a series of focus groups involving both ED and EMS team members using a crisis scenario as the basis of the focus group discussion. We also collected organizational workflow data.
Results: We identified three major challenges to coordination between ED and EMS teams including ineffectiveness of current information and communication technologies, lack of common ground, and breakdowns in information flow.
Discussion: The three challenges highlight the importance of designing systems from socio-technical perspective. In particular, these inter-team coordination systems must support socio-technical issues such as awareness, context, and workflow between the two teams.

1. Introduction

From a healthcare perspective, emergency crisis management is a broad-based and collaborative activity that focuses on saving lives during and after a crisis. As crises such as the 9/11 attacks and Katrina aftermath highlight, a close cooperation between pre-hospital emergency medical services (EMS) and hospital emergency departments (ED) teams is crucial for rapid and effective care of victims [1]. For instance, the decisions taken by emergency medical personnel without effective coordination with ED personnel during the World Trade Center attacks in 2001 to transport all the initial casualties to the three nearest hospitals overwhelmed those institutions [2]. They were unable to handle the large influx of patients in such a short time-span. Although crisis response requires close cooperation between EMS and ED teams, this coordination was sparse and often non-existent during 9/11 and the Katrina. In fact, the lack of coordination between pre-hospital and hospital teams was highly detrimental to the response to the crises.

One of the key factors for effective crisis management is designing information and communication technologies

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(ICTs) that support effective and seamless coordination between teams during a crisis. Although systems are currently being developed to support first responders and other emergency personnel [3], we must also develop systems that bridge the gap between pre-hospital (e.g., EMS) and hospital (e.g., ED) teams. Medical informatics researchers are beginning to develop information technologies to be used in disaster response [4]. These technologies include tele-presence systems that present live video feeds to help first responders [5] and electronic dashboard [6] for crisis situations that allow all personnel to see information such as team leaders. Although these technologies help address a number of important problems, there are still few technologies that are designed to support *inter-team* coordination [7]. For instance, many of the current technologies focus on improving intra-team communication. They are not designed to support the flow of information and coordination between these teams. Therefore, we need to develop information systems that will support inter-team coordination.

However, before we can effectively design these systems, we must first understand the challenges that these teams face when trying to coordinate with each other during a crisis. To investigate the challenges that ED and EMS team members face when communicating and coordinating their activities with each other during a crisis, we conducted scenario-based focus groups with EMS and ED team members of a major regional teaching hospital. Through focus groups, we identified a set of coordination challenges and *socio-technical* design requirements [8] for information and communication technologies to support inter-team coordination during a crisis response.

2. Background

In this section, we describe some studies that have focused on coordination in crisis response. We then provide some background on socio-technical theory.

2.1. Crisis response

Crisis management demands rapid and timely coordination, not only between members within a team but also between members of different teams. Each team has different roles and responsibilities. In particular, during a crisis, the coordination between EMS and ED team members need to be tightly coupled and aligned with organizational goals for effective crisis response [9,10].

The dynamic and complex nature of a crisis often makes it difficult for EMS and ED teams to coordinate their activities. Some of the major challenges associated with team coordination during crisis management include information mismanagement [11,12], resource allocation issues [13], and ineffective communication [14,15]. These challenges collectively can lead to coordination and communication breakdowns between these teams. One proposed solution that has been reported to alleviate these challenges is to design information and communication technologies (ICTs) that facilitate coordination of crisis response activities. For instance, Kyng et al. [12] found that the use of biosensors to obtain critical parameters in evaluating patients, and tracking of patients using a combination of unique ids with pictures of patients to support effective information management. Other systems have also been developed to support collaboration and effective resource management during a crisis [3].

Although medical informatics researchers have demonstrated the benefit of information technologies in both pre-ED and ED settings [3], they have not focused as much attention on the role of ICTs in supporting coordination between these heterogeneous teams. Studies on coordination during a crisis have primarily focused on highlighting the importance of coordination either within pre-ED teams [16,17] or within ED teams [3]. For example, in one study [16], the authors examined the cooperation between pre-ED teams in improving organizational performance. The authors highlighted requirements for developing workflow management systems that can support coordination among pre-ED teams but not between pre-ED and ED teams.

