Decision Making Tasks in Time-Critical Medical Settings

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ABSTRACT
We examine decision-making tasks and information sources during fast-paced, high-risk medical events, such as trauma resuscitation. Interviews with surgical team leaders and ED physicians reveal several environmental aspects that make decision making difficult, including diagnostic tradeoffs, missing and unreliable information, and managing multiple patients simultaneously. We discuss the implications of these findings for the design of wall displays to support decision making in time-critical medical settings.

Categories and Subject Descriptors
H.5.3 [**Group and Organization Interfaces**]: Computer-supported cooperative work.

General Terms
Design; Human Factors.

Keywords
Decision making, information sources, healthcare.

1. INTRODUCTION
The development of clinical decision support systems over the past decades shows continued effort in improving and augmenting a key aspect of high-quality medical care—clinical decision making [5]. Medical researchers have been seeking ways to improve accuracy, efficacy and expediency of decision making by studying how physicians make decisions [3]. Although not directly focusing on decision making, CSCW research has contributed to this body of work through studies of work coordination, awareness, and idea formation [7][8][10]. Yet, little is known about what constitutes decision-making tasks in emergency care and how different information sources support this medical activity. Unlike other areas of medicine, decision density in emergency medicine is extremely high [3]. Understanding the complexity of decision-making process is thus essential to designing and developing computerized support.

This work is part of a larger research effort to examine work processes of trauma teams and elicit design requirements for wall displays to improve situation awareness and decision making. Here we focus on decision-making tasks and information sources used by team leaders. We analyze interviews with ten leaders collected during a six-month field study in a Level I trauma center. This study complements our prior work in which we observed resuscitation events and performed micro-analysis of video recordings to understand trauma teamwork processes. The contribution of this note lies in empirically identifying major decisions, information sources, and challenges in decision making during a fast-paced, high-risk medical event.

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1.1 Trauma Resuscitation Overview
Trauma resuscitation—the initial management and treatment of injured patients in the emergency department—is a fast-paced, information-intensive medical domain, with critical decisions made about once a minute [4]. A team of seven to 15 medical specialists rapidly performs different but complementary tasks that are focused on identifying life-threatening injuries and stabilizing the patient. Patient evaluation follows the Advanced Trauma Life Support (ATLS) protocol that provides an organized approach to management and treatment of an injured patient [1]. Awareness of events that occur during trauma resuscitation is essential for effective decision making.

Trauma teams form dynamically upon patient arrival. Each team has a designated team leader, often a senior surgical resident or a fellow, who supervises patient care, makes major decisions and delegates work to others. The surgical team leader is assisted by a junior surgical resident who performs hands-on evaluation and reports to the team leader. Although directed by surgeons in most U.S. trauma centers, trauma resuscitations at some centers also involve emergency department (ED) physicians.

2. METHODS
Our research site was a Level I trauma center of an urban pediatric teaching hospital in Washington, DC that provides 24-hour emergency and trauma care to over 1,000 patients a year. Trauma patients are treated in one of two designated rooms within the emergency department, called code rooms. The study was approved by the hospital's Institutional Review Board (IRB).

We individually interviewed ten trauma team leaders, including four ED physicians, five senior surgical residents and one surgical fellow. On average, ED physicians reported 20 years of experience in emergency medicine. Senior surgical residents were in their fourth year of residency and on a three-month rotation at our research site during the interviews. The surgical fellow had seven years of surgical training and was board certified in general surgery. Interviews lasted from 30 minutes to an hour, depending on providers' availability. The questions focused on their roles and responsibilities, decisions, and information sources.

The interview transcripts were analyzed using Atlas.ti, a program for organizing, storing, and manipulating qualitative data. All transcripts were read to uncover statements representing key steps in decision making. We then used an open coding technique to identify common themes. This analysis resulted in a set of distinct themes that described major decision-making tasks, information sources, and factors affecting decision making.

3. FINDINGS

We first describe decisions that leaders make from the moment they learn about an incoming trauma patient to the patient's transfer to another hospital unit. We then describe information sources used for decision making. Finally, we discuss factors that increase the difficulty of making decisions.

