A Study of Collaborative Information Behavior in Trauma Resuscitation

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ABSTRACT
In high-reliability work settings, most human work is performed by teams of workers who often engage in collaborative information behavior to solve complex problems. In this paper, we examine collaborative information behavior of trauma teams during trauma resuscitation, a team-dependent, fast-paced and information-laden process of evaluating critically injured patients early after injury. We identify trauma teams' tasks in which collaborative information behavior plays an important part and provide examples of collaborative information behavior activities.

Categories and Subject Descriptors
H.5.3 [**Group and Organization Interfaces**]: Computer-supported cooperative work; H.1.2 [**User/Machine Systems**]: Human information processing.

General Terms: Design, Human Factors.

Keywords: Collaborative information behavior, information needs, information technology, healthcare, trauma.

1. INTRODUCTION
The proliferation of information technologies that enable individuals to engage collaboratively in information seeking, searching and use has shifted our research focus from individual to collaborative aspects of information behavior. Over the past decade, we have witnessed an increased number of studies of collaborative information behavior (CIB) in various work settings, e.g., [2],[6],[9]. Although much remains to be understood about CIB, researchers have so far identified major characteristics of CIB, as well as triggers for CIB activities [8], [9]. Not surprisingly, IR technologies have been found to play an important role in supporting collaborative information behavior of working teams in industry and healthcare [5],[6]. There are, however, work settings where task accomplishment requires teamwork, but IR technology is rarely present due to high risks, time criticality, and workers' resistance. An example of such work domain is trauma resuscitation, a medical setting in which teams of physicians, nurses, and technicians evaluate critically injured patients early after injury. The purpose of this paper is to examine collaborative aspects of information behavior in trauma resuscitation. We hope to contribute to the understanding of CIB by identifying and explaining collaborative information behavior activities of trauma teams.

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GROUP'09, May 10–13, 2009, Sanibel Island, Florida, USA.
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2. OBSERVATIONAL STUDY
We conducted an observational study at a regional, Level 1 trauma center of an urban, teaching hospital over the past two years. Level 1 trauma center provides the highest level of specialty expertise and meets strict national standards, as set by [1]. Our trauma center admits over 1200 trauma admissions per year, among which about 600 require full trauma team mobilization. Common mechanisms of injury include motor vehicle accidents, falls, burns, knife and gunshot wounds, and sport or recreational injuries.

The study involved a total of 60 days of fieldwork in the trauma center. Data was collected through observations, videotaping, and informal interviews with trauma team members. Observational data and transcripts of videotaped resuscitations were analyzed using grounded theory approach [12]. We started by identifying types of collaborative tasks in trauma resuscitation and manifestations of collaborative information behavior in those tasks. In the process of identifying instances of collaborative information behavior in trauma teamwork, we adopted a definition of CIB proposed by [6] and used by other researchers who have examined CIB in the context of healthcare, e.g., [8]: "activities that a group or team of people undertakes to identify and resolve a shared information need."

3. WORK DOMAIN DESCRIPTION

3.1 Trauma team structure
The medical team performing trauma resuscitation forms rapidly upon arrival of the patient and often reconfigures according to the needs of the patient. Care providers include the attending surgeon, residents, an anesthesiologist, an orthopedic surgeon, nurses, a respiratory therapist, a pharmacist and an X-ray technician.

The roles, responsibilities and chain of command among members of the team are precisely defined. The team leader (usually a senior resident) supervises patient care, makes major decisions and delegates work to other team members. A resident physician assists the team leader and performs hands-on evaluation and treatment. The primary nurse is dedicated to the care of the patient and is aided by the nurse recorder, who is also responsible for documenting the event on a paper-based trauma flow sheet. An anesthesiologist assists with the management of the airway, and an orthopedist manages orthopedic injuries. The role of the team leader may shift between residents and attending physicians

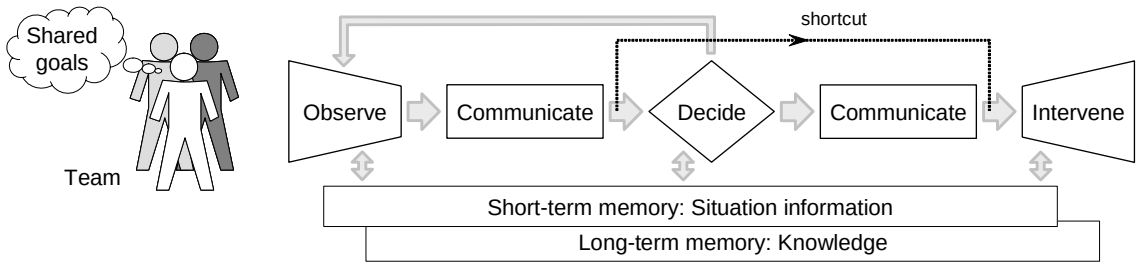

Figure 1: Our framework for modeling team activities during trauma resuscitation.

depending on the patient condition and the skills and availability of other individuals.