Furthermore, although studies have highlighted the *need* to coordinate the activities of EMS and ED teams at a state, regional and federal levels [18], the details of the challenges of coordinating these two types of teams at the local level have not been widely examined. For instance, Comfort and Haase [19] analyzed the coordination activities among public, private and nonprofit organizations that evolved in response to Hurricane Katrina. The authors then proposed a model of auto-adaptation that can improve inter-organizational performance by supporting features such as timely access to information and information exchange between organizations at different levels (e.g., state, regional).

2.2. Socio-technical theory

Highlighted in the seminal work of Trist and Banforth [20], socio-technical theory argues that the social and technical features of organizations are closely connected to and effect each other. So, for instance, the introduction of a new technology in an organization will impact how people work in the organization. Yet, at the same time, the people doing the work will also impact how the technology is utilized. Consequently, designers must not only consider the technical challenges of the system but also how the social features (e.g., people) of the organization can effect the implementation and use of the system [21,22]. Enid Mumford played a key role in articulating the principles of socio-technical theory through her research on the interaction of people and technology [23,24]. In particular, her work has focused attention on the importance of understanding the social features of the organization and how technologies must be designed to support and empower the people using the technology [25].

Consequently, the focus of socio-technical research in the medical informatics field has largely been on understanding the interactions between people, healthcare organizations, and health information systems [26]. Researchers such as Marc Berg [21,27,28] have discussed the importance of considering socio-technical issues when designing, implementing, and evaluating health information systems. Without understanding the social features of healthcare organizations, it is difficult to develop information and communication technologies that can appropriately support individuals and teams

in these organizations [29]. In this paper, we used the socio-technical perspective articulated by Mumford and others to guide our data collection and analysis. In particular, we were interested in identifying socio-technical issues that designers must pay attention to when developing ICTs to support inter-team coordination.

3. Methods

To understand the challenges to inter-team coordination at the local level, we conducted focus groups with both EMS and ED staff at a large academic medical center. We also observed meetings that took place after a practice disaster response at the hospital. In the focus groups, the participants were given a time-sequenced scenario of crisis in the local region. They were then asked to respond to the scenario as if it was unfolding in real time. The study was approved by the hospital's Institutional Review Board.

3.1. Research site

We conducted seven focus groups with a total of twenty-one EMS and ED personnel at Hershey Medical Center (HMC), a major teaching hospital in Pennsylvania. HMC is a 500-bed hospital that has nearly 48,000 ED visits per year. During a crisis, HMC's ED would be a major recipient of casualties in the Central Pennsylvania region. HMC's *ED team* comprises of healthcare providers including attending physicians, residents, charge nurses and staff nurses, emergency medical technicians and other administrative support workers. HMC's ED is serviced by an *EMS team* consisting of:

- LifeLion service: two medically equipped helicopters and a pediatric mobile intensive care ground ambulance. A Communication Center (CC) supports the LifeLion service. The CC is staffed by specially trained air medical communications and ground dispatch specialists.
- University EMS (UEMS) service: nine Advanced Life Support-equipped ground ambulances.

Both the services transport patients from the incident scene to the ED.

3.1.1. Research subjects

We conducted three focus groups with care providers who work in the HMC's ED and three focus groups with EMS staff belonging to LifeLion and UEMS services and one focus group with communication center staff (Table 1).

Table 1 – Focus group participants

Type of participant	Participants	Focus group#
Attending physicians	5	1
Emergency medicine residents	6	2,3
Ground and air transport personnel	8	4,5,6
Communications center staff	2	7

- *Attending physicians* (*Focus Groups 1*): The attending physicians were included to obtain a perspective on crisis response protocols and procedures within the ED. For example, they provided insight into mechanisms used to prepare for incoming patients. Furthermore, since the attending physicians were responsible for running the ED during an emergency, they were able to provide details about the particular type of information that they needed from the EMS team.
- *Emergency medicine residents* (*Focus Groups 2 and 3*): The emergency resident physicians were included to provide another perspective on the ED team during a disaster response.
- *Ground and Air Transport Personnel* (*Focus Groups 4–6*): The LifeLion and UEMS personnel were included to capture the viewpoint of emergency responders during a crisis. For instance, they provided information on whom they report to at the incident site or how does the incident commander allocate his resources etc.
- *Communication Center staff (Focus Group 7)*: The communication center staff were included in the focus groups because they played a unique role as intermediaries between the ED and EMS teams because they serve as the main conduit for information between the two groups.

3.2. Research procedures

We utilized a qualitative research method (focus groups) to understand the challenges to coordinating an effective response to a crisis. The use of qualitative methods was particularly appropriate here because of our interest in the details of the contextual nature of healthcare work [30].