3.1 Decision Tasks in Trauma Resuscitation

Decision making during trauma resuscitation centers around two goals: (1) address immediate threats to life, and (2) determine multiple treatment plans. Decisions about treatments require observations (evidence), but observations take time and resources. The key is identifying the best tradeoff. The code room is only a temporary stop on a patient's hospitalization path; the patient's stay in the room is kept at a minimum (on average, 20 minutes), until the patient is stable enough to move to a different hospital unit. Because the goal is to treat the greatest threats first, a definitive diagnosis is not a priority. Hence, the very first decisions can be formulated from the triage (routing) perspective. Our interviews revealed three such decisions. First, the leader determines if the patient needs surgery. Making this decision early allows the team to reserve the operating room and notify the surgeon. This initial triage decision is based on patient pre-hospital information. An ED attending explained:

"What was going on in my mind was that he was going to need a very short stay in the code room and was going to quickly need to go to the OR. Especially once I saw him. I thought, he's stable enough, but he needs to go to the OR. Let's just move this along, call the attending, and get him to the place where they can see what's cut, sew it up, fix him up." [ED1]

Second, the leader determines if the patient needs a computer tomography (CT) scan. CT scan decisions are also based on pre-hospital information (e.g., loss of consciousness signals the need for a CT scan) or on physical exam upon patient arrival.

Finally, the leader decides if additional specialists or more experienced providers are needed. Depending on the severity of injury, the patient may need a neurosurgeon, an orthopedic surgeon, or an intensive care unit fellow. Similar to other triage decisions, the decision to call a specialist is made early in the process to allow sufficient time for the specialist to arrive:

"*If a patient comes in and it sounds like a pedestrian was struck and is now having a bad airway and is hypotensive, then I know right away I may have to call the anesthesia attending just so there's somebody more experienced there."* [SF1]

Once triage decisions are made, the leaders move onto decisions that can be done with people and resources available in the room. These decisions follow the evaluation protocol, and are based on findings from each protocol step. A surgical resident described:

"Does this person need to be intubated? Is their airway clear? Are they awake enough to protect their airway? Do they need fluids? Is their neurological status adequate? Do they need blood? … So, I have to make those decisions based on what I hear about the physical exam, keeping in mind the mechanism." [SR4]

3.2 A Decision Needs Information

To make decisions, trauma team leaders rely on a diverse set of information sources.

Pre-hospital information: Information about the incoming patient is conveyed by EMS paramedics in a phone call to ED attending physicians receiving the patient. Based on this phone call, a page is sent to the trauma team, giving the first clue about the patient's injuries. Page information includes estimated arrival time, number of patients, mechanism of injury, and patient status. Team leaders use this information to prepare equipment, summon the specialists, and anticipate treatments. An ED attending described the importance of pre-hospital information:

"So [you hear] a child who fell from a tree and landed on their back, breathing 60, oxygen saturation 89%, you are saying to yourself there's a lung contusion or a hemothorax or a pneumothorax. You immediately want to presume that's happening. So you need chest tubes out. And we should think about intubating on arrival. Let's agree upon a weight. Let's get these meds drawn up before the child even arrives…" [ED3]

EMS report: Similar to pre-hospital information, a brief, verbal report provided by the EMS paramedics during patient handover helps guide leaders' decisions about treatments. The most critical information here is the mechanism of injury:

"It's very important because you need to know mechanism of injury, like velocity, whether it's penetrating, whether it's blunt. You need some frame of reference to start. There's a big difference between a restrained passenger in a rear-ended vehicle versus a rollover, unrestrained, with a passenger found outside the car. That's why you listen for 30 seconds or a minute to hear the story, so you know what's going on." [SR5]

Patient: Patients are an important source of information throughout the resuscitation. A quick glance at the patient upon arrival provides valuable context for forming a decision:

"If I hear a three year old fell from the couch, no loss of consciousness, and is now crying, then to me it sounds like not that sick because it's not very significant mechanism and there is no loss of consciousness. I also think, probably does not have to go to the OR because it's stable." [SF1]

Physical exam: Results from exams prescribed by the ATLS protocol (airway, breathing, circulation, and neurological) provide critical information by which leaders maintain awareness about the patient status and make major decisions:

"I typically stand at the foot of the bed, listening to the information from the resident who is on the primary and secondary survey, and making decisions about fluid boluses, medications, x-rays, and blood tests that are required." [ED3]

Sometimes, however, leaders may not be satisfied with the quality of information received from the resident examining the patient. To confirm the findings, leaders evaluate on their own:

"If I don't feel like I'm getting the information that I want from the resident doing the exam then I will do my own exam. If I can't trust what they're doing, it doesn't seem like they know what they're doing, and I need that information to make a decision then yes, you have to jump in there for the patients." [ED4]

***Vital signs monitor*:** The vital signs monitor is a salient source of information. It displays live data such as oxygen saturation, heart rate, respiratory rate, and blood pressure. Vital signs data help leaders monitor patient status and their reactions to treatments:

"A patient is hypotensive, they got a fluid bolus, and then they respond, their blood pressure goes up, and after a while, the blood pressure drops again. The nurse reports 'the pressure is back down, should we give another bolus' and you may say, 'yes, give another bolus." [SF1]

Team members. Trauma resuscitation is a team-based process; each member has a role and a set of responsibilities. Information exchanged during the process is critical to decision making as

different team members acquire different information. Although communication breakdowns are common, the collocated nature of work makes information sharing fast and efficient:

"For an individual patient, it's fairly easy to get the information because you have a group of people that are focused on treating the patient, and you have a bunch of nurses and techs there that can draw blood, insert IV, get you the vital signs…" [SR1]

Laboratory tests. Laboratory tests provide additional information but take time to obtain. Most common tests include x-ray imaging, blood, and urine tests. The tests provide reliable evidence, as the results either confirm or refute the initial diagnoses.

3.3 What Makes Decision Making Difficult

Interviews with trauma team leaders revealed several aspects of the resuscitation environment that complicate decision making.

System complexity and diagnostic tradeoffs. Trauma patients are complex systems, each presenting a unique set of symptoms and injury combinations. Although treatment decisions are grounded in evidence from physical exam and laboratory tests, leaders often face situations in which clear indications for an intervention are absent. A surgical resident described:

"There was one patient recently... [where] the mechanism of what actually happened was not clear and then the difficult part was that there was no acute indication to intubate the patient, but the patient ended up intubated, and I don't think it was a wrong or a right decision, but there just was no clear-cut indication to put a definitive airway in the patient." [SR1]

The lack of clear indications for an intervention has significant implications for decision making. Time pressure demands that decisions be made fast. Yet there are associated risks and benefits of proceeding vs. not proceeding with a procedure. Invasive procedures, such as intubation or chest tube insertion may result in further complications (e.g., infections); they also take time and resources. Alternatively, by not proceeding with an intervention, the leader risks overlooking a potential injury that may result in adverse outcomes. The resident continued:

"*If a patient doesn't need an invasive intervention, if there's no clear-cut evidence that they need it, then doing that is considered something of—I don't know if faux pas [false step] is the right word—but I guess it's just one of those things where you get into the gray area. There's no definitive reason to do a procedure, there's some subjective, at least hinting at the indication for whatever the procedure is, but it's nothing that's like clear-cut that says I should do this."* [SR1]

Similar tradeoffs are made when deciding about CT scans. If the patient moves and is conscious, there is no clear indication to scan the patient' head for a brain injury. Nonetheless, surgical leaders often order head and spinal cord CT scans (exposing patients to unnecessary radiation) to ensure no injury has been missed. To cope with such situations, surgical leaders seek advice from a senior supervisor, such as an attending surgeon or ED attending:

"It's good to let him [attending] know, not only to keep him in the loop but also because sometimes they have stuff to tell, like a feedback. They would say 'I think we should do this too, how about we obtain x-ray, how about we order this.'" [SR3]

If there are no supervisors in the room, leaders make decisions based on their knowledge of past similar cases and medical training. Solo decision making is, in fact, common in trauma resuscitation. Time pressure rarely allows deliberation or brainstorming activities. Because decisions are made individually, surgical leaders often miss the benefits of collaborative reasoning.

Communication breakdowns. Efficient communication helps leaders maintain awareness of patient status and activities in the room. Code rooms are noisy and crowded, with many people moving and talking in parallel. Although ambient factors pose challenges for information sharing, leaders usually manage to get the information they need. A greater challenge, however, is a lack of communication. Leaders rely on others to collect information and report it aloud. Often times this information sharing is absent:

"The worst communication is no communication, like somebody took blood pressure and just didn't tell anybody else…" [SR1]

"It's important to tell things aloud. I like to hear the medications, especially when we're doing CPR or when I'm putting epinephrine in or atropine. I like to hear it because I want to know that it's been given. And second, I want to hear and remember, okay is this the first dose, is this the second dose, because then you know it's been given, as opposed to not knowing, when you wonder, 'okay how many doses did I give?'" [SR3]

Information reliability. Effective decision making depends on an accurate and comprehensive understanding of the patient status. Having reliable information is thus essential. Often, however, information from sources both internal and external to the hospital is unreliable. Interviews with leaders revealed, for example, that pre-hospital information does not always reflect the actual state of the patient. A resident described:

"I try to get the mechanism of injury out of it, and I might try to get a story, but I don't rely heavily on it, even when people come from outside ED, like a physician will tell you something, and it's not necessarily the case. Sometimes what they're saying is true, and sometimes it's not, for whatever reason." [SR2]