3.2 Information sources

Information that is being acquired and used in decision making comes from a variety of sources within and outside of the hospital. In addition to *patient*, trauma teams have access to the following information sources [10]:

- *Trauma pagers*, for receiving pre-arrival information and summoning the trauma team;
- *Trauma flow sheet*, a paper-based form for documenting patient data and treatments;
- *Vital signs monitor*, for displaying the patient's continuously measured vital signs;
- *Digital x-ray workstation*, for x-ray images access;
- *Diagnostic tools*, for tests such as HemoCue for analyzing hemoglobin and glucose levels in blood;
- *Wall charts*, for information on treatment parameters by patient age/weight;
- *Whiteboard outside the trauma bay*, for providing summary of pre-arrival patient information; and,
- *Healthcare providers*, including members of the trauma team, ED staff, and other specialists.

Trauma teams use a variety of instruments to obtain patient data. Some physiological variables are even obtained by more than one instrument. For example, pulse rate can be measured via ECG electrodes or the pulse oximeter. Blood pressure (BP) is measured both automatically and manually. Each measurement method has limitations on accuracy and reliability, and each intervention method carries risks associated with it.

The members of the team have had different training, and hence, have different bodies of information available to them. Not every team member is qualified to do every task; some tasks are carried out only by trained staff due to the associated risks. For example, patient intubation is almost always performed by the anesthesiologist. The ultrasound exam for abdominal bleeding is typically performed by leadership roles. Additionally, each member has the task of monitoring a different set of instruments. For example, the critical care technician is assigned to read the vital signs monitor periodically and share the readings with others in the team. The respiratory technician monitors patient ventilation and alerts the team about critical changes.

Previous studies of CIB in healthcare found that IR technologies played an important role in supporting collaborative information behavior activities of medical teams [3],[5],[7],[8],[9]. Unlike other clinical settings, the trauma bay lacks sophisticated technologies for accessing patient information. The only IR technology used by trauma teams to retrieve patient information is a digital x-ray workstation for accessing x-ray images. In the current practice, information is transmitted mostly verbally. Although some external records are created during the resuscitation event (e.g., trauma flow sheet and physician's notes), they are rarely used for information retrieval in real time.

3.3 Trauma resuscitation goals and tasks

The purpose of trauma resuscitation is to identify and immediately treat life-threatening injuries. The key aspect of this process is to stabilize the patient, determine the extent of the injury and develop a treatment plan that can be carried out during hospitalization. Trauma teams manage patients with unstable or fluctuating medical status, whose detailed medical history is commonly not available and who require time-critical decisions. Unlike most clinical settings, trauma resuscitation requires that care providers treat patients based on emerging information during a short period (about 30 minutes). The main challenge is in figuring out what injuries the patient has sustained.

Resuscitation goals and tasks are determined by the anatomy and physiology of human body. The trauma team has a clear subject of work, i.e., the patient, with observable parameters that are used to specify the goals and their success criteria. For clarity, a *goal* is defined as a state that a care provider wants to achieve. For example, one of the goals in trauma resuscitation is to maintain adequate ventilation of an injured patient. A *task* is a means of achieving a goal. For example, to maintain adequate ventilation, a care provider may provide supplementary oxygen to the patient.

Because resuscitation goals are intrinsic to human body, they remain invariant for the duration of patient evaluation and their achievement signals the completion of resuscitation. To achieve these goals, the trauma team members must observe and evaluate the patient's clinical signs (i.e., state variables). The primary goals are to eliminate or resolve the conditions that are *immediate* threat to life. This is the *primary survey* part of the ATLS protocol [1]. Evaluation tasks following the primary survey identify and treat injuries that are a *potential* threat to life, which is the *secondary survey* part of the ATLS protocol. The key tasks involved in achieving resuscitation goals are (Figure 1):

1. *Observing*: a set of activities performed by a health care provider to measure the current value of a state variable
2. *Deciding*: comparing the current with the goal state and devising methods to reach the goal
3. *Intervening*: a set of activities performed by a health care provider to change the current value of a state variable
4. *Communicating*: conveying observations, decisions, and other information about goals and tasks
5. *Memory-lookup*: for facts not directly observable.