The focus groups were given a scenario of a train derailment involving leakage of hazardous materials (Table 2). The scenario was designed to progressively provide participants with time-stamped events to mimic how information would be presented to them during an actual crisis. The scenario was based on an actual train derailment that occurred in Hershey, PA on July 5, 2006. The medical issues presented in the scenario were developed in conjunction with one of the co-authors who is also the Director of HMC's ED.

3.3. Data collection and analysis

After presenting participants with an event, we asked them several questions regarding how they would respond to the event. The questions were related to (1) their information and communication needs, (2) their ICT use, and (3) their roles and responsibilities during the crisis (Table 3). During the focus groups, there were two researchers present in the room taking notes and guiding the discussion. We tape-recorded the focus groups and also attended review meetings conducted after a disaster drill to discuss the positive and negative aspects of the coordinated response during the drill. Finally, we reviewed after-action reports and HMC's disaster response plan, and gathered patient triage sheets used during an actual crisis, The data collection led to over 100 transcribed pages of focus group data to analyze.

After transcribing the focus group data, we used the Grounded Theory [31] approach to conduct our analysis. The underlying assumption of Grounded Theory is that a deep

Table 2 – Scenario used for ED focus groups

#	Time	Event
1	5:30 pm	Date: Wednesday, July 5th A nurse comes into the ED saying there has been a train derailment in Derry Township. The derailment seems to have occurred near the golf course of the Country Club of Hershey.
2	5:36 pm	Communications room notifies the ED that 8 cars of a Norfolk Southern freight train have derailed near Hershey Park Drive. Five of the cars were carrying potentially toxic chemicals.
3	5:42 pm	Some of the derailed cars were carrying hazardous materials, such as potassium hydroxide and chlorine.
4	5:45 pm	First responders confirm that around 200 people may have suffered aerosol and contact exposure from chlorine gas.
5	5:50 pm	A gunshot victim presents to the ED with hypotensive, tachychardic and decreased breath via a private vehicle.
6	5:52 pm	An ambulance brings in 3 patients with exposure; 2 of them are in respiratory distress (they might have closing down airways due to the exposure). EMTs report that 50 more patients are likely on their way to the ED.
7	5:57pm	Another ambulance brings in 3 more patients suffering from severe dyspnea. This is followed by a private vehicle bringing in 6 patients with dyspnea and mucous membrane irritation.
8	6:04 pm	20 more patients present with symptoms of non-life threatening exposure. At the same time, LifeLion informs of a freeway accident in Mechanicsburg involving 3 people suffering from possibly fatal trauma; victims are on their way to the ED.

understanding of social phenomena can occur only from real-world observations. However, Grounded Theory does not provide a theoretical perspective because it does not provide a particular worldview through which to look at the data; rather, it is a way of doing analysis of qualitative data. Grounded Theory foregrounds this data and helps create an evolving hypothesis through systematic coding of the data. In the course of this coding, patterns become visible giving rise to hypotheses that in turn are strengthened or dismissed through further coding. The strength of Grounded Theory lies in the interaction between the data collection and the coding. The coding is a continual process that occurs not at the end of the data collection but during it; categories (e.g., themes or variables) *emerge* from the data and are strengthened, modified, or discarded as more data is collected. At a more abstract level, we used socio-technical theory [21,24] as a framework for understanding the data especially as it related to inter-team coordination. Grounded Theory and socio-technical theory served different purposes. Socio-technical theory focused our attention on the interplay between social and technical features of inter-team coordination. Grounded Theory techniques were used to identify categories of these issues as they emerged from the data.

Table 3 – Types of questions asked during focus groups

What do you do with this information?
Do you verify this information and if so, how?
Does this affect your work (in the ED/outside the ED) at this point?
What kind of preparation are you going to do?
Who do you share this information with?
Do you need any other information, and if so, what?
Where would you get the needed information?
Are you going to use any IT tools at this point? If so, what tools?
How do you respond to this given the plans/preparations you have already made?
How would you allocate resources to this patient?
Would you communicate with other departments/institutions at this point? If so, with whom?
How do you delineate roles and responsibilities?
Is there a chain of command established and where do you fit in?
What steps are being taken to decontaminate?
How do you decide allocation of resources to the accident victims given most of your resources are consumed by treating the exposure victims?