Our participants expressed the need for more detailed and timely pre-hospital information. An ED attending elaborated:

"If there was a way to get EMS report to us from the original team on the ground that was more inclusive of the stuff we need to know like vital signs or patient status. There are many intermediary steps they go through to get the information to us, so a text to us directly from the scene might be more useful as far as decision making before the patient arrives." [ED4]

In addition, information from sensors, such as blood pressure cuff, thermometer or pulse oximeter may not always reflect the actual patient status. Here, the leaders have difficulties determining if the problem is caused by equipment malfunction or if something is wrong with the patient. A resident described a case in which the system's malfunction was caused by a patient's condition:

"I think some of the issues were more of a system thing. The patient was cold, so our sensors didn't work as quick as we'd like, so that was a delay in assessment and care." [SR5]

***Severely injured or multiple patients*:** Interviews with trauma leaders showed that managing individual routine trauma patients is feasible. The difficulties with information gathering and retention arise with severely injured or multiple patients, each requiring rapid response and attention. In these situations, decision making is demanding, with margin for error increasing and cognitive resources decreasing for each additional patient:

"If you have two patients you have to start taking notes. Patient A has no loss of consciousness and patient B has loss of consciousness. For many, two patients are still manageable. Let's say you have four! The other night, we had four patients and one is patient L, one is M, one is N, and one is O. So already differentiating between N and M is almost impossible." [SF1]

4. DISCUSSION AND CONCLUSION

Although the experience of team members increases with every resuscitation, currently there are no mechanisms by which patient information is accrued for rapid integration and analysis of patient data. Decision making is now only minimally supported by technology and trauma teams rely mainly on verbal exchanges to gather and share information. Attempts to introduce computer-aided decision support systems so far have shown limited, though encouraging, results [4]. Interviews with trauma leaders revealed several decision-making challenges, including diagnostic tradeoffs, unreliable information, and information overload. These findings suggest three ways in which information technology can facilitate decision making in trauma resuscitation: (1) provide more information about the current patient; (2) engage other team members in the room or remote specialists; and, (3) enable comparison with past similar cases.

CSCW researchers have proposed different solutions to support coordination and awareness in collocated work, including large wall displays. Wall displays and whiteboards provide a shared and focused memory, which helps with engaging team members in collaborative activities [2][11][13]. Visualizing critical patient information could facilitate decision making by enabling shared mental models and providing real-time patient data throughout the resuscitation process. For example, the display could show trends in vital sign data, administered medications and their timing, the amount of fluid received and completed protocol steps. The challenge here is how to effectively capture information from the environment for timely presentation.

Based on our findings, we envision several possibilities for both capturing and providing more information about the patient. First, leaders emphasized the importance of pre-hospital information, yet complained about its reliability and timeliness. Recent advances in ubiquitous computing, such as environment sensors found on roads, in vehicles and buildings could be used for collecting information at the time of the accident (e.g., sensors in vehicles could provide information about the speed or collision impact for motor vehicle accidents). This information could then be fed (in processed and easily accessible form) directly into hospital wall displays in real-time. Moreover, increased citizen participation in gathering and sharing information through social media in times of crisis could also be explored [12]. For example, witnesses and first responders could send pictures or text information from the accident site directly to the hospital. Such information (processed, organized and vetted) could populate wall displays and allow trauma teams to better prepare for the patient.

Second, our data showed that trauma leaders often proceed with unnecessary procedures to ensure that no injury has been missed, preferring to err on the side of caution. To support decision making in such situations, we envision using an evidence-based approach where past cases could be searched and consulted. Given the hands-busy nature of work, leaders could use natural interaction modalities, such as speech (for querying the system) and gesture (for interactive analysis of the visualized data). Recent study on touchless interaction in neurosurgery using Microsoft's motion sensing input device Kinect has shown that such approaches are feasible [6].

Finally, leaders could also engage with remote specialists when confronted with difficult decisions. Our data showed that surgical residents often seek advice from their attending surgeons, if they are available. Currently, leaders use traditional communication channels such as phone to discuss cases with their supervisors. Telepresence technology could be used to sustain this practice and enable richer communication. Soderholm et al. [9] evaluated the potential of such technology for facilitating paramedic-physician collaboration during resuscitation and found fewer harmful procedures when the technology was used.

In conclusion, by examining decision-making tasks and information sources in trauma resuscitation, we have identified factors that complicate decision making during fast-paced, high-risk medical work. This study is a step toward a more comprehensive understanding of complex teamwork processes in safety-critical medical settings; it considers how factors affecting decision making need to be accounted for when designing technology for emergency medical work.

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