The "pipeline" model in Figure 1 contains boxes showing different tasks performed by team members and arrows representing a "logically-leads-to" relationship. The figure also indicates a possible shortcut: pre-wiring observations to interventions bypasses decision making for routine activities.

Although a full-fledged task, communication is intended as a *link* between other types of tasks. In other words, communication is always in service of other tasks and must be preceded and followed by non-communication tasks. In the context of dynamic, high-risk teamwork, communication only indirectly contributes to the goal achievement.

The collaborative nature of patient assessment requires that members of the team collaborate in accomplishing trauma resuscitation tasks. Because much of trauma teamwork depends on emerging patient information, collaborative information behavior plays an important role in observation tasks, decision-making tasks, intervention tasks, and memory-lookup tasks. Sections 4.1 through 4.4 describe each task in detail and provide examples of collaborative information behavior.

4. FINDINGS

An important observation about the work of trauma teams is that there is no one, single shared information need. Instead, information needs of trauma teams change rapidly over time and respond to the patient's state and the dynamics of the event [10]. Each resuscitation event starts with an overall, shared information need: "what's the story?" or "what did we get?" Once the team members learn about the accident details and treatments en route (from EMS paramedics transporting the patient or other team members), they move onto patient evaluation.

4.1 Observation tasks

Patient evaluation starts with observations and data collection. Various team members gather information from the environment via physical examination, simple sensing, instrument reading and manual measurement. Consider the following example:

While the team leader (TL) is relaying information about pre-hospital events to the attending physician (ATP), the technicians (CCT1, CCT2), orthopedist (ORT), junior residents (JR1, JR2), nurse recorder (REC), and primary nurse (PNR) engage in collaborative information gathering:

TL (continues report to ATP) ... *vital signs have been stable, looks like he's been a little tachycardic with heart rate in the 130s, but the blood pressure was stable…*
CCT (places automatic BP cuff on PTN's right arm)
TL (puts stethoscope, listens to breath sounds)
JR1 (palpates PTN's feet, talks to TEAM) *2+ distal pulses.*
TL (finished listening to breath sounds, talks to TEAM) *Breath sounds bilaterally.*
ATP (talks to EMS1) *What was he doing? Was he moving his extremities?*
ORT (examines pelvis)
EMS1 (talks to ATP) *They say he was decerebrating at the scene, and may have possible seizure activity...*
TL (examines eyes with the penlight)
ORT (finishes pelvis exam, talks to TEAM) *Pelvis is stable.*
JR2 (examines popliteal pulses) *2+ popliteal.*
CCT2 (attaches pulse oximeter to PTN's right finger)
JR2 (examines femoral pulses, talks to TEAM) *2+ femoral.*
CCT (looks at the monitor, talks to TEAM) *Got blood pressure 128/78*
TL (finishes eye exam, talks to TEAM) *Pupils are 4 mm and sluggish, bilaterally.*
TL (examines PTN's ears)
REC (talks to CCT) *Do you have heart rate?*
CCT (looks at the monitor, talks to TEAM) *I got heart rate of 133, sat [oxygen saturation] is 98%*
TL (finishes exam, talks to TEAM) *TMs are clear bilaterally.*

As team members performed their prescribed tasks, they reported relevant patient findings and observations to other team members. Information needs of participating team members, although not explicit, roughly followed the primary survey of ATLS protocol. The team leader first examined patient's chest and lung sounds ('B' step in the protocol), while junior residents checked for adequate perfusion by observing pulses ('C' step). At the same time, the technician reported the first blood pressure, another sign of adequate perfusion ('C' step). The team leader then moved onto the examination of pupils, which is primarily used for identifying neurological injuries ('D'). In this example, the team skipped over step 'A' because the patient arrived with an oxygen mask and a cervical collar. Based on this information, the team concluded that the patient had a patent airway ('A').

The above-described practice of collaborative information gathering has been observed in all resuscitation events. In general, observation tasks are the most collaborative in nature. In order to obtain data needed for decision making, the leadership roles rely on other team members to collect critical pieces of information and share them with the rest of the team.