For our analysis, we reviewed the data from the focus groups looking for similarities and commonalities. We went through the transcripts to code categories related to coordination. The data was analyzed paragraph by paragraph, and at times, line-by-line to identify categories, and their properties, from the data. At this point, initial hypotheses about categories and particularly about relationships between categories emerged from the data. Further analyses were done to strengthen or dismiss these initial hypotheses. In addition, a deeper review of literature was performed once hypotheses were formed and strengthened [31]. The final core categories (e.g., challenges) that emerged from the data are presented here.

4. Results

From the focus groups, we identified three major types of challenges that ED and EMS team members faced in coordinating their activities. These challenges were (1) ineffectiveness of current information and communication technologies, (2) lack of common ground, and (3) breakdowns in information flows.

In the following section, we describe each of the challenges to inter-team coordination and provide fieldwork data to highlight the important points in each section.

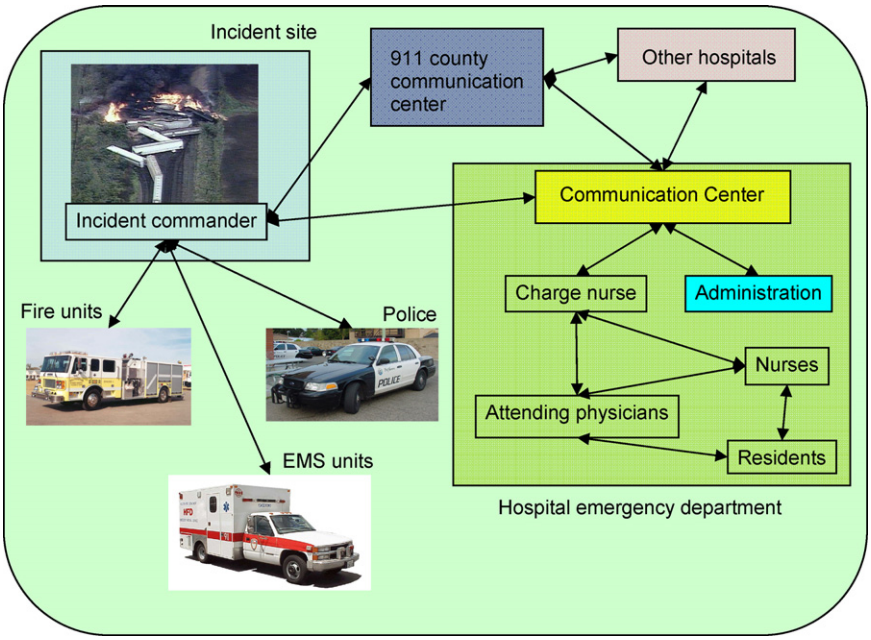

Fig. 1 – Web of communication.

4.1. *Ineffectiveness of current information and communication technologies*

A unique characteristic of coordination between ED and EMS teams is the presence of multiple parties who need to communicate in order to coordinate patient care. Fig. 1 depicts this "web of communication" that aids coordination in a mass casualty incident (MCI) such as the one discussed in our focus groups. The incident commander who is in-charge of on-site operations contacts the communication center of the hospital while at the same time giving directions to various first responder teams (such as fire, police, EMS) about how, when, and where to transport patients.

Given the importance of communication for inter-team coordination, a range of ICTs are used. Focus group participants mentioned the use of pagers, computer systems, radio, cell phones, walkie-talkies, and face-to-face interaction as a means of communication during crisis response. In spite of the important role played by high-tech communication tools, there were severe inadequacies in existing communication tools that hampered coordination between various teams involved in crisis response.

4.1.1. *Inadequacies of current communication tools*

One of the key mechanisms for coordination between EMS and ED teams are communication technologies such as cell phones, and 2-way radios. These technologies are important for supporting the flow of information between teams and, consequently, are an important part of the communication mechanisms of these teams. However, these devices often have severe limitations. The ED team focus group participants reported that they experienced communication breakdown with EMS team members when either team's devices were in a "dead spot". Additionally, EMS team participants highlighted other problems that significantly affected their coordination. For example, the 2-way radios failed to work effectively in many areas because of the mismatch between certain frequencies. The lack of interoperability among communication technologies during disaster response was a significant challenge for coordination [32] as mentioned by EMS team members who were frustrated with interoperability issues:

> "Lebanon County has a new radio system but you wouldn't able to talk to it. Lancaster County has new radio system but you won't be able to talk to Dauphin or Lebanon [counties]. So, here we are again. It's a large incident and we can't talk to [each other]."

While walkie-talkies were a major tool of communication for ED staff, EMS personnel were skeptical about their utility in a disaster scenario. One of them said:

> "Yeah, well the walkie-talkies in the ED, that's another scenario... traditionally, hand-held portables don't like concrete and steel, you know the things that they are all surrounded by."

The location of the incident was another important factor that affected the working of these communication technologies. HMC services a large rural population. So, connectivity is a problem as one of the paramedics highlighted.

> "Lots of places we can't get cell phone signals...you got to remember that technology is great except if you are in the middle of the boondocks."

Consequently, there was a great deal of focus on the use of a low-tech solution – paper – as a communication tool that supported coordination.

4.1.2. *Paper as a coordination tool*

In response to the scenario, many of our focus group participants preferred paper over computer systems for coordination

between ED and EMS teams. The time-critical nature of the response was one of the reasons for this preference. Another reason was the inability of the currently used computer systems to support coordination in an effective manner as paper forms. In the final steps of our scenario (Events 7 & 8 in Table 2), when faced with the potential arrival of hundreds of victims exposed to hazardous materials to the hospital, the focus group participants were specifically asked to respond to questions about the role of information technologies in coordinating crisis response activities during such an overwhelming situation and whether they had enough technology support We received the following responses from attending physicians:

AP (attending physician)1 IT [information technology] will go right out the door the moment this [crisis] happens. Paper is so much better than the computer.

AP2 That has been everyone's disaster experience too that have had an IT system available.

AP1 I want to write down on a piece of paper and staple that piece to the patient's chest and he moves on.

AP3 Because in a situation like this is when the IT system gets overwhelmed. And there is going to be so much going on with it that it doesn't function.

AP1 The way to do it. The military solved it years ago with toe tags. You write it down and it's on his leg so the next guy down the road knows what was done and what needs to be done now.

AP2 One of the unresolved major problems is how do you get hold of the lab specimen; how do you get reliable lab reports back to verify. Because the current IT system would be completely unworkable.

Thus, paper would not only be useful because of its accumulation property but also because the current IT systems would not be able to support the kind of coordination that paper affords in this time-critical domain. EMS team members also raised concerns about the utility of computer-based systems in the field due to concerns about speed and rapid nature of response.

> "It takes time, things are happening on scene so quickly. Things can escalate rather quickly. So if you take time to start playing with the PDA, you can lose track. Maybe paper would be quicker; you can jot notes, your short notes, short hand…"

The paper referred to by the EMS team member above is the casualty triage sheet or the "yellow MCI sheet" used by both ED and EMS teams. These sheets are used to capture information about patients at the incident site as noted by an EMS member:

> "The yellow MCI sheet is a flowchart that we carry on our clipboards [for] tracking patients, because that's the key, how many patients you had, what severity and where to go."

This MCI sheet is handed over by the EMS team to the ED team when the patient is dropped off at the ED. Thus, paper served as a better coordination mechanism to communicate patient information between the EMS and ED teams receiving the patient.

Several studies have highlighted the role of paper forms for coordinating activity within hospitals [28,33,34]. Berg [28] discussed how the order form coordinates the activities of co-located providers (e.g., physicians, nurses). For instance, the paper form *constrains* the types of things that can be written (length of messages, sequence of information, drugs and tests that can be administered), thereby, making it easy to understand and interpret. It also helps the *accumulation* of patient information which enables care providers to know where the patient is in the care process. Furthermore, paper is much more easier to tailor [35] than its electronic counterpart. However, for all the benefits that paper provides, it still does not facilitate real-time coordination between teams. Therefore, although paper is a useful coordination tool, we still need to overcome the inadequacies of current ICTs.

4.2. *Lack of common ground*

One of the biggest challenges of coordinating crisis response is developing and maintaining "mutual knowledge" among geographically dispersed ED and EMS teams. Mutual knowledge is the knowledge that all team members share and know that they share [36]; this is referred to as "common ground" [37]. Experience and interaction [38] are two important mechanisms by which common ground is established. The ED and EMS teams have little direct knowledge of each other's activities (including roles and responsibilities) because of constant changes to the teams. For example, different care providers may be working in the ED on different days of the week or during different times of the day, and hence there is little shared experience of working together. Furthermore, various EMS agencies provide services to different EDs and therefore during a crisis response, there may be little shared work experience between some ED and EMS teams. Although there are training and other coordination building activities, building *common ground through experience* is difficult to achieve during a crisis environment.