4.2 Decision-making tasks

As seen above, clinical data is simultaneously and rapidly accrued by several care providers and used to make decisions within minutes. The rapid pace often limits full explanation of decisions, which contributes to incomplete shared mental models necessary for efficient group decision-making. Hence, the decision-making tasks appear to be the least collaborative.

In the example below, the team is managing a patient who had sustained four stab wounds. Upon listening to the patient's breath sounds, the team leader decided to insert the chest tube. The example shows discussion between the team leader (TL) and the attending physician (ATP), who entered the trauma bay after the team leader has made his decision:

ATP (talks to TL) *What have you got?*
TL (talks to ATP) *I only hear his breath sounds on the right and with pulse in 140s... (unintelligible)*
ATP (approaches patient, examines the wounds)
TL (points to stab wounds, talks to ATP) *I am putting the chest tube.*
REC (talks to TL) *You don't hear anything on the left side you say?*
TL (talks to REC) *Left side diminished.*

Previous research has shown that critical decision-making in trauma teams is mostly concentrated in the current leader's role [4], and the above example confirms this finding. Nevertheless, we did observe a few instances of collaborative decision making during discussions of examinations, such as abdomen ultrasound exam for internal bleeding, administration of medications, and review of x-rays [11].

4.3 Intervention tasks

Upon reaching diagnosis and deciding on the treatment, the team leader assigns intervention tasks to other team members. The most common intervention tasks include administration of fluid or medications, insertion of chest tube for draining blood, intubation, and various orthopedic procedures. Some tasks are more complex than the others, and some require the use of sophisticated equipment. In most cases, this complexity entails collaboration of two or more team members. While performing the task, team members often need information in order to proceed with it. Consider for example the task of intubating a patient. Intubation is almost always performed by the anesthesiologist. However, in order to intubate the patient, the anesthesiologist must first paralyze the patient. He or she then needs assistance from a respiratory therapist to connect the endotracheal tube to the automatic ventilator. In short, this task requires coordination of several team members and their activities. The pharmacist prepares the medication and the nurse administers it. The anesthesiologist then inserts the tube and the respiratory technician connects it to the automatic ventilator. Information needs arising during this intervention task are: do we have anesthesia present, is medication ordered, how much needs to be prepared, is medication ready, is medication administered, what is the tube size and its position, do we have ventilator ready, etc. Satisfying these information needs requires engagement of multiple actors and their understanding of the task.

4.4 Memory-lookup tasks

Trauma team members rely on their memory and various artifacts to retrieve situation-specific and medical information when performing their tasks [11]. Memory-look up tasks are in fact information retrieval tasks, except that information is retrieved from memory rather than from an information system. Similarly to communication, memory-lookup tasks are usually in service of other tasks. For example, to decide on the next step, the supervisory team members might inquire about the steps performed so far in the evaluation process. In response to this inquiry, the members of the team would provide their updates by recalling their recent activities from their memories. Another example, shown below, depicts the primary nurse (PNR) and the nurse recorder (REC) engaged in a collaborative memory-lookup task in which they were trying to resolve the amount of medication that had been ordered by the attending physician:

REC (talks to PNR) *Are you giving ancef or zosyn?*
PNR (talks to REC) *I am gonna give ancef, 1 gram.*
REC (talks to PNR) *I thought they wanted 2!*
PNR (talks to REC) *They did, and I asked Dr. (ATP) and told him this is all we have.*
REC (talks to PNR) *Can you give two bags of 1g?*
PNR (talks to REC) *Yeah, I'll give that.*

5. CONCLUSIONS

Findings of our study revealed that trauma team members participate in multiple collaborative information behaviors, such as information seeking, use and retrieval of critical patient information. Most of these activities are only minimally supported by information technology. Information gathering and decision making primarily rely on experience and judgment of team members. This study is only the first step towards understanding the complexity of collaborative information behavior in trauma resuscitation setting. The study also raised several questions, and we are interested in discussing some of them with workshop participants. For example:

1. How do communication breakdowns affect collaborative information behavior, given the critical importance of verbal communication in this environment?
2. How can we support CIB activities in work settings where use of IT poses strict limitations and where teams have been demonstrating constant resistance towards information technology?
3. What other methods could we use, in addition to ethnography, to examine CIB "in the wild"?

6. ACKNOWLEDGMENTS

Many thanks to R. S. Burd, M. E. Lesk, I. Marsic, and ED staff at Robert Wood Johnson University Hospital.

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