Therefore, creating *common ground through interaction* is most common during a crisis response. To achieve common ground through interaction, ED and EMS teams must share information on a regular basis. However, because of the dynamic nature of the incident, there is often little information that is shared between the ED and EMS teams. A communication center (CC) personnel stated that during a crisis very little information is available to be conveyed from EMS personnel at the incident site to the ED team that needs to prepare for incoming patients:

> "… you are going to get briefer and briefer reports, which mean you are getting little to no information. You are going

to get 'such and such female, how old she is' three minutes out, you are not going to get vitals or anything like that."

The lack of complete and accurate information shared between the EMS and ED teams affected the creation of common ground between them, potentially resulting in poor decisions [38]. For instance, the decision by the ED to activate an internal disaster plan is based on the information received from the EMS team about the potential number and acuity of patients that will be transported to the ED. At the same time, information about the resources (such as beds, physicians, trauma rooms) available at an ED is required by EMS teams to decide how many patients can be transported to that ED. Thus if information critical to taking decisions is not shared appropriately or not available for sharing, teams may end taking poor decisions such as ED administrators failing to activate the disaster plan at the appropriate time or the incident commander transporting too many patients to a single ED.

Another interesting factor that affected common ground was related to the amount of information that is actually shared between teams. We found that this was highly dependent on the initiative individual team members take to seek and transmit information. When asked if they had faced any problems with the quality of information passed to them from ED by the CC, one of the EMS members stated:

"It depends on who's there, depends on their mood. There should be very standard ways to do it. They should not really translate anything, but I know they do it instead of passing us exactly what they've heard. It's done in the reverse. I've called in saying "please tell so and so this and this." I try to make it simple and I get there to that person and it's a totally different. I don't know where it gets translated."

"It's caused problems. It's disturbing."

As the examples highlight, effective information sharing is built on the mutual knowledge between teams. If there is common ground, teams can effectively coordinate even with minimal information because each team has an understanding of the other team.

4.3. *Breakdowns in information flow*

Breakdowns in information flow are a prominent challenge that affects inter-team coordination. One of the EMS personnel commented on how the communication center transmits information from EMS team to ED team:

"Sometimes depending on who is in the comm. center they might be listening to their radios. Some listen more than others. And they might have picked it up and some of them might have given us a heads up."

The CC personnel, on the other hand, highlighted a different kind of breakdown in information flow. They were concerned that information exchanges between the ED and EMS teams often did not occur through them, as required by protocol. When asked whether all information being relayed to the ED about an MCI would go through the CC, a CC personnel responded:

"Technically it should be coming through us. But as you see, people circumvent and call directly. They get the charge nurses extension from us that they are not supposed to have, they call MOA [medical office associate] and ER. I guess there is a rule that it should come here but it doesn't. It doesn't work ideally as it should."

Information transmitted through different channels than anticipated, such as described in the vignette above, led to breakdowns in information flow because important people are often "left out of the loop". For instance, in the above vignette, when the EMS personnel directly communicates with the ED personnel (i.e., charge nurse) without going through the CC, the CC will not have the most current information to pass along to other personnel. This breakdown could result in potential loss of patient information, misrepresentation of patient issues and transporting patients to wrong locations during a crisis situation.

5. Discussion

In the previous section, we identified three prominent challenges to coordination between EMS and ED teams. We now turn our attention to discussing the broader implications of these challenges. In particular, we discuss the importance of overcoming these challenges through developing inter-team coordination technologies that support not only the technical transmission of data but also important *socio-technical* issues. We then discuss our study limitations.

5.1. *Socio-technical issues*

As other medical informatics studies [8,27] have highlighted, understanding socio-technical issues is essential for developing healthcare technologies that will be successfully implemented and adopted. In particular, we identified three socio-technical issues that designers must take into account when developing technologies that supports inter-team coordination to deal with the challenges raised in the previous section. These issues were also highlighted by focus group members as important to consider in the design of inter-team coordination technologies. The three socio-technical issues are *awareness*, *context*, and *workflow.*

These three socio-technical issues are related to design requirements [24] at a high level. Developers need both high-level design requirements as well as low-level concrete requirements when designing systems. The socio-technical issues in this section focus attention on the high-level design requirements for ICTs supporting inter-team coordination. For instance, the concept of awareness draws designers' attention to the importance of ensuring that users know what other users are doing. Socio-technical issues often focus designers' attentions to high-level design requirements [21].

5.1.1. *Awareness*

Maintaining awareness of on-going activities is vital to the coordination between EMS and ED teams especially because these teams are geographically separated. So, each team must have some ability of tracking the activities of the other team unfolding in real time during a crisis. For instance, EMS

team members must know whether the ED can accept any more patients; similarly, the ED needs to know the conditions (e.g., acuity of patient, crisis details) of the patients that are being sent to the unit. Currently, awareness is often solely maintained by verbal communication that is mediated by communication tools. However, as described in the last section, relying only on verbal communication can lead to information breakdowns.

Therefore, we need to develop technologies that can supplement this verbal communication. An important class of technology artifacts that provide awareness of tasks, roles, personnel, and scheduling details are *public display boards*. Public display boards have been found to enable coordination between co-located teams in emergency rooms, editorial offices, and train control rooms [34].

Public display boards can provide similar awareness features for EMS and ED teams during crisis response. For example, information on command structure (roles and responsibilities during a crisis) is a key piece of information that could be displayed on these public display boards to establish better common ground, thus improving inter-team coordination between EMS and ED teams. EMS teams are very hierarchically organized and as a result they are trained to operate under a strict command structure. ED teams, on the other hand, are not very hierarchical and often have a more flat structure. So, one of the problems faced by EMS teams in interacting with ED teams during patient drop-offs was the lack of an evident command structure. The importance of the command structure was highlighted in these quotes:

> EMS1: "That's where hospitals mess up because. . .fire personnel and EMS personnel have been using the command structure day-to-day for the last 20 years. But it's critical that the hospitals soak it [command structure] up and absorb it."

> EMS2: "Why wouldn't we as a hospital recognize the need that we are in crisis situation where emotions are running high, where we are now going to get run over with patients,. . .why wouldn't we agree that the command structure is important? If you have a command structure everything can run as smooth as possible."

Having stressed the importance of the command structure, one EMS team member suggested that the best way to make ED and EMS personnel aware of this command structure would be to have it publicly displayed during the crisis.

> "If you have 20 computers hooked up in the ER, what a better way than to have a diagram showing the command structure and start filling in the roles right there and it appears in all the computers in the emergency department. Any computer you walk by says that we are in 'condition green' for an external disaster, here is the command structure, and this person is taking this role. Having it broadcast, you now have a visual thing. Now when one of the pediatric surgeons comes and needs to know who the one in-charge is, he can go to the computer."

Thus, a public display board showing information about command structures and incoming patients would help maintain awareness not only within teams but also for exchanges between teams. Another challenge facing EMS personnel was the difficulty in keeping track of the multitude of other first responder teams as well as ED personnel who need information from them. One mechanism that they suggested was a tool that will allow them to keep track of other team leaders and ED personnel that they need to report to. These types of systems can allow the teams to build better awareness of each other's activities.

5.1.2. *Context*

One of the key difficulties in coordination between geographically distributed teams is the difficulty the teams have for providing context to the other teams in their communication with each other [38]. Furthermore, the lack of information sharing during such a rapidly changing environment makes it even more difficult for crisis responders to convey context in their communications. As information moves from one context (e.g., EMS) to another context (e.g., ED), it loses its original meaning. Context is difficult to design into systems. The traditional view of context argues that it is easily representable in systems because it is stable and can be separated from the activity that it surrounds. This representational view has been one that system developers have traditionally used when designing for context into computational systems. However, Dourish [39] argues that an alternative view more accurately captures the challenges of context. In this view, context is dynamic and cannot be separated from a particular activity. The second perspective highlights the difficulty of capturing and using context in systems supporting inter-team coordination.

Because context is based on activity and often arises from the interaction of team members, one approach that designers can take is to develop multiple representations of context to capture the different aspects of the activity and interaction. These representations allow designers to robustly deal with improving coordination. By providing multiple representations, team members can see the information in a manner that is most relevant to their work while the information still retains its original meaning. These multiple representations are being currently used in many electronic medical records [40]. In these systems, the EMR provides different representations (screens) of the same information to different groups (e.g., physicians, pharmacists, and nurses) to contextualize information in a manner that is understandable by that particular group. For instance, there are different screens that the pharmacists, physicians, and nurses use to monitor medication administration. Although the information is the same, it is presented to each group in the context that makes the most sense to them. Another approach is to design intelligent agent systems [41] with richer contextual features to support information sharing between teams during a crisis.

5.1.3. *Workflow*

Providing appropriate care during a crisis response depends on getting "right information to the right people at the right time". Breakdowns in workflow can commonly occur when team members are not communicating with the appropriate members of other teams. From our focus groups, there was some confusion about how the information would be transmitted between teams in a way that supports their work

activities. It was often seen that information flows did not match workflows. Therefore, the question of how to ensure that the information transfer supports the workflow is an important design question.

In a previous study of alert wireless pagers in a surgical intensive care unit [29], we found that the pagers did not support established clinical hierarchy workflow. For instance, attending physicians would receive the page at the same time as the resident even though the resident would usually notify the attending of the problem. This led to the under-utilization of the pager. Similarly, there are concerns that the current ICTs do not support the team hierarchy during a crisis. This is especially true when focusing on the coordination between the EMS and ED teams. It was stressed by focus group members that it is important that access to information be given to the appropriate people. One of the EMS members mentioned that while walkie-talkies play an important role in crisis response, "*just giving everyone a portable radio could be your worst nightmare*". One of the EMS personnel added:

> "Communications are very critical in a big incident like that. So when you have radios, they need to be issued to leadership roles."

Thus, ICTs need to be designed to support inter-team workflow. For instance, telemedicine solutions have been proposed to help in crises response [42]. Although these systems provide useful patient information between teams, there are still a number of workflow issues that these systems must address. These issues include routing of information (e.g., who should receive the information), embedding proper workflow protocols and procedures into the system, and matching the information flow to the workflow of the different teams.

5.2. *Limitations*

This study has two major limitations. First, we did not conduct mixed focus groups that consisted of team members from both the ED and EMS. Because of the different schedules of the various team members, it was difficult to schedule a focus group that members from the two teams together could attend together. Therefore, we may have missed some interesting discussion about coordination and technology expectations that might have occurred when both teams were in the same room. However, in this study, we were primarily interested in the *individual* team perspective of the crisis scenario, team information needs, use of ICTs, and challenges faced during a crisis situation. Therefore, by not having the members from both teams in the same focus group, we were able to gather useful data about how each team viewed coordination between the teams.

The other major limitation of the paper was the inability to get a nursing perspective on these issues. Because of events outside of our control, we were unable to have nurses in the focus groups to provide us their perspective. However, we believe that the focus groups in the study provided us with a representative view of the challenges that ED and EMS teams faced in coordinating care.

Summary points

What was already known

- Inter-team coordination is difficult during crisis situations.
- Most information and communication technologies (ICTs) are designed to support intra-team not inter-team coordination.

What the study has added to our knowledge

- There are three major challenges to inter-team coordination.
- The major challenges to inter-team coordination between emergency medical services teams and emergency department teams has a strong *socio-technical* aspect.

6. Conclusion

Coordination between ED and EMS personnel is vital to a successful response to a crisis. However, as events from 9/11 to Katrina have highlighted, coordination does not simply happen but must be managed and supported by information and communication technologies.

The *socio-technical* aspects of coordination are multifaceted and complex. For instance, developing ICTs to support coordination requires designers to understand the workflow within the ED and EMS teams when supporting the coordination between the two teams. Without understanding the workflow within each team, designers would be unable to identify potential areas of breakdown in the coordination between the teams. These teams are not the same and it is important to capture these differences before designing systems to support them. ICT designers can use the three socio-technical issues (e.g., awareness, context, workflow) discussed in this paper as guides for adapting their design methods to support inter-team coordination. Furthermore, there are no purely technical solutions to the problem of coordination. Although better technologies will improve coordination activities, they must go hand-in-hand with the development of organizational policies and procedures that focus on improving coordination between these teams.

A variety of ICTs are being designed to help EMS personnel track casualties and equipment, communicate with receiving hospitals, and triage casualties effectively. These systems are based on personal digital assistants (PDAs), geographical information systems (GIS), geographical positioning satellites (GPS), and wireless networks [3]. However, many of these systems focus on supporting intra-team communication and coordination. When designing for inter-team coordination, certain issues are essential for ensuring coordination and communication between the different teams. Through this study, we have identified challenges to inter-team coordination that effect crisis response and discussed ways to overcome those challenges.